S0300-BE-MAN-010

0910-LP-232-6900

CASE STUDIES OF SELECTED HARBOR CLEARANCE OPERATIONS

DISTRIBUTION STATEMENT A: THIS DOCUMENT HAS BEEN APPROVED FOR PUBLIC RELEASE AND SALE; ITS DISTRIBUTION IS UNLIMITED.

THIS DOCUMENT SUPERCEDES: NAVSHIPS 0994-000-3030
SEPTEMBER 1973

PUBLISHED BY DIRECTION OF COMMANDER, NAVAL SEA SYSTEMS COMMAND

1 JUNE 1989

0910LP2326900

SUPERVISOR OF SALVAGE
U.S. NAVY

15 September 1989

FOREWORD

The specific case studies presented in this volume are illustrative of the broad spectrum of harbor salvage operations. Initially distributed to the Fleet in 1973 as The U.S. Navy Ship Salvage Manual Volume III Harbor Clearance Operations (NAVSHIPS 0994-000-3030), these case studies remain relevant today. Therefore, although NAVSHIPS 0994-000-3030 is being superseded, the case studies in their entirety are being reissued in this document.

Lessons learned from just one of these case studies may make your day. Keep them handy for ready reference.

C.A. BARTHOLOMEW
Director of Ocean Engineering
Supervisor of Salvage and Diving, USN

NAVSEA TECHNICAL MANUAL
CERTIFICATION SHEET

NAVSEA 9086/11 (8-88) SHEET 1 OF

TM Identification Number	Publication Date
S0300-BE-MAN-010	1 JUNE 1989

Change No. ______ Revision No. ______ Volume No. ______ Part No. ______
Book No. ______ Chapter No. ______ Other No. ______
TM Specification, TMCR/TMSR No. ______

Title: CASE STUDY OF SELECTED HARBOR CLEARANCE OPERATIONS

FOR CHANGES AND REVISIONS: (Indicate "NA" if item not applicable)

Purpose of Change/Revision: ______

TM/Change/Revision Numbers Superseded: ______

TMDER/ACN Numbers Incorporated: ______

Ship or Equipment Alteration/Field Change(FC)/Engineering Change(EC) Numbers Incorporated: ______

CERTIFICATION STATEMENT

This is to certify that responsible NAVSEA activities have reviewed the basic technical manual [ ], revision [ ], or change [ ] for acquisition compliance, technical coverage, and printing quality. This form is for internal NAVSEA management use only, and does not imply contractual approval or acceptance of the technical manual by the Government, nor relieve the contractor of any responsibility for delivering the technical manual in accordance with the contract requirements.

NAVSEA SIGNATURES

Activity	Name	Signature	Organization	Code	Date
Acquisition	CHERYL L. DANIELS	Cheryl L. Daniels	NAVSEA	00CAB	11 SEP 89
Technical	CAPT C. A. BARTHOLOMEW	[signature]	NAVSEA	00C	11 SEP 89
Printing Release	Gregory R. Burns	Gregory R. Burns	NSDSA	5H24	18 Sep 89

Attachment A

RECORD OF CHANGES

CHANGE NUMBER	DATE OF CHANGE	DATE ENTERED	ENTERED BY

INFORMATION REGARDING THE MANUAL

SCOPE

The HARBOR CLEARANCE OPERATIONS MANUAL presents, in case study format, the artform used for clearing harbors and navigable waterways. Of 15 chapters, nine are devoted to single ship salvage cases, five to massive multi-ship operations, and one to unique individual cases.

SECTION NUMBERS

This manual is divided into 15 major chapters; each chapter is further divided into sections. Divisions are based on subheadings in the chapter and each chapter subdivision carries the chapter number.

The Table of Contents lists all material in the manual by Section Number.

PAGE NUMBERS

All pages are numbered consecutively; page numbers appear at the bottom of each page.

The chapter title and number appear at the top of every page.

LIST OF FIGURES

All drawings and photographs are listed in the List of Figures sequentially according to their position in the chapter. All figures carry the chapter number, sequence-in-chapter number, and a subject title.

LIST OF TABLES

All tables are listed by number and title in the List of Tables.

HOW TO LOCATE INFORMATION

Information regarding a specific harbor clearance operation can be located by the use of the Table of Contents.

Information regarding a specific subject, or item, can be located by the use of the Alphabetical Subject Index.

TABLE OF CONTENTS

Section Title	Section Number
Preface	
Record of Changes	
Information Regarding the Manual and Its Use	
Table of Contents	
List of Figures	
List of Tables	
Introduction	
TODARO	1.
Brief	1.1.
Description of the Ship	1.2.
How the Ship Sank	1.3.
Condition of the Wreck	1.4.
The Salvage Plan	1.5.
Horizontal Pivoting	1.6.
Pumping Program	1.7.
Righting the Wreck	1.8.
Refloating	1.9.
Equipment Used	1.10.
MAILLE BREZE	2.
Brief	2.1.
Description of the Ship	2.2.
How the Ship Sank	2.3.
Condition of the Wreck	2.4.
Method of Salvage Chosen	2.5.
The Salvage Plan	2.6.
Major Problems	2.7.
Equipment Used	2.8.
Parbuckling Effort	2.9.
The First Lift	2.10.
The Second Lift	2.11.
The Third Lift	2.12.
The Fourth Lift	2.13.
Refloating	2.14.
EMPRESS OF CANADA	3.
Brief	3.1.
Description of the Ship	3.2.
How the Ship Sank	3.3.

Method of Salvage .... 3.4.
Sources of Righting Moment .... 3.5.
Anchorage Blocks .... 3.6.
Winches and Steam Supply .... 3.7.
Purchases and Hauling Wire .... 3.8.
Tripods .... 3.9.
Buoyancy Pontoons .... 3.10.
Counterweights .... 3.11.
Internal Buoyancy .... 3.12.
Compressed Air Supply .... 3.13.
Calculations .... 3.14.
Refloating .... 3.15.

USNS MISSION SAN FRANCISCO .... 4.
Brief .... 4.1.
Description of the Ship .... 4.2.
How the Ship Sank .... 4.3.
Condition of the Wreck .... 4.4.
Clearance Methods .... 4.5.
Salvage of the Stern Section .... 4.6.
Channel Clearance .... 4.7.
New Plans .... 4.8.
Operations .... 4.9.
Demolition Methods .... 4.10.

VASA .... 5.
Brief .... 5.1.
Description of the Ship .... 5.2.
How the Ship Sank .... 5.3.
Early Salvage Methods .... 5.4.
Renewed Interest .... 5.5.
Preliminary Investigations .... 5.6.
Salvage Methods .... 5.7.
Tunneling Efforts .... 5.8.
The Lift .... 5.9.
Pumping Phase .... 5.10.
Drydocking .... 5.11.

M/V FEDERAL EXPRESS .... 6.
Brief .... 6.1.
Description of the Ship .... 6.2.
How the Ship Sank .... 6.3.
Importance of Immediate Clearance Operations .... 6.4.
Method of Salvage .... 6.5.

The Deflector .... 6.6.
Diving Operations .... 6.7.
The Air Curtain .... 6.8.
Lifting Operations .... 6.9.
Dismantling the Deflector .... 6.10.

M/V MONTROSE .... 7.
Brief .... 7.1.
Description of the Ship .... 7.2.
How the Ship Sank .... 7.3.
Condition of the Wreck .... 7.4.
The Salvage Plan .... 7.5.
Equipment .... 7.6.
Preliminary Work .... 7.7.
Preliminary Righting .... 7.8.
Pumping Operation .... 7.9.
Dragging Operation .... 7.10.
Final Work .... 7.11.

RAJAH SOLIMAN .... 8.
Brief .... 8.1.
Description of the Ship .... 8.2.
How the Ship Sank .... 8.3.
Condition of the Wreck .... 8.4.
Method of Salvage .... 8.5.
Equipment Needed .... 8.6.
The Righting Phase .... 8.7.
First Parbuckling Attempt .... 8.8.
Second Parbuckling Attempt .... 8.9.
Third Parbuckling Attempt .... 8.10.
Fourth Parbuckling Attempt .... 8.11.
Fifth Parbuckling Attempt .... 8.12.
The Lifting Phase .... 8.13.
The First Lift .... 8.14.
The Second Lift .... 8.15.
Preparations for Pumping .... 8.16.
The Third Lift .... 8.17.
The Pumping Phase .... 8.18.
Fourth Lift and Dewatering .... 8.19.

USNS CARD .... 9.
Brief .... 9.1.
Description of the Ship .... 9.2.
Howthe Ship Sank .... 9.3.

Pacific Fleet Assistance .... 9.4.
Condition of the Wreck .... 9.5.
Stability Calculations .... 9.6.
Immediate Damage Control Measures .... 9.7.
Early Salvage Operations .... 9.8.
The Pumping Plan and Preliminary Pumping Effort .... 9.9.
The Main Pumping Effort .... 9.10.
Temporary Repairs .... 9.11.
Preparations For the Tow .... 9.12.
Tow to Subic Bay .... 9.13.

SCAPA FLOW .... 10.
Brief .... 10.1.
Background .... 10.2.
Equipment and Operations .... 10.3.
The First Success .... 10.4.
Routine Salvage and Some Special Cases .... 10.5.
The *MOLTKE* .... 10.6.
The *HINDENBURG* .... 10.7.
Total Ships Raised .... 10.8.

WORLD WAR II HARBOR CLEARANCE OPERATIONS .... 11.
Brief .... 11.1.
Historical Background .... 11.2.
Basic Methods of Harbor Clearance .... 11.3.
Casablanca, Morocco .... 11.4.
Port Lyautey (Kenitra) .... 11.5.
Bizerte Channel, Tunisia .... 11.6.
Ferryville, Tunisia .... 11.7.
Palermo, Sicily .... 11.8.
Naples, Italy .... 11.9.
Cherbourg, France .... 11.10.
Manila, Republic of the Philippines .... 11.11.

PEARL HARBOR .... 12.
Brief .... 12.1.
86 Ships Present—9 Were Sunk .... 12.2.
Early Estimate of the Situation .... 12.3.
Start of Salvage Operations .... 12.4.
Schedule of Repair Work .... 12.5.
Raising and Salving of the *NEVADA* .... 12.6.
Raising and Salving of the *CALIFORNIA* .... 12.7.
Raising and Salving of the *WEST VIRGINIA* .... 12.8.
Refloating and Salving of the *OGLALA* .... 12.9.

Salvage Work on the *CASSIN* and *DOWNES* .... 12.10.
Work on the *ARIZONA* and *UTAH* .... 12.11.
Work on the *OKLAHOMA* .... 12.12.
Diving Operations .... 12.13.
The Navy Yard, Pearl Harbor .... 12.14.

SUEZ CANAL CLEARANCE .... 13.
Brief .... 13.1.
How the Canal Was Blocked .... 13.2.
Initial Anglo-French Clearance of Port Said Harbor .... 13.3.
The Magnitude of the Task .... 13.4.
Plan of Operation .... 13.5.
Terms of Contract Between U.N. and Salvors .... 13.6.
Equipment Required .... 13.7.
UNSCO Operations .... 13.8.
Observations on Selected Aspects of the Clearance Operation .... 13.9.
Summary of Clearance of the Anglo-French Forces .... 13.10.
Conclusions 13.11

HARBOR CLEARANCE UNIT-ONE .... 14.
Brief .... 14.1.
The Mission of Harbor Clearance Unit-One .... 14.2.
History .... 14.3.
The Organization .... 14.4.
HCU-One Salvage Craft .... 14.5.
The Salvage of the dredge *JAMAICA BAY* .... 14.6.
The Salvage of the dredge *SANDPUMPER* .... 14.7.
NEW JERSEY .... 14.8.
HCU-One Today .... 14.9.

SALVAGE BRIEFS .... 15.
Net Tenders .... 15.1.
USS LAFAYETTE (ex-*SS NORMANDIE*) .... 15.2.
Apra Harbor .... 15.3.
LUMBERJACK .... 15.4.
AFDM-2 .... 15.5.
S/T OCEAN EAGLE .... 15.6.
USS GUITARRO (SSN-665) .... 15.7.
SS ARROW .... 15.8.
.... 15.9.
M/V ORIENTAL WARRIOR .... 15.10.
SS SIDNEY E. SMITH .... 15.11.

References ....
Alphabetical Index ....

LIST OF FIGURES

Title	Chapter	Number
The Tanker *TODARO* Sunk Alongside the Pier	1	1
Gantry Detail	1	2
Arrangement of Purchase Gear	1	3
Diver Tunneling Under the Ship	2	1
Lift Craft in Position over *MAILLE BREZE*	2	2
Mooring Legs for Lift Craft Positioning	2	3
Section Through Lift Craft Positioned for Parbuckling. Original Position of the Wreck.	2	4
Section of the Wreck in Position "A", Lifted on an Even Keel	2	5
Section Through the Lift Craft in Position "B"	2	6
Cross Section of the Lift. Position "C"	2	7
Cross Section of the Lift in Position "D"	2	8
Movement of *MAILLE BREZE*. Positions "A" to "E"	2	9
SS EMPRESS OF CANADA, Liverpool	3	1
SS EMPRESS OF CANADA, Gladstone Dock, 26 January 1953	3	2
General Arrangement of Winches and Pulling Wires	3	3
Blocks Used to Carry Winches	3	4
East Anchorage Block Before Winches Were Fitted	3	5
Purchases, Standing Blocks, and Pendants	3	6
Hoppers on South Quay Supplying Steam	3	7
Steam Supply Headers	3	8
Winches, Steam Receivers, and Pipe Bridge	3	9
Winches Showing Exhaust Steam Line	3	10
Purchases, Moving Blocks, and Pendants	3	11
Position of Tripods	3	12
Typical Arrangement of a Single Tripod on the Ship's Side	3	13
Typical Arrangement of a Double Tripod on the Ship's Side	3	14
Anchorage of 9-Inch Wire to Tripod	3	15
Single Tripod	3	16
Completed Tripods, Looking Forward	3	17
Wire Stopper, 7-Inch	3	18
Counterweight Pontoons	3	19
Anchorage of Counterweight Pontoon	3	20
Buoyancy Compartments and Pontoon's Air Supply	3	21
North Quay Compressed Air Supply, Control Panels, Etc.	3	22
Upsetting and Uprighting Moments	3	23
Position of Pontoons and Wires	3	24
Inclinometer	3	25
View From Bow at Commencement of Heave	3	26
List 77 Degrees	3	27

View From Aft. Buoyancy Pontoons Being Released	3	28
Camel Attached to Tripods	3	29
Refloating Diagram	3	30
"C" Deck Port Side	3	31
First-Class Dining Salon	3	32
"C" Deck Port Side, Sluice Valve Ready for Fitting	3	33
EMPRESS OF CANADA in Graving Dock	3	34
EMPRESS OF CANADA Leaving Liverpool After Salvage	3	35
Sunken Bow Section of the *MISSION SAN FRANCISCO*	4	1
Sunken Stern Section of the *MISSION SAN FRANCISCO*	4	2
Sunken Stern Section of the *MISSION SAN FRANCISCO*. Clamshell Can Be Seen Recovering Steel Sections in the Background	4	3
Bow Section of the Wreck *MISSION SAN FRANCISCO*	4	4
VASA Under Sail	5	1
Diving Bell	5	2
Typical Tunnel Under *VASA*	5	3
Position of Tunnels	5	4
Lift Pontoons	5	5
Deflector Tower About to be Positioned	6	1
Deflector Tower Under Tow	6	2
Deflector Wall Under Construction	6	3
Position of the Deflector	6	4
Current Deflector in Position	6	5
Deflector Tower in Anchored Position	6	6
Current Deflector in Position Protecting the Wreck	6	7
Derricks Positioning a Breakwater Tower	6	8
Tower Work in Progress	6	9
Completed Curtain as Seen on the Surface	6	10
Explosive Charge Fired on the Wreck	6	11
Derricks Lifting Sections to the Surface	6	12
Bow Section Clears the Surface	6	13
Derrick Lifting Wreck Section	6	14
M/V MONTROSE Sunk in Detroit Harbor	7	1
Shoring Timber in Position	7	2
Righting Gear on *MONTROSE*	7	3
Beaching Gear Purchase Tackle	7	4
Weather Deck Shoring Detail	7	5
Pouring Concrete Using a Tremie	7	6
Righting Summary	7	7
Rigging of Pumping Platforms	7	8
Layout of Righting Rigging	7	9
Pumping Platform	7	10
Remaining List After Rotation	7	11
M/V MONTROSE in Dry Dock	7	12

Pier After Battering by the *RAJAH SOLIMAN* is Badly Damaged	8	1
Arrangement of Forces for the First Parbuckling Attempt	8	2
Arrangement of Forces for Parbuckling Attempts Numbers 2 & 3	8	3
Bow and Stern Lifting Chains Being Positioned	8	4
Attempted Righting of the Ship. Lift Craft and Cranes are Lifting, Two ARS' Are Causing Righting Moments	8	5
Aerial View of the Wreck and Lift Craft	8	6
Parbuckling Effort on the Wreck	8	7
Arrangement of Forces for Parbuckling Attempts Numbers 4 & 5	8	8
Lift Craft With 2¼-Inch Chain Secured on the Wreck	8	9
Night Work on the Wreck. Lift Craft and Crane are Causing Righting Moments	8	10
Arrangement of Forces for Lifting the Wreck	8	11
Lift Craft and Wreck Cross Section Showing Arrangement of Lift Wires	8	12
Sailor Tightening a Bouillivant Clamp During a Pin on Board Lift Craft	8	13
Types of Pumps Used and Their Location on Board the Wreck	8	14
Sailor Using a Fire Hose For Washing Down Mud in the Wreck	8	15
The Wreck Buoyed Up by Two Lift Craft Alongside and the Floating Crane Holding the Stern for Added Stability	8	16
Floating Crane YD-120 With Lifting Chain in Position Under the Stern	8	17
Yard Tug Taking the *RAJAH SOLIMAN* From *USS BOLSTER* (ARS 38) on Arrival in Subic Bay	8	18
The German War Fleet at Scapa Flow in June 1919	10	1
Purchase Gear and Winch on the Dock	10	2
Parbuckling a Destroyer Using Lift Rotation	10	3
Air-Lock in Position on a Sunken Ship	10	4
Battleship Floating on an Air Bubble Ready for Tow to Scrapping Yard	10	5
Salvors Rigging a Pump on Board a Sunk Italian Freighter in Casablanca	11	1
Italian Freighter Sunk off Casablanca	11	2
Wrecks Blocking the Channel at Bizerte, Tunisia	11	3
Wrecked Submarine Blocking the Channel at Bizerte, Tunisia	11	4
Sunken Ship Blocking the Channel at Bizerte, Tunisia	11	5
Damaged Mole and Rail Line. The Ship *RESOLUTE*, Damaged, Can Be Seen in the Background	11	6
Capsized Hospital Ship in Naples Harbor	11	7
Capsized Ship in the Harbor at Naples	11	8
A Capsized Italian Cruiser off Mole "B". Most of a Small Boat Yet to be Removed Can Be Seen. LST in the Background is Used to Unload Vehicles from Transports	11	9
Italian Cruiser Sunk at Mole "B"	11	10
Dockside Wreckage in Naples	11	11
British Lift Ship Working in Naples Harbor	11	12
Capsized German Tanker in the Harbor at Naples	11	13
Sunk Hospital Ship Alongside Pier "C"	11	14

Wrecked Hospital Ship	11	15
U.S. Army Soldiers Survey Damage in Naples Harbor	11	16
North Harbor and Pasig River Entrance, Manila	11	17
Entrance to the Main Harbor at Manila. Several Blockships Can Be Seen	11	18
Wreckage of Pier Number 7, South Side, Manila	11	19
Blockship in the Pasig River, Manila	11	20
Location of Ships in Pearl Harbor on 7 December 1941	12	1
USS CALIFORNIA Fully Afloat With Fence-Type Cofferdam Erected Around the Ship	12	2
USS WEST VIRGINIA in Drydock. Removal of One Section of the Smaller Forward Patch Shows Some Details of Construction and Securing Methods	12	3
Fence-Type Cofferdam Installed on Deck Edge of *USS OGLALA*	12	4
With the Assistance of Submarine Salvage Pontoons, the *OGLALA* is Righted on 23 April 1942	12	5
Position of Wrecks in Port Said	13	1
Position of Wrecks and Obstructions Throughout the Canal	13	2
Salvage Tugs Engaged in Clearance Operations	13	3
The German Lift Craft *ENERGIE* and *AUSDAUER*	13	4
Heavy Lift Craft Recovering Wreck	13	5
Shearlegs in Operation	13	6
Shearlegs Recovering Canal Craft	13	7
Floating Crane *CONDOR* Lifting Ferry Pontoon	13	8
Lift Crane Working On the Removal of the El Ferdan Bridge	13	9
Diver Connecting Lift Bridle for an El Ferdan Bridge Section Lift	13	10
Lift Craft Removing Section of the El Ferdan Bridge	13	11
Recovery of the 1400-Ton Tug *EDGAR BONNET*	13	12
The Recovered Dredge *PAUL SOLENTE*	13	13
Port Side Patch for the *SS BATON ROUGE VICTORY*	14	1
Four Lift Craft Arrangement on the *JAMAICA BAY* Dredge Salvage, 19 February 1967	14	2
Aerial View of the *JAMAICA BAY* Salvage Operation	14	3
Port Quarter View of the Sunken Dredge *JAMAICA BAY*	14	4
Looking Aft on the Starboard Side of *JAMAICA BAY*	14	5
Starboard Patch for the *JAMAICA BAY*	14	6
Port Radius Patch Fabricated to Cover Damage at the Turn of the Bilge, *JAMAICA BAY*	14	7
JAMAICA BAY Stern Compartment Foam Filling Operation. Note Air Mask Used for Fresh Air and 55-Gallon Drums Used to Reduce the Volume	14	8
Dredge *SANDPUMPER*	14	9
Dredge *SANDPUMPER*	14	10
SANDPUMPER/YHLC Lifting Arrangement	14	11
Lift Craft *CRILLEY* and *CRANDALL* Moored Alongside Dredge *SANDPUMPER*	14	12

Lifting *SANDPUMPER's* Ladder	14	13
Dredge *SANDPUMPER* Salvage Operation at Final Grounding Site	14	14
Steel Patch Used on *SANDPUMPER*	14	15
Concrete Patch. *SANDPUMPER*	14	16
Dredge *NEW JERSEY*	14	17
Dredge *NEW JERSEY*	14	18
Flooding Plan of the Dredge *NEW JERSEY*	14	19
Flooding Plan of the Dredge *NEW JERSEY*	14	20
NEW JERSEY Port Side Explosion Damage	14	21
Ten and Six Inch Pumps on Port Side, *NEW JERSEY*	14	22
Twenty-Four Inch Cofferdam, Port Side on the *NEW JERSEY*	14	23
Two Net Tenders Alongside *GRAPPLE*	15.1.	1
Connecting Method of Eight Wires to Eight Winches on the ANs	15.1.	2
Configuration of the Lift Wires on each AN	15.1.	3
Location of the Eight Lift Pendants on the Tailgate	15.1.	4
Stepping-Lift Method Used to Recover the Tailgate	15.1.	5
Setting the Tailgate on a Pontoon Barge	15.1.	6
USS LAFAYETTE in Capsized Position Between Pier 88 and Pier 90	15.2.	1
Salved *YSR-19* Floating on an Air Bubble	15.3.	1
Pumping of *YTM-521*	15.3.	2
PC-705 With Main Deck Almost Awash Subsequent to Lifting	15.3.	3
The Barge *LUMBERJACK* Aground	15.4.	1
Stern Section of the *LUMBERJACK* Afloat on Foam	15.4.	2
Hurricane Track on 9-10 September 1965	15.5.	1
Capsized Drydock Turns Rightside Up in a 12-Stage Salvage Operation at New Orleans, Louisiana	15.5.	2
Capsized *AFDM-2*	15.5.	3
Beach Gear Rigged Ashore for Parbuckling the *AFDM-2*	15.5.	4
S/T OCEAN EAGLE Broken Amidships	15.6.	1
S/T OCEAN EAGLE Bow Section Under Tow to Disposal Site for Sinking	15.6.	2
USS GUITARRO on the Surface After Being Pumped Out	15.7.	1
Fabrication of the Cofferdam Seat	15.7.	2
Electric Pump Being Lowered into Cofferdam on the *GUITARRO*	15.7.	3
Primary Method for Heating and Lifting the Bunker "C". *SS ARROW* Salvage Operations. 1970	15.8.	1
USS REGULUS (AF-57) Hard Aground Port Side to Kau Yi Chau Island, Hong Kong Harbor	15.9.	1
USS REGULUS Underwater Damage Survey Results	15.9.	2
Starboard View *USS REGULUS (AF-57)* Hard Aground. Note Discontinuity of the Hull Girder	15.9.	3
Rock Damage on the Bilge Keel Section of the Ship	15.9.	4
Reefer Deck Section Being Removed	15.9.	5
Port River View of the *M/V ORIENTAL WARRIOR*. Midship Discoloration From Fire Damage Can Be Seen	15.10.	1
M/V ORIENTAL WARRIOR Sunk Alongside the Dock. Note Dockside Preparations	15.10.	2
Anchor Points For Parbuckling Stations. Note Purchase Gear and Winches in Position	15.10.	3

Longshoremen Loading One Ton Lead Ballast Pigs From Railroad Car.	15.10.	4
Early Photograph of the *SS SIDNEY E. SMITH* capsized and Sunk in the St. Clair Channel	15.11.	1
Locating Mechanism Positioning Divers' Access Cofferdam.	15.11.	2
Diver Preparing to Enter Diving Access Cofferdam.	15.11.	3
Crane Positioning Deck Patch.	15.11.	4
Parbuckling Winches Stationed Ashore.	15.11.	5
Deck Plate Patch Being Lowered Into Position.	15.11.	6
Rolled Stern Section Alongside	15.11.	7

LIST OF TABLES

Title	Chapter	Number
Summary of Schedules	3	1
Condition Summary	3	2
Final Progressive Moment Table	3	3
Use of Explosives	4	1
Wrecks in Port Said Harbor	13	1
Wrecks in the Suez Canal Outside Port Said	13	2

INTRODUCTION

The blockage of a harbor or navigable waterway can seriously disrupt waterborne commerce; similar navigational restrictions can severely limit the movement of U.S. Navy ships. Damaging tactical or economic effects will result if harbor clearance is not effectively undertaken. Concurrently, harbor clearance is generally time critical and it is especially important to clear obstructed harbors and seaways in time of war.

This volume presents numerous harbor clearance operations, as case studies, to afford the salvor guidelines for operations and logistic support requirements. The success of harbor clearance is varied, and generally a function of the salvor's determination and resources.

Several harbor clearance operations conducted by the U.S. Navy are worthy of recollection. When, during World War II, the French port of Cherbourg was captured, it was ruined, blocked, and booby-trapped. The work of Commodore William A. Sullivan, USN, and his U.S. Navy salvage experts in quickly reopening this port, in great measure made it possible for the Allied forces to receive the supplies they needed for rapid movement through France into Germany. The availability of this port ahead of schedule undoubtedly shortened the course of the war.

Perhaps the finest and most extensive example of the value of salvage and harbor clearance occurred in Pearl Harbor in the months immediately following the 7 December 1941 attack. The core of the U.S. Pacific battle force was shattered. *ARIZONA* was burning and torn in two, *OKLAHOMA* had capsized; *WEST VIRGINIA* had sunk; *CALIFORNIA* was sinking; *UTAH* was sunk; and every other battleship was damaged. Sunk also were the destroyer *SHAW* and the drydock (YFD-2) in which she was lying. Also lost were the destroyers *DOWNES*, the minelayer *OGLALA*, and the target ship *UTAH*. The berths and drydocks of the Naval Shipyard and operating base at Pearl Harbor were badly blocked, though the main channel was still open.

The light cruisers *HELENA*, *HONOLULU*, and *RALEIGH*; the seaplane tender *CURTISS*, the destroyer *CASSIN*, and the repair ship *VESTAL* were damaged but not sunk.

Prompt surveys conveyed pessimistic views; great doubt existed as to whether the ships could be salved or returned to service. As Captain H.N. Wallin, USN, later stated in his salvage report:

> "One great lesson learned is that the real damage in such cases usually turns out to be relatively much less than estimated by the casual eye. The eye seems to take note of things that are wrong—emphasizing the superficial evidence—and is prone to pass by the many things still intact which may be found only after careful inspection. Also, in time of calamity or great adversity the human mind is impressed more by the desperateness of a situation, rather than by its hopefulness."

Motivated by this attitude, and greatly aided by the shop facilities at Pearl Harbor, Captain Wallin directed a highly successful salvage operation. The cleaning of the docks and berths and the salving and return to duty of many of the sunken ships made a major contribution to the Navy's rapid recovery and eventual victory in the Pacific.

After Manila was recaptured, it was imperative for the execution of the then projected invasion of Japan, that the harbor was to be cleared as soon as possible; this vast harbor was to be a principle base for operations to the north. Accomplishments of the U.S. Navy harbor clearance forces at Casablanca, Palermo, Naples, Cherbourg and Le Havre were to be repeated in Manila Harbor.

Hundreds of ships had been scuttled in the bay, and were blocking the harbor; Japanese forces, prior to and during their retreat, has successfully denied the immediate use of the harbor to the Allies. U.S. Navy salvage forces, working with the aid of two battalions of Seabees, several Salvage Ships and minecraft, and a special brigade of the Army Engineers, moved so rapidly that within three weeks, Manila's inner harbor was handling 50,000 deadweight tons of shipping a week. In less than two months the inner harbor and channels had been cleared of 350 sunken ships and craft. This work was the result of a complete absence of lost motion. When the clearance crews could not lift or destroy a wreck, they would have divers seal it up, fill it with air, float it on a bubble and, after it surfaced, tow it to the outer harbor where it could be beached and left to be dealt with later.

At the beginning of the war, pressing requirements for trained salvage personnel caused the U.S. Navy to turn a disaster to good advantage. After the *USS LAFAYETTE*, formerly the French passenger liner *NORMANDIE*, took fire, capsized and sank next to Pier 88, New York Harbor, a salvage school was set up to train both divers and salvage officers. During the war, the Navy Salvage School trained 2500 salvage officers and enlisted salvage divers. Graduates of this school were involved in every major invasion in Europe and the Pacific. The equipment and ships salved or reclaimed by these men had a value of more than $2 billion; and their tactical contribution through rapid clearance of sunken or stranded ships from harbors and other areas of attack or supply was beyond estimation in terms of dollars.

As an outgrowth of this great expansion and training period gained during the war, and the pre-war experience with having no standby salvage capability, the Navy retained a significant salvage force after the war.

Some notable instances in which this force has been employed were in connection with the grounding of the *USS MISSOURI*, the clearing of Korean harbors after the Korean War, harbor clearance in Guam after typhoons Karen and Olive, the refloating of the *USS FRANK KNOX*, and the many operations conducted by Harbor Clearance Unit-One in Southeast Asia.

The Navy's salvage forces were faced with the most extensive harbor clearance operation since World War II when, in November 1962, the Marianas Islands were struck by two violent typhoons. During the harbor clearance operations conducted in Apra Harbor, Guam, 16 ships and barges were refloated. Vital to the success was the availability of Navy salvage vessels and the nearby industrial support of the Ship Repair Facility, Guam.

Harbor clearance often requires the removal of a single ship and this does not have the great demands of massive, multi-ship operations; the solitary ship can just as effectively block a navigable waterway or pier, as massive sinkings. As related in Chapter Nine, the rapid refloating of the *USNS CARD* in 1964, after it had been sabotaged and sunk alongside its mooring in Saigon, RVN, illustrated the excellent harbor clearance capability of the U.S. Pacific Fleet. The *CARD* refloating operation, carried out by means of patching and pumping, was the largest of its type carried out by the U.S. Navy since World War II.

These are but the highlights of harbor clearance operations as they have been faced by the U.S. Navy; similar operations will be required so long as men follow the sea in ships.

1. TODARO

1.1. BRIEF

The French were faced with the monumental task of clearing their harbors, rivers, and shorelines after World War II. This included more than 3,200 wrecks of all sizes, representing over 1.6 million displacement tons. Of this, 3,152 wrecks were sunk in major ports, and in most instances the ships had been voluntarily sunk with multiple damage inflicted. Despite a shortage of equipment, materials, funds and the limited number of special organizations and personnel available, much of the clearance was accomplished in two years. The case of the salvage of the *TODARO* is one example of a particularly difficult refloating operation encountered by the French harbor salvage groups.

1.2. DESCRIPTION OF THE SHIP

The *TODARO* was a steam-powered tanker, vintage 1913, with one alternating engine and two cylindrical boilers, possessing the following characteristics:

Length	402 feet
Beam	53 feet
Molded depth	29 feet
Gross Tonnage	5,612 tons
Deadweight	7,500 tons

The ship was constructed with a watertight longitudinal bulkhead, summer tanks topside, and seven pairs of main tanks inboard. These tanks were of the longitudinal type with bottom, walls, deck and bulkheads supported by longitudinal bands; each tank had two web frames to support the bands.

Unloaded, the ship weighed 3,270 tons: 2,535 tons for the steel hull; 390 tons for the appointments, wood piping, and pumps; and 345 tons for the engines and boilers, auxiliary engines, decking, and accessory equipment.

1.3. HOW THE SHIP SANK

The tanker *TODARO* was scuttled in Bordeau Harbor, France, at pierside.

1.4. CONDITION OF THE WRECK

The ship was lying on its side in 26 feet, below the low water level, on a sand and shingle bottom. The forward part of the keel was 12 feet from the pier, and the heel of the stern post was 53 feet from the pier. This position prevented righting the wreck by rolling it along the harbor floor.

The ship had been scuttled by charges placed at the bottom of starboard tanks 4, 5, 6, and 7 and in the engineroom, as shown in Fig. 1, No. 1. The tank holes varied from one to two feet, although the engineroom fracture was larger.

At low water, the water level reached the symmetry plane of the ship which was heavily silted. The starboard tanks, hold, and engine compartments were still submerged and filled with silt varying in depth from 12 to 18 feet. The port tanks had shipped only about three feet of silt.

In addition, a certain amount of silt had accumulated along the outside of the hull, amounting to a height of almost ten feet above the starboard beam and covering a considerable portion of the ship's length. It was necessary to remove this silt before pivoting the wreck.

1.5. THE SALVAGE PLAN

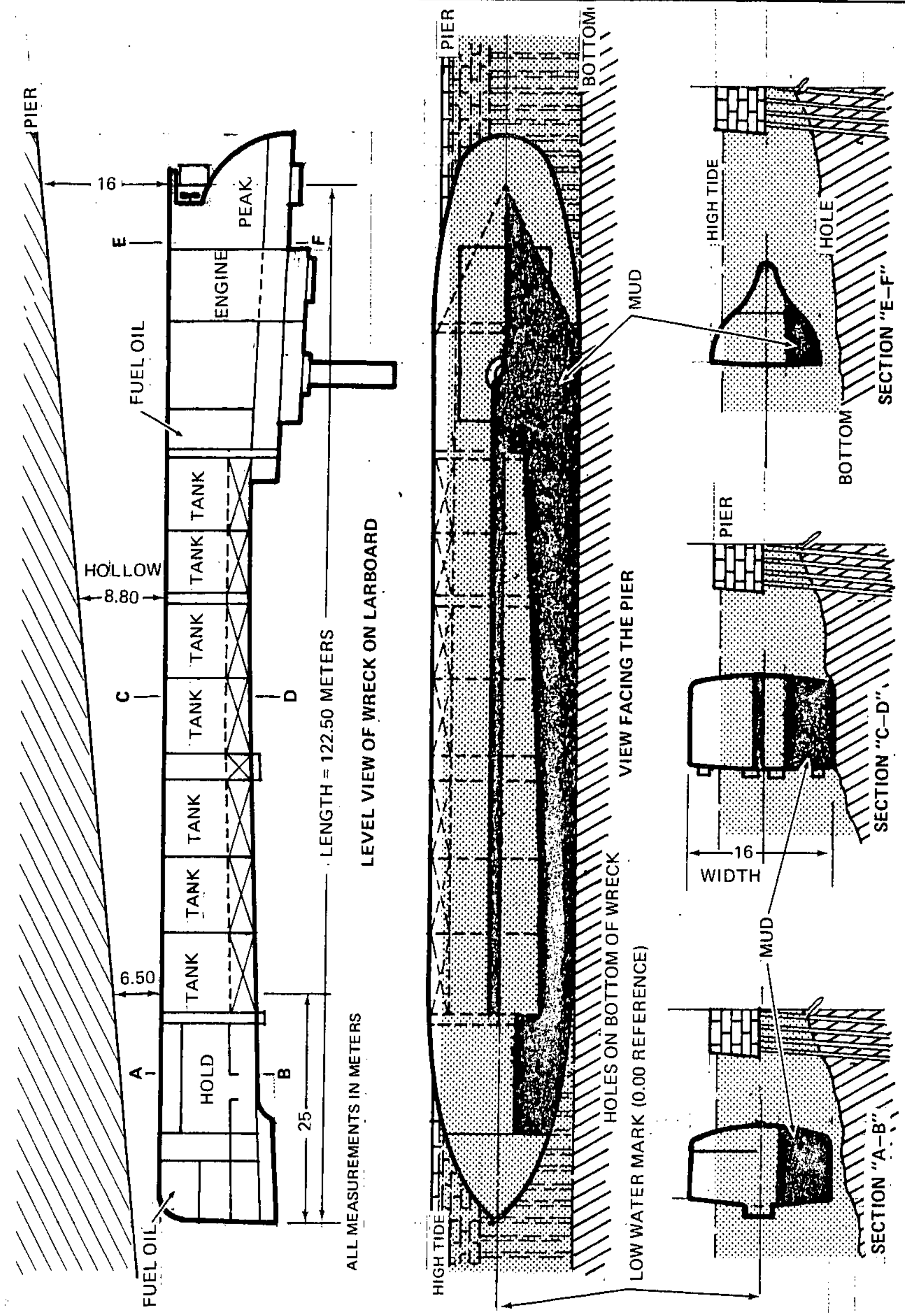
The salvage plan consisted of the following steps:

a. inside silt removal;
b. closing of holes and the removal of the castle;
c. outside silt removal;
d. installation of pumps, compressors, and a deck tackle arrangement designed to move the forward section outward and away from the pier by means of horizontal pivoting of the wreck around the aft section;
e. horizontal pivoting of the wreck;
f. installation of devices for righting the wreck through partial lightening and rolling on the bottom, and continuation of silt removal from inside the ship and between the pier and the ship;
g. righting the ship; and
h. completion of silt removal followed by return of buoyancy and refloating.

1.6. HORIZONTAL PIVOTING

The removal of some 4,800 cubic yards of interior silt plus clearing outside silt was accomplished by means of liquifying the silt and pumping it away. Holes in the tank were closed with sheet steel boxes designed to provide a tight seal, and the submerged portions of the castle were removed by means of light linear explosive charges.

To assure that the pivoting motion would achieve its end of moving the forward section from the pier, 55-ton concrete blocks were positioned in the river, each block being backed by two bridles to which were attached two additional 20-ton concrete blocks. To this seaward anchor the *TODARO's* topmast was attached by means of a belt of steel cables connected to 80-ton pulley-blocks. These deck tackle blocks were held out of the water by floats, and the tackle ran back to the capstans of the two LCTs moored both by their anchors and by attachment to the concrete blocks.



THE TANKER "TODARO" SUNK ALONGSIDE THE PIER.
FIG. 1 NO. 1

To calculate the effort needed for the pivoting it was necessary to know the supporting force of the wreck on the aft bottom, the supporting surface, and the friction coefficient of the bottom. The latter factor was determined by a combination of experience and experiment. The experiment consisted of sliding a steel sled of known weight in a basin possessing a bottom like that in which the ship was embedded. The coefficient was found to be 0.52.

To lighten the ship and float its forward section, pumps were installed on barges alongside rather than on the pier, thus reducing the suction height of the pumps. Compressors were used to create an overpressure in the pumped compartments, thereby facilitating the work of the pumps and preventing the crushing of the deck or of the axial bulkhead under hydrostatic pressure.

1.7. THE PUMPING PROGRAM

The pumping program used on the *TODARO* was as follows:

a. the peak was emptied to the maximum extent;
b. forward hold dewatered to a maximum extent by two 400-ton per hour pumps;
c. the forward water ballast was left full to aid in the transverse equilibrium of the wreck;
d. tanks 1-5, port, were emptied by air up to about nine feet below the outside water level;
e. tanks 6 and 7, port, were also emptied by air to a level six feet below the outside water level;
f. tanks 1-5, starboard, were emptied of about 12 feet of water with pumps and compressors; and
g. the starboard summer tanks were emptied by pumping; the port summer tanks were left full of water.

A prime consideration in this pumping program was to assure that no part of the structure experienced excessive pressures. Since the tanks of tankers are tested with an overpressure of 7.9 feet of water above the deck, this provided a margin of safety that permitted maximum pressure on decks and longitudinal and transverse bulkheads of 1.1 pounds per square inch with the stress in the stringers and strakes reaching the limit of elasticity. Therefore, during all phases of silt removal and pumping, it was necessary to avoid placing any part of the structure under a pressure exceeding that of 15 feet of water. Had this figure been exceeded, there was grave danger of bursting a compartment.

Removal of silt from the starboard tanks could only be accomplished by divers, who penetrated through the deck panels or through openings cut into the longitudinal bulkhead. These openings were later closed for the refloating phase.

Horizontal pivoting was achieved without difficulty and according to plan on 22 June 1946. The forward section of the ship was moved so that its keel was parallel to and about 45 feet from the pier.

1.8. RIGHTING THE WRECK

Two large gantrys were placed on the port side to the right of the poop deck. As shown in Fig. 1, No. 2, each of them was constructed of two strong beams 35 feet long with a square cross section of about 20 by 20 inches, and were designed to pivot at their base. These gantrys, inclined at 35 degrees to the vertical, were linked to the poop deck beam by a system of two inch steel cables and pulleys arranged to distribute the strain uniformly. A 150-ton three-fold deck tackle was attached to the upper end of each of the two masts of each gantry, making a total of four deck tackles. These were moored to concrete blocks anchored in the pier. Each of the tackle falls of the four deck tackles was then connected to the block of one 25-ton two-fold deck tackle, and the fall of this latter deck tackle was finally reeled up on the drum of a five to six ton electric winch. See Fig. 1, No. 3 for arrangement.

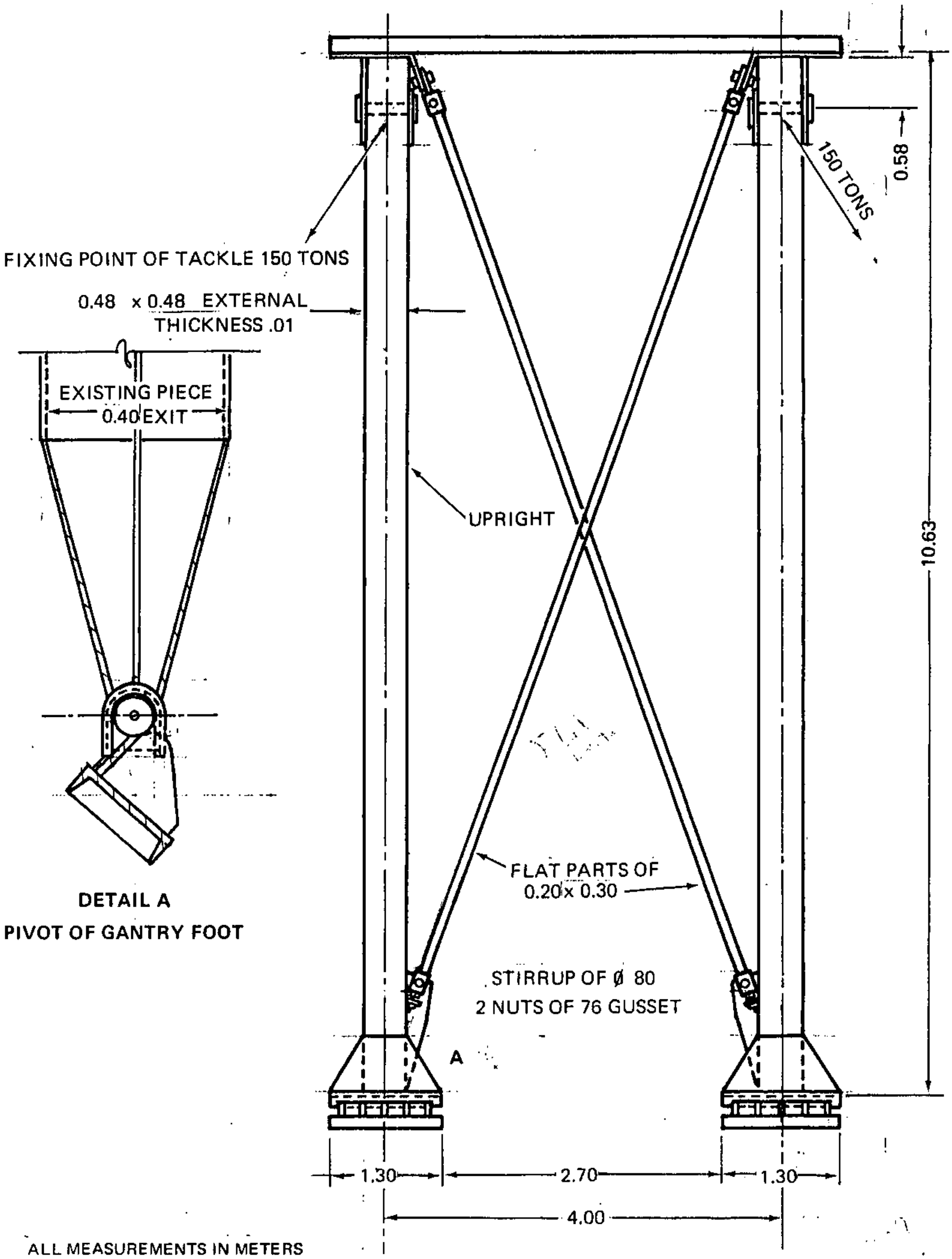
The gantrys were placed on the after part of the ship because righting was to commence immediately after the pivoting was accomplished. Had the gantrys been placed in the middle, as would seem logical, the traction of the lifting cables would have prevented the horizontal pivoting of the hull around the aft section.

Davit-equipped barges were also positioned at the forward section of the wreck in order to push the bow.

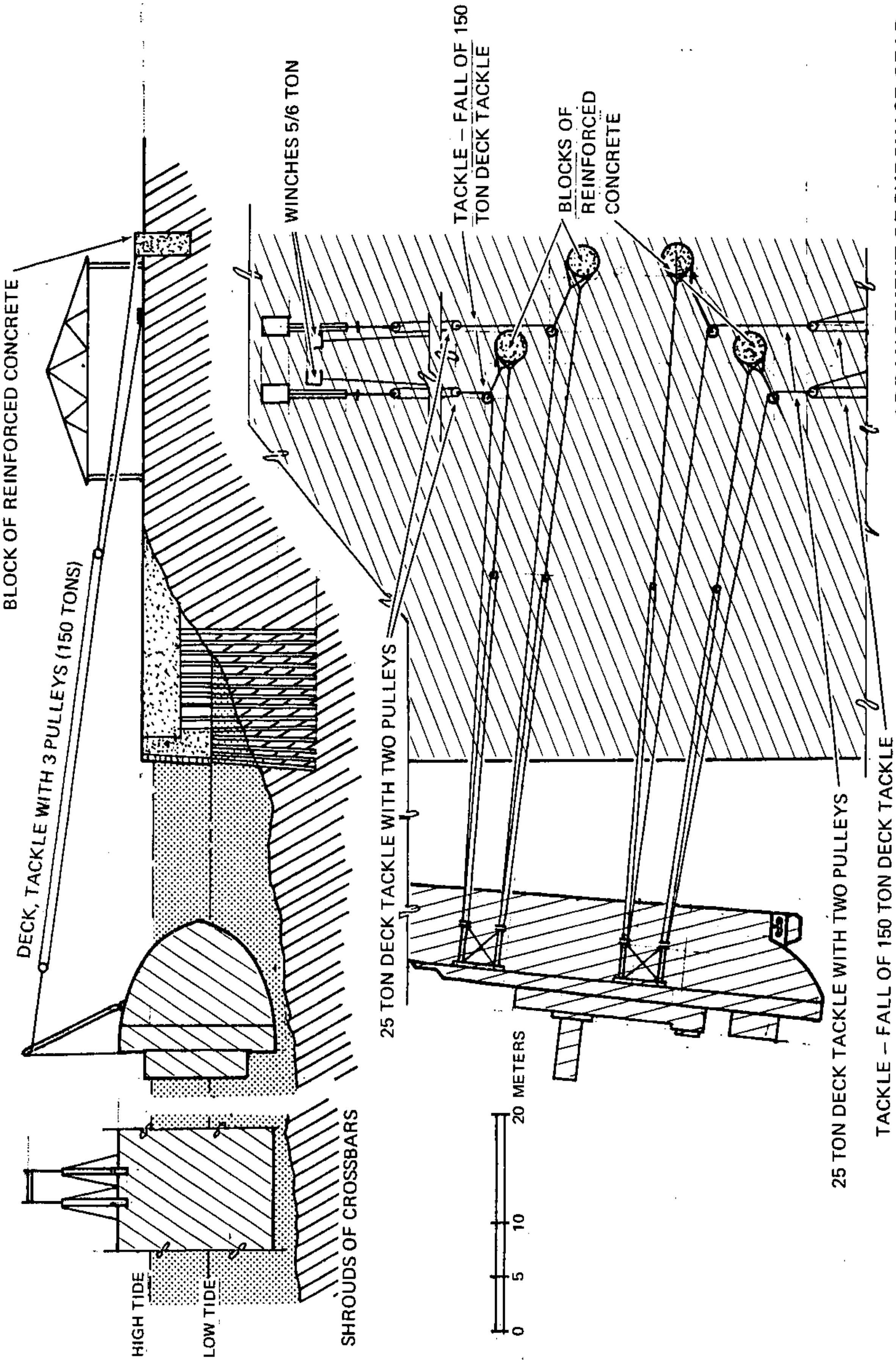
All of these arrangements were tested by a 1:100 mockup, and the forces to be generated for the righting were determined to be 53,888 foot-tons (short) for the rolling couple, and 44,080 foot-tons for the righting couple. To compensate for the difference of 9,808 tons between the rolling and righting couples, it was necessary to introduce additional lifting capacity. This included three lifting barges totaling 2,972 tons and four masts of the two gantrys for the remaining amount, 6,836 tons. This was calculated to be 68 tons per mast. To provide a margin of safety, it was decided to use the barges to overcome the bottom suction only, and to rely on the gantrys for the entire effort. The actual load per mast would be 98 tons, but they were designed for 165 tons to provide for contingencies.

The planned righting commenced immediately after the pivoting. The four electric winches were started and the vessel began to turn, rolling on its starboard side. However, it appeared that the weight of the silt still remaining had been underestimated. The winches began working hard, and at a critical moment, with the tide running out, the motor of one winch failed. The only recourse was to place the ship back on the bottom as quickly as possible. Unfortunately the emergency hand crank on the damaged winch was not working properly, so the paying out of the deck tackle could not keep pace with the dropping tide. The corresponding 165-ton deck tackle became overloaded, took increasing strain and began to vibrate and shake. The gantry to which it was connected began to burn and the fire gradually spread to the second crane.

After the failure of this first try, the effort needed was recalculated. It was obvious that the amount of silt remaining in the castle and summer tanks had been underestimated by some 1,102 tons. In addition, an extra 2,534 tons of load were produced by the impossibility of emptying tanks 3 and 4 caused by the escape of air at the patches; 220 additional tons were produced by not filling the port



GANTRY DETAIL.
FIG. 1 NO. 2



ARRANGEMENT OF PURCHASE GEAR.
FIG. 1 NO. 3

tanks at the necessary time. As a result the shearing couple was increased by 3,857 tons, to a total of 13,665 tons, requiring a load of 137 tons on each of the four masts and the two gantrys. While this was still below the theoretical limit of 165 tons, there was not a sufficient margin of safety. To provide this margin the following measures were taken:

a. the shearing couple was reduced by removal of silt to the right of the castle and in the summer tanks;
b. patches in tanks 3 and 4 were tightened;
c. the righting couple was increased through reinforcement of gantrys to bring the pull per mast up to 132 tons, totaling 13,224 tons;
d. adding six A-shaped brackets 18 feet high, capable of handling 5,500 tons; and
e. use on the pier of a counterweight to aid in the righting operation at high tide.

Deck tackle was connected to three six-ton mechanical winches from each of the brackets, and winches and deck tackle holding ropes were in turn anchored on a steel net hammered into the pier.

The counterweight posed a problem. After it had performed its function it might interfere with the last stage of the righting operation by coming between the bilge and the pier as the ship was righted. This problem was solved by constructing the 500-ton counterweight from an easily crushed wooden crate filled with sand.

The cranes were repaired and reinforced by external counterbraces while further silt was removed and the patches reinforced. A new portion of the castle was removed and on 27 July 1946 the second righting effort commenced. The righting was a success, with the sand box counterbalance being broken up as expected.

1.9. REFLOATING

After further silt removal and pumping on 21 August the ship rose ten degrees on the starboard side with over 2½ feet of freeboard on the port side; the deck beam of the starboard deck was still level with the water. As the tide went out, the ship settled on the bottom. During the night a 15-ton floating crane was able to move the pumps to better positions. Divers plugged some additional holes, and the ship's draft was reduced to about 25 feet with a slight list to starboard. One hour before high water, six tugs, four in front and two aft, towed the *TODARO* away.

1.10. EQUIPMENT USED

The following equipment was employed in this operation:

- 2 barges carrying refloating equipment
- 2 LCTs and two dredging scows to pull the forward tackle for the horizontal pivoting
- 4 electric winches

- 6 mechanical winches
- 5 600-ton per hour pumps, 2 400-ton per hour pumps, 1 250-ton per hour pump, totaling more than 4,000 tons per hour pumping capacity
- 6 rotating compressors
- 2 welding groups

There were 70 men, including four divers, involved in this operation, which took 11 months to successfully complete.

2. MAILLÉ BRÉZÉ

2.1. BRIEF

The French destroyer *MAILLÉ BRÉZÉ* caught fire and sank at her mooring as a result of the accidental explosion of a torpedo warhead on board. Because of the growing concern over the possibility of oil pollution and the threat of her unstable ammunition reserves, salvage operations commenced using a tidal lift method with two pairs of lift craft. Four lifts were successfully completed to move her to shallow water for patching and refloating.

2.2. DESCRIPTION OF THE SHIP

The *MAILLÉ BRÉZÉ* was a destroyer with raised forward deck and twin-screw steam turbine propulsion, possessing the following characteristics:

Length overall	424 feet
Breadth (moulded)	39 feet
Depth (moulded)	24.9 feet
Displacement (at time of sinking)	3,600 tons

2.3. HOW THE SHIP SANK

On 30 April 1940, the French destroyer *MAILLÉ BRÉZÉ* caught fire and sank at her moorings off Greenock near Glasgow, Scotland, on the southern section of the Firth of Clyde. The fire and subsequent sinking was the result of the accidental explosion of a torpedo warhead starboard side and inboard of the foredeck break near No. 1 boiler room.

2.4. CONDITION OF THE WRECK

Early in 1953 it was decided to remove the wreck as concern was growing over the possibility of oil pollution from the 500 tons of fuel oil thought to have been aboard when the ship sank. There was also a threat from the remaining ammunition which may have been unstable.

Preliminary examinations revealed the main damage to the ship had occurred at frames 41-43 in the way of the forward boiler room. Main deck plating and structure in this area was completely ruptured by the explosion for about 23 feet of the ship's length, from the starboard deck edge to a point just beyond the center line. This damage extended ten feet down the ship's side to the rubbing band where the hole was nine feet across. Below this main damage a crack extended vertically for about 18 inches. The superstructure in the area of the forebridge was heavily damaged and it seemed likely the main deck under the forecastle would also have been affected; this was subsequently confirmed after removal of the forecastle deck. No other damage was apparent, and in the light of the information available at that stage there seemed to be a reasonable chance of lifting the ship intact.

In June of 1953 two salvage ships and teams removed the loose wreckage and much of the accumulated silt. Early in July the first sweep wire was tunneled under the stern post and worked forward under the keel to frame 22, 145 feet from the stern. There a pilot wire was pulled through and left in this position; attempts to sweep the wire any further than frame 22 were unsuccessful. During the latter part of July and early August only one salvage ship was available, and so the work centered on a tunnel driven under the wreck at frame 55, some 62 feet from the stern, with the intention of sweeping the wire aft. However, large sandstone boulders were encountered and progress was impeded. When the second salvage ship returned attempts were made to work this wire aft, in the hope that all the remaining wires between frames 55 and 22 could be positioned in this manner. This proved to be impractical and the alternative of tunneling for each wire was reverted to. (See Fig. 2, No. 1.)

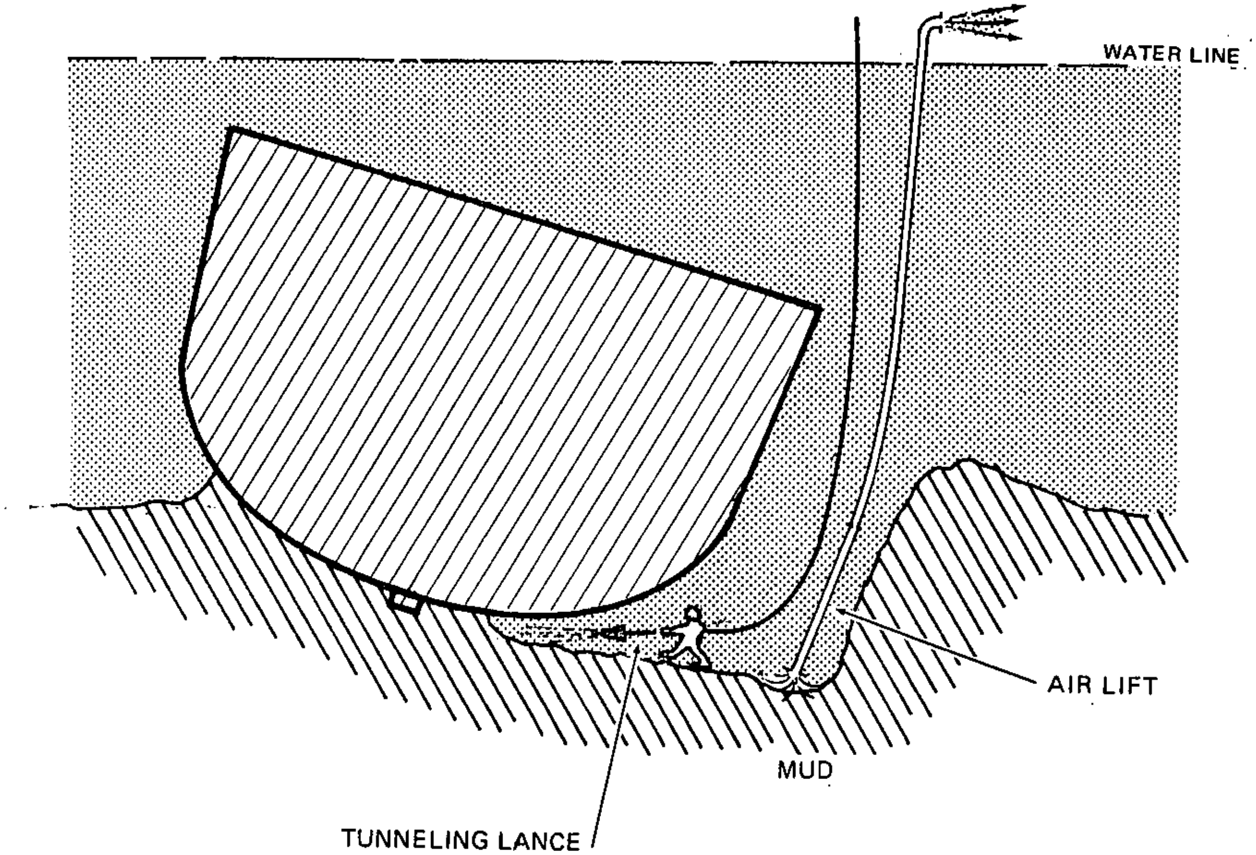
2.5. METHOD OF SALVAGE CHOSEN

Several methods of removing the wreck were examined. The main concern was whether the ship could be lifted intact or if it would be necessary to cut her into two or more sections. If she were cut into sections each section could be handled by one pair of lift craft with little risk of mishap. However, the operation would have been more time consuming, there was a risk of oil being lost when the ship was sectioned, and the disposal of the separate sections would have been difficult, especially as the fore end would have been unstable and unless supported in some way could not have been beached upright. Several schemes involving pontoons and compressed air in conjunction with lift craft placed athwart the wreck were considered, but the plan finally chosen was a four ship lift; a tidal lift by means of four lift craft aided by salvage pontoons. Two 750-ton capacity, and two 1200-ton capacity lift craft were used, as shown in Fig. 2, No. 2 and Fig. 2, No. 3.

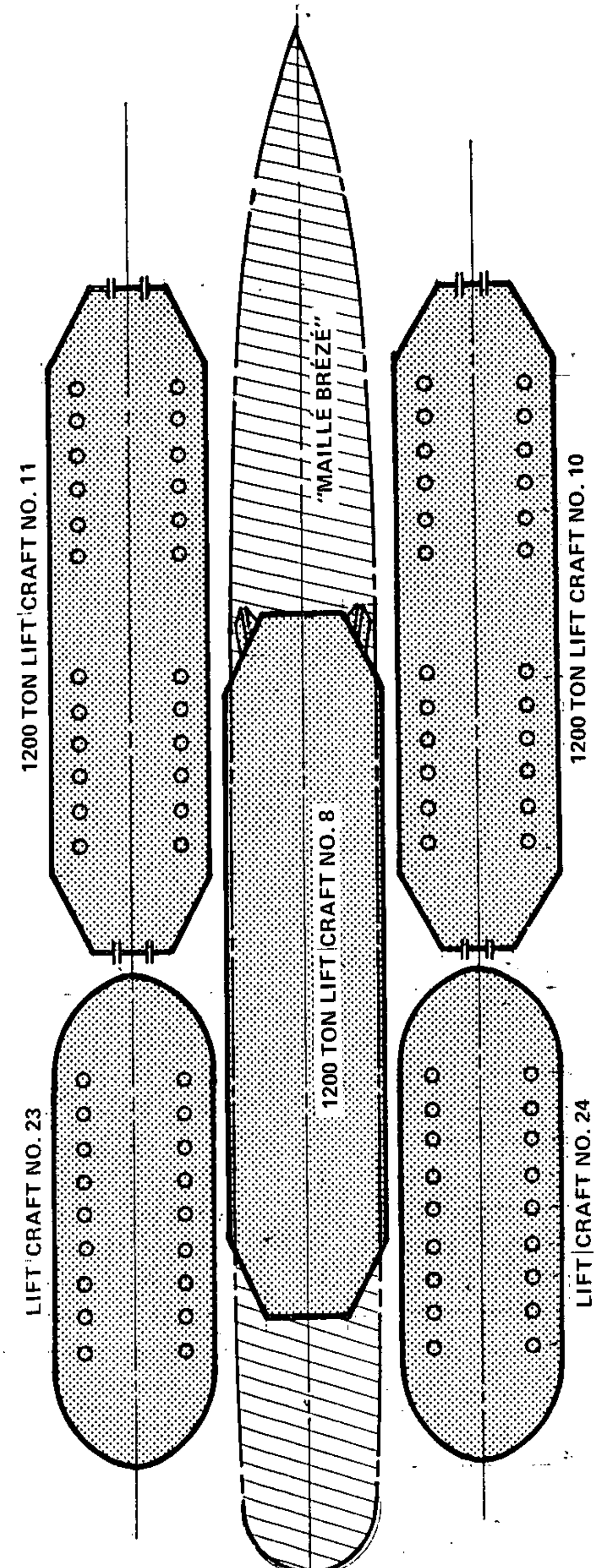
2.6. THE SALVAGE PLAN

The salvage plan was devised as follows:

a. Preparations of drawings and scale models based on calculations from available data.
b. Driving 18 tunnels under the wreck at 20 foot intervals, working aft from frame 52.
c. Passing two 1½ inch diameter steel wire rope messengers through each tunnel, to be made fast at deck level.
d. Clearance of rubbish and silt and removal of the forward superstructure, funnels, forecastle deck, capstans, propellers and side shell plating above the main deck.
e. Removal of as much ammunition as possible.
f. Location of suitable intermediate grounding positions and determination of a final beaching site by hydrographic survey.
g. Reeving 18 pairs of three inch diameter lift wires under the wreck with the aid of the 1½ inch diameter messenger wires.

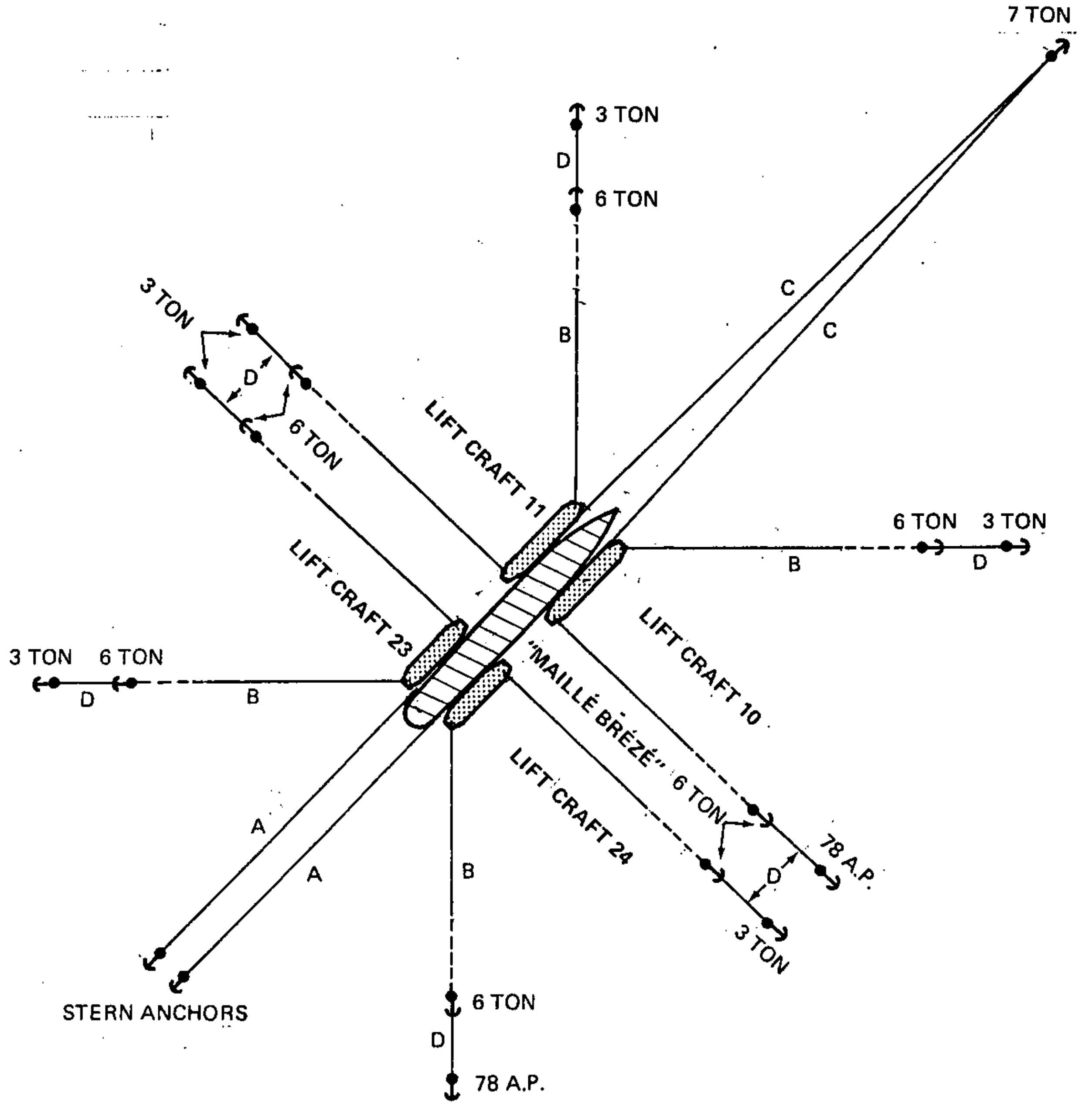


DIVER TUNNELING UNDER THE SHIP.
FIG. 2 NO. 1



LIFT CRAFT IN POSITION OVER "MAILLÉ BRÉZÉ."
FIG. 2 NO. 2

A – 500' OF 4" CIRCUMFERENCE WIRE ROPE
B – 720' OF 6" CIRCUMFERENCE WIRE ROPE & 180' OF 2½" CIRCUMFERENCE
C – 900' OF 4½" CIRCUMFERENCE WIRE ROPE
D – 210' OF 4½" CIRCUMFERENCE WIRE ROPE



MOORING LEGS FOR LIFT CRAFT POSITIONING.
FIG. 2 NO. 3

h. Securing parbuckling wires to the remains of the gun pedestals, to the base of the torpedo races and to the propeller shafts.
i. Positioning two pairs of lift craft over the wreck and then lifting and towing as many times as necessary to arrive at the selected beaching site.
j. Patching and pumping in order to refloat the ship for the tow into a shipyard for scrapping.

2.7. MAJOR PROBLEMS

The main risks involved in the method of salving chosen were the difficulty of coordinating the lifts of the two pairs of lift craft to ensure even distribution of weight; the possibility of damage from straining the wreck; and the danger of the lift wires cutting the shell plating and releasing fuel oil.

The first lift was to be the most crucial as a survey showed that the wreck had settled into the sea bed eight feet six inches. With a mean spring tide range of about ten feet there was little margin on the tidal lift to bring her out of the hole onto the surrounding level.

2.8. EQUIPMENT USED

Four lift craft were used; two of 1200 tons lifting capacity each, LC 10 and LC 11, and two of 750 tons capacity, LC 23 and LC 24. In addition four 80-ton pontoons were used. Since the submerged lifting weight was about 3000 tons the available lifting capacity provided the minimum required 25% margin of safety. A fifth lift craft, LC 8, was used as a spacing fender between the other two pairs of craft. Three salvage craft, the *SUCCOUR*, *BARILLA* and *BARGLOW* were also employed, as well as tugs.

2.9. PARBUCKLING EFFORT

It was obviously desirable to get *MAILLÉ BRÉZÉ* on an even keel before lifting her, if only to reduce the depth of water over the low starboard side and get the lift craft into a better position for the initial lift. The salvors planned to try to parbuckle the ship before trying to roll her on the lift wires when making the lift.

Four parbuckling wires had been secured to the remains of the gun pedestals, base of the torpedo races and one of the stern shafts; however, with the exception of the foremost gun pedestals, none of the securing positions were considered to be strong enough, so an additional turn was taken around the wreck in preference to spending valuable time fabricating the heavy clench plates and fitting these with the necessary doublers, underwater.

The first attempt to parbuckle the ship with the starboard lift craft was made at 1000, 1 August, with no success. Some 1,150 tons of buoyancy effort had been applied on a rising tide and careful measurements showed the list had decreased by only three degrees, from 17½ degrees. It seemed probable that the only effect of this effort had been to take in the slack and tighten up the turns of the parbuckling wires around the wreck. Another attempt was planned for 2 August, during daylight at low water. Although the buoyancy effort of the lift craft was increased by some 200 tons on a rising tide, no appreciable righting movement could be obtained on this attempt either. At high water, 1546, it was evident that the tidal lift could not be applied successfully with the arrangement of the wires adopted. Careful measurements of the depth of the water over the high and low sides of *MAILLÉ BRÉZÉ* were taken by sounding with a chain. They were corrected from tide chart readings and compared with the water depth over the ground. The results showed only one degree had been gained over the previous day's results. The divers reported no change in the position of the ship except that the foremost parbuckling wire had cut in at the deck edge near the flare of the starboard bow. This was not unexpected, but in conjunction with the fact that on both attempts there had undoubtedly been movement of the ship, it was decided to try a maximum effort lift on the night tide of 3 August. It was hoped to get a parbuckling action as in the original plan, in conjunction with a straight lift. Previous experience and history supported this decision, though not with so fine lined or deeply embedded a ship.

On 3 August final preparations were made for the lift. Parbuckling wires were passed onto LC 8 and LCs 24 and 10 and secured there. Four additional nine inch lifting wires were passed singly under the wreck to give extra support at midlength, near the boiler room and engineroom, and the ends were passed to LC 8, thus taking full advantage of her position and the buoyancy available. This was more than enough to replace the two salvage pontoons which were originally assigned to the task. (See Fig. 2, No. 4.)

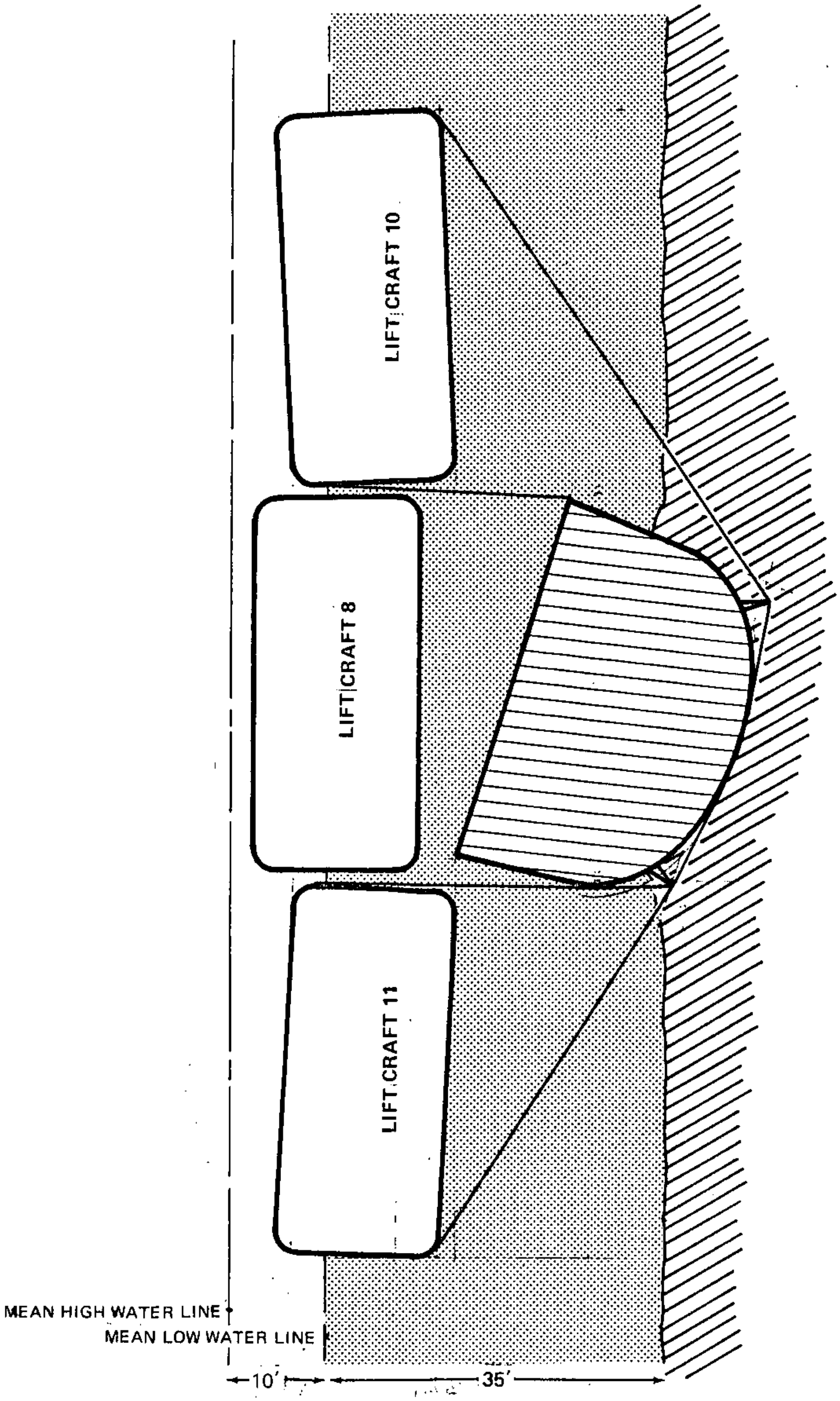
2.10. THE FIRST LIFT

Low water, 1.6 feet, was at 2138 on 3 August; high water, 11.5 feet was at 0413 on 4 August. The range was 9.9 feet and duration, 6 hours 35 minutes.

At 2000 all was ready. The lift craft were positioned so that the calculated center of buoyancy of the lift was slightly forward of the center of gravity of the wreck as a whole; the intention was that the forward end should leave the bottom first, thereby breaking any suction remaining after the tunneling, and the wreck should be carried on the initial lift with a slight trim by the stern.

SUCCOUR now lay astern with her heavy 100-ton purchases connected to a nine inch circumference steel wire rope strap under the stern of *MAILLÉ BRÉZÉ*, to act as a "trimming ship"; *BARGLOW* was outside LCs 10 and 24 giving steam to LC 8 and additional air to LCs 10 and 11. All lift craft were then flooded down to get the maximum buoyancy from their tanks when pumped out, and the slack of the wires was steadily taken in as the tide continued to fall.

Pinning down commenced at 2010. At 2055, all ships were reported pinned down and the breast lines were slacked further with the discharge of water continuing. This was done carefully, trying to synchronize the heavy life craft and their bigger main pumps with the smaller lift craft pumps. All 4,200 tons of ballast were discharged by 0225 and it was apparent that *MAILLÉ BRÉZÉ* was afloat, though probably still in her hole.



SECTION THROUGH LIFT CRAFT POSITIONED FOR PARBUCKLING.
ORIGINAL POSITION OF THE WRECK.
FIG. 2 NO. 4

Tide gauge readings were passed every 15 minutes which was extremely helpful because tide poles and hand signals no longer needed to be used.

By 0235 the tide had made seven feet six inches and assuming that it was running as predicted another 2.4 feet could be expected. Soundings were taken across *MAILLÉ BRÉZÉ* on the forecastle and quarterdeck and at 0300, one hour 13 minutes before high water, there were ten feet over the forward end of the wreck and 20 feet aft. The soundings were fairly evenly spaced from deck edge to deck edge and it was clear *MAILLÉ BRÉZÉ* was almost out of her hole, with little list, but a slight trim by the stern. This trim could be corrected before beaching the ship in shallow water at a later stage. *SUCCOUR* was ordered to put an increased strain on her 100-ton bow purchase and at 0330 she hove down to the limit of the spread of her wires in order to decrease the trim.

At 0400 *BARILLA* took up station ahead with her anchors down, and using main engines, commenced heaving the wreck and lift craft to the northeast. Movement was at first slow but it was obvious *MAILLÉ BRÉZÉ* was out of the hole for almost her entire length. The heavy unit inched slowly ahead. All moorings not required were paid away, buoyed and finally slipped, and by 0445 the wreck had moved approximately 200 feet to the northeast, well clear of her old bed. (See Fig. 2, No. 5 for Position A)

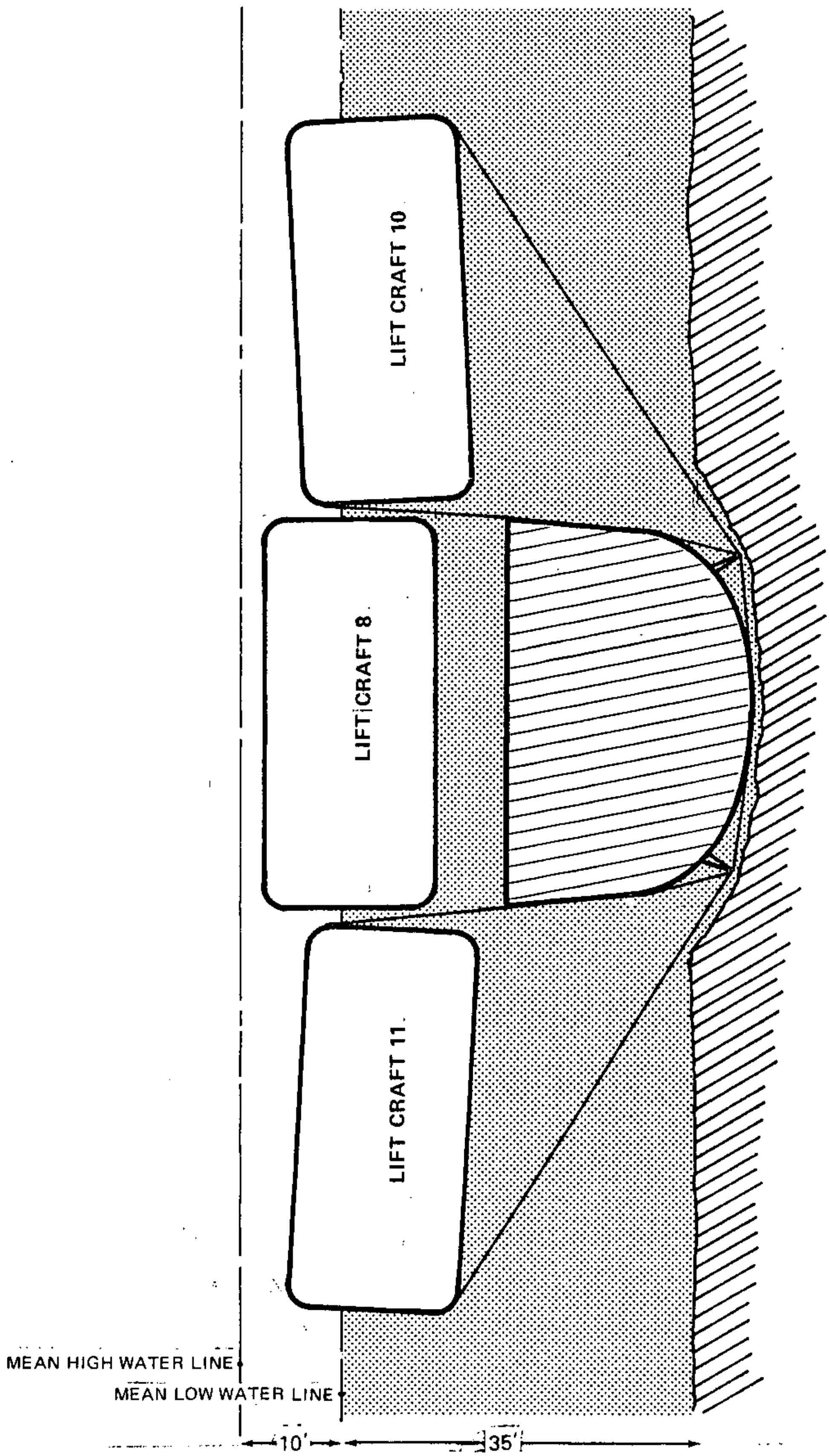
By this time the tide had begun to fall and low water was expected at 0951. The unit was held in position and all lift craft commenced flooding down at 0508 in preparation for the next tide. The *MAILLÉ BRÉZÉ* was now in 35 feet of water, M.L.W., and sitting almost upright. As the lift craft increased their draft by flooding down, and the tide fell, the slack of 18 pairs and four single nine inch circumference wires was taken in.

2.11. THE SECOND LIFT

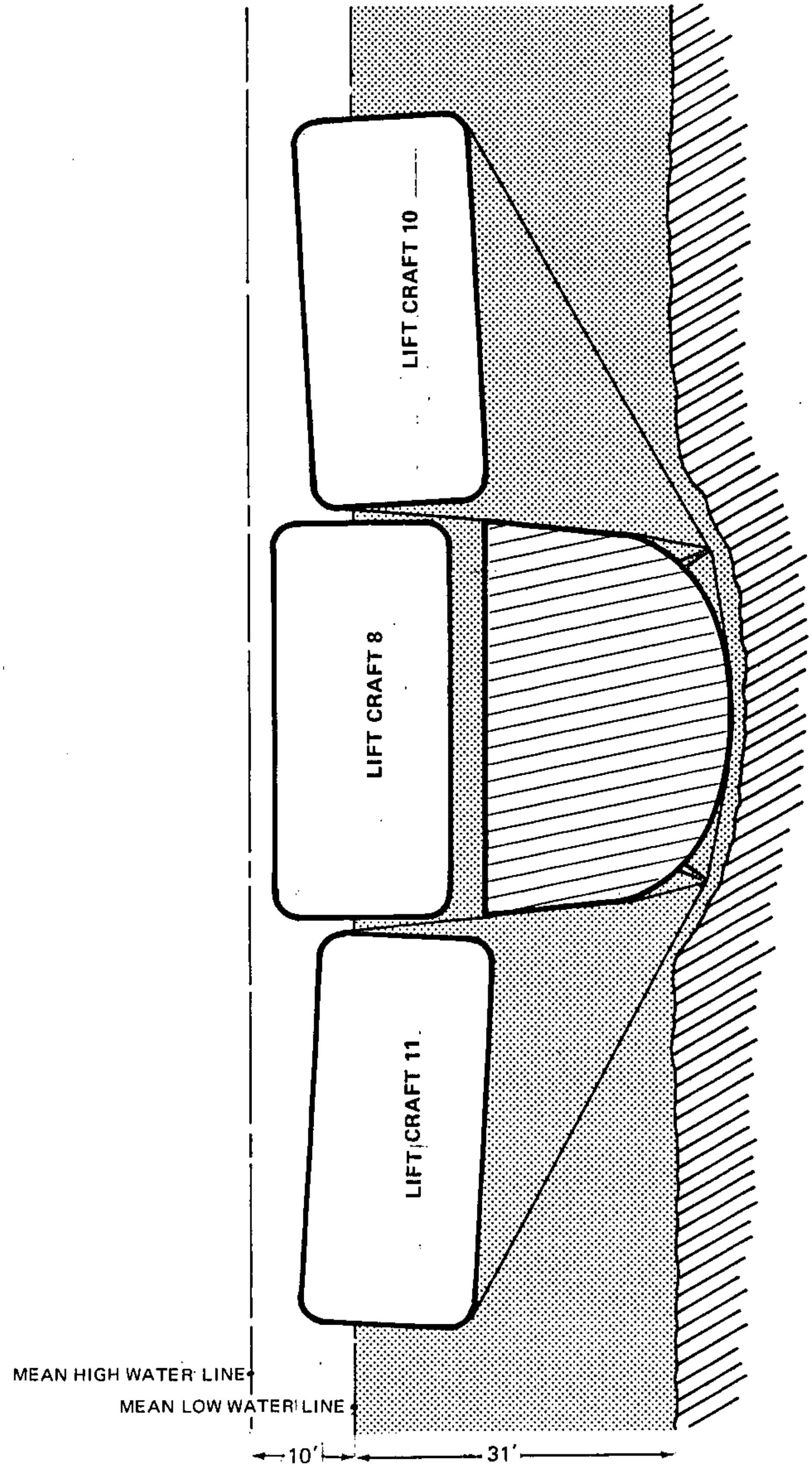
Low water, 1.4 feet, was at 0951 and high water, 9.8 feet at 1658 on 4 August. The range was 8.4 feet and the duration seven hours seven minutes.

Owing to a series of minor setbacks LCs 23 and 24 were not pinned down completely until 1115, one hour 24 minutes after low water. However, there was a good reserve of buoyancy with which a tide range of only 8.4 feet permitted a lift from the tanks as well as the tide. The seabed shelved very slightly upwards for 2,000-3,000 feet ahead. The lift was uneventful and two tugs were in attendance when the unit moved off at 1600. At 1630 the unit was brought up in 31 feet L.W., and at 1700 the lift craft were flooded down to unpin. They had made a distance of 2,350 feet to a position some 6,000 feet from the northwest corner of Princes Pier, Greenock. (See Fig. 2, No. 6 for Position B.)

This tide was five inches below prediction and with the approaching neap tides a few days away, a decision was made to wait for the spring tides of 14 August for the next lift. The new grounding position had soft sand mixed with shingle and the wreck buried herself about five feet into the sea bed after she was unpinned. However, her massive bilge keels tended to keep her upright when she sank into the sand bottom. The tides were slacking off and would be insufficient to lift *MAILLÉ BRÉZÉ*



SECTION OF THE WRECK IN POSITION "A", LIFTED ON AN EVEN KEEL.
FIG. 2 NO. 5



SECTION THROUGH THE LIFT CRAFT IN POSITION "B".
FIG. 2 NO. 6

into appreciably shallower water. The present objective had been gained; to get her out of the hole and well on her way towards beaching ten to fourteen days prior to the top of the spring tides of 17 and 18 August. There was no danger of the wreck sinking further, and she was still in the cradle of nine inch lift wires. The lift craft were suitably positioned for breaking suction at any stage of the lift; the center of buoyancy of the lift craft was forward of the estimated center of gravity of the wreck and consequently she had to come out of the sea bed forward end first. It was important that the trim by the stern should not be greater than the height of the tide predicted, otherwise the ship's stern would not come clear of the bottom.

Bow and quarter breast moorings, each consisting of a three-ton anchor, a shot of chain, cable and 120 fathoms of 4½ inch circumference FSWR were laid out from the unit. The stern anchors of LCs 23 and 24 which had been slipped after coming out of the hole, were relaid. A heavy anchor was laid ahead and the LC 8 was disengaged and put to her moorings by *BARGLOW* to await the next move. Moorings were set up reasonably taut and the unit lay in wait until 13 August.

Meanwhile divers inspected the wreck and found her almost upright with a list of one or two degrees to starboard. There was no sign of damage to the shell plating or deck edge and no push-in effects had been discovered of the nine inch wires at the bilge keel. The beaching ground was resurveyed and the rate of tidal streams rechecked by observation and experiment.

The final beaching site had to be very carefully selected as at that point in the operations it was intended to withdraw most of the nine inch lift wires, pump out the wreck, unload ammunition and bunker oil, and bring the ship to a convenient draft for towing to the shipbreaker's yard. The ground below the layer of silt must not be too soft; there must not be excessive sinkage because of the need for adequate freeboard between half ebb and half flood for pumping and patching. It must be sufficiently soft to keep the ship upright when aground considering her fine lines.

After careful consideration it was decided to use LC 8 as a spacing ship again. The next move was planned for 14 August when it was decided to take *MAILLÉ BRÉZÉ* into 26 feet of water (M.L.W.) with a predicted range of only nine feet. The moulded depth of the wreck was 25 feet and there were a number of vertical projections which divers had not been able to burn off flush with the upper deck. By removing everything portable on LC 8 and trimming tank No. 1 forward, a draft of six feet six inches forward and seven feet aft could be expected. These figures gave a clearance between LC 8's keel and the *MAILLÉ BRÉZÉ* deck of three feet, and one foot to 15 inches over the projections, providing that;

a. the tide came up to prediction,
b. the *MAILLÉ BRÉZÉ* was not taken into less than 26 feet of water, and
c. LC 8 was disengaged and clear of the ship before the first ebb.

If she were not, then it was certain that she would be bilged on the projections as the tide fell away, about 35 to 45 minutes after low water. The resources of personnel and equipment, however, were considered adequate to deal with the situation.

By the afternoon of 11 August LC 8 had been suitably lightened and ballasted, and on 13 August the approach to the bank was again resurveyed and an anchor put down to mark the edge of the bank immediately north and south of the anchor.

2.12. THE THIRD LIFT

Low water, 0.4 feet, was at 0627 and high water, 9.4 feet at 1312 on 14 August. The range was nine feet and the duration six hours and 45 minutes.

The weather conditions were very good, and the sea was flat. Work commenced at 0500 and soundings were taken over the wreck and checked with the rate of fall of the tide. The lift craft were pinned down at 0715 and commenced discharging water ballast immediately.

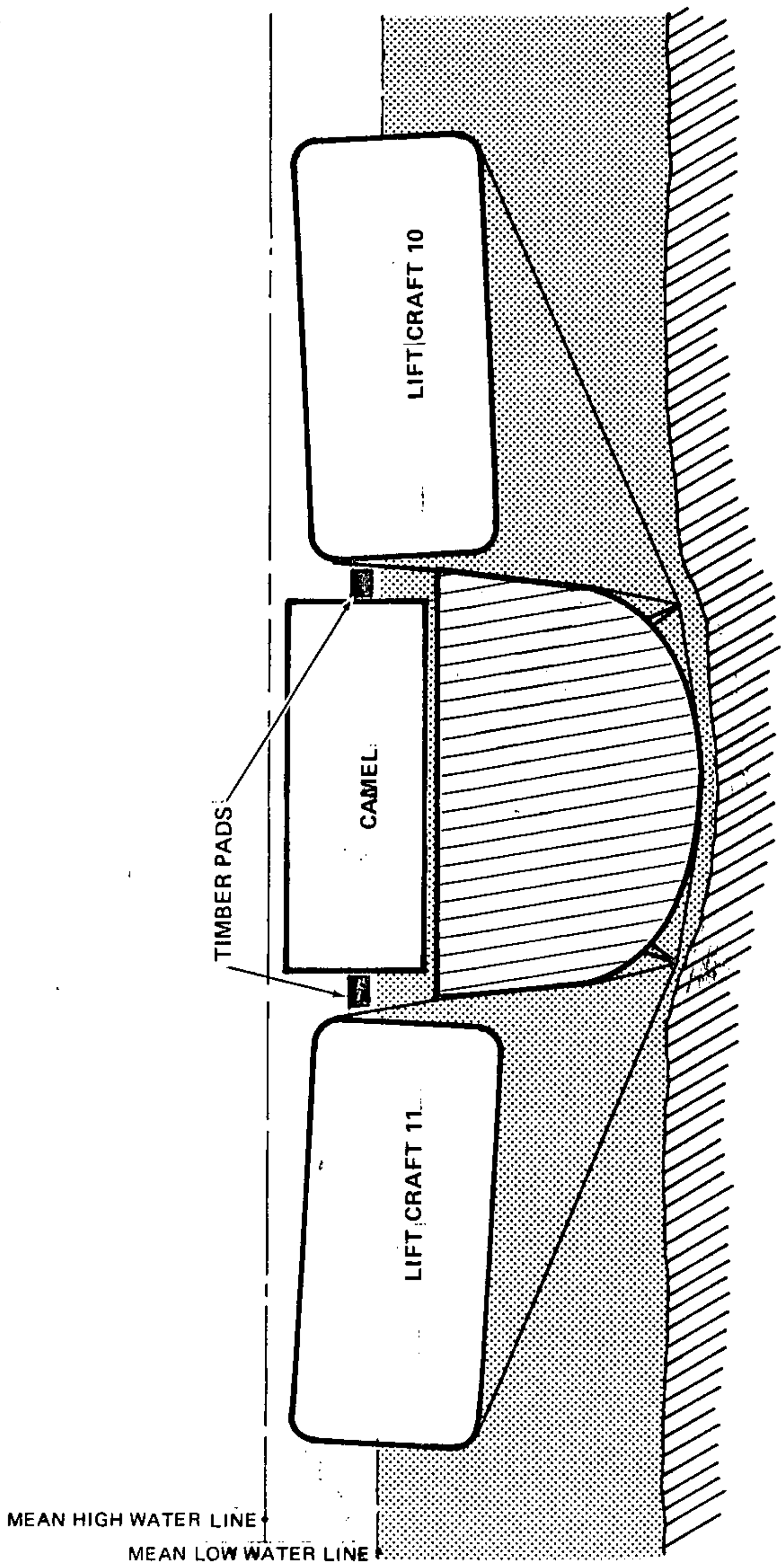
The unit was arranged exactly as before, with *SUCCOUR* at the right and aft to act as a trimming ship, but *BARRINGTON* was made fast alongside LC 23 port side and *BARGLOW* berthed on LC 24 starboard side. The two tugs took position on LC 10 and LC 11 respectively, ahead of 23 and 24. The tide had made six feet nine inches by 1030, and *MAILLÉ BRÉZÉ* had cleared the silt and was leaving the sea bed with one foot of water over her after deck at 0935. By 1100 the operation was proceeding extremely well and an Echo Sounding Cutter was sent ahead towards the area laid down on the 13th. The Cutter was requested to show a large red flag when a depth of 27 feet M.L.W. was reached.

The unit moved off at 1100, tugs and "Bar" class vessels alongside to act as a twin-screw ship. Speed of advance was controlled to allow the tide to rise during progress toward the flag. At 1200 the course was altered slightly to starboard until the unit came abeam and ten feet off the Echo Sounding Cutter.

The tide had now risen eight feet nine inches and a halt was made to allow time to disengage LC 8 before the tide started to fall. *SUCCOUR* was anchored by the stern with the last of the flood slightly on the port quarter, and the tugs maintained the position while the lift craft flooded down and LC 8 rendered her wires by slacking back the clamps. The flexible steam hose from *BARGLOW* which provided LC 8 with power for her pumps and capstans was disengaged, and her lift wires were passed to LCs 10 and 11.

BARGLOW and *BARRINGTON* now cast off from alongside LC 23 and 24, anchoring by the stern with bows onto 23 and 24, and passed their main winch wires to these ships, setting them taut. *BARILLA* who had been following up the main unit lay off to perform a similar service for LC 10. Once LC 8 was clear *SUCCOUR* was to hold LC 11 off the wreck in a similar fashion.

The first three ships could hold the lift craft off the wreck as their tanks flooded and the tide fell away; by heaving on their stern anchors, they could ease the grip of the lift craft on LC 8 as she was hoved astern by *SUCCOUR*. After several unsuccessful attempts attributable to the fouling of one of LC 8's fenders with a lift wire, she was finally pulled away by *SUCCOUR*. The wreck grounded 1.34 miles from the northwest corner of Princes Pier in 36 feet of water, M.L.W. (See Fig. 2, No. 7 for Position C.) Allowing that she would again sink about four feet into the soft sand sea bed, there should have been six feet of water over her upper deck at low water.



CROSS SECTION OF THE LIFT. POSITION "C".
FIG. 2 NO. 7

This meant that when LC 10 and 11 were flooded down to a draft of 12 feet six inches pinning down on the next tide, there should be at least six feet six inches of *MAILLÉ BRÉZÉ'* side to act as a bearing surface to keep the craft from pulling over the wreck and thus ensure the maximum lift from the wires at low water. This way no fender was necessary.

Preparations were now pushed forward for a final lift over the bank on 18 August on the top of the spring tides. The lift just completed had brought the wreck 2,200 feet nearer the objective and a total distance of 4,800 feet had been covered between the spring tides. It had been decided that in view of the hull form of the *MAILLÉ BRÉZÉ*, as few lifts as possible should be employed in order to subject the wires to a minimum amount of work. A move was attempted therefore only when the tides or weather promised to make a gain toward the beach. It could not be assumed that the top of the springs would synchronize with good weather and nothing could be left to chance. The aim was to get right up under the bank as soon as possible. Once there, the bank would be negotiated between spring tides, and so although the bank was only 1,400 feet away, the fourth lift was planned for the morning of 17 August, to be followed by the final move the evening of that day or the morning of 18 August.

Because the after end of *MAILLÉ BRÉZÉ* was well tapered, there was every prospect of LCs 23 and 24 pulling over the wreck unless they were kept apart when taking the weight and in doing so, losing several feet of lift. *BARGLOW* and *SUCCOUR* were both too deep in draft to be used as a spacing ship, but four pontoons of cylindrical construction 33 feet in length and 13 feet in diameter were available and would serve the purpose.

All four lift craft were first positioned 20 feet further astern on *MAILLÉ BRÉZÉ* to bring the center of buoyancy of the lift closer to the center of gravity of the wreck and so decrease the trim by the stern to allow her to float comfortably over the bank. The lift craft were accordingly moved the 20 feet astern and the necessary adjustments made to the position of the wires on the pinpoints.

While the work of repositioning the four lift craft was in progress, some 16 timber pads were constructed. These pads were of sufficient length to cover the diameter of the cylindrical pontoons at each end, and broad enough to give a good bearing surface over the frames of LC 23 and 24 when they were imposed between these ships. It was intended to hang these pads over each lift craft side having first bought the timber to just negative buoyancy by fastening fire-bars to them. This was to avoid reeving bottom lines under the craft and hauling the pads down into position. In practice it was easy to reeve the bottom lines, notwithstanding the number of lifting wires, messengers, and other wires that the lift craft were already handling, and this latter method was adopted. The pontoons were towed out to the unit on 16 August and positioned during the evening. The night of 17-18 August was devoted to crossing the three fathom line and making the final beaching position. Two lifts would be required to reach the objective and it would be necessary to "pin down" on both the morning and evening tides.

2.13. FOURTH LIFT

Low water of the morning tide was at 0823 and high water at 1521, with a range of 10.4 feet. The evening tide low water came at 2037 on 17 August, with high water at 0334 on 18 August; a range of 11 feet.

Once again the weather was fair with little wind and no sea. All lift craft were flooded down by 0700 and the task of removing all slack from the nine inch wires began. Final adjustments to the pontoons between LC 24 and 23 were made and soundings taken over the wreck's after end. *BARGLOW* was positioned on the port side of the unit overlapping LCs 23 and 11, and *SUCCOUR* on the starboard side overlapping LCs 10 and 24 in a like manner. At 0815 the tide was four inches short of prediction and was falling slightly. It began to make at 0850 but was still two inches short of predicted low water, and with such a tide a good lift was expected.

Pinning down commenced at 0840 and by 0945 the wires on all four lift craft were secured. The water ballast discharge, some 3,700 tons, was completed at 1145 and at noon it was apparent *MAILLÉ BRÉZÉ* was again off the bottom for the whole of her length. A report from the tide gauge indicated that the water had risen six feet eight inches at noon and that the tide was likely to reach the predicted height of 10.4 feet by high water. The lift was going well and the conditions were ideal. At 1200 the tugs *SPITFIRE* and *TYPHOON* berthed on LC 10 and 11 just ahead of *BARGLOW* and *SUCCOUR* and at 1350 the unit moved off again with the salvage ships and tugs controlling the line of advance.

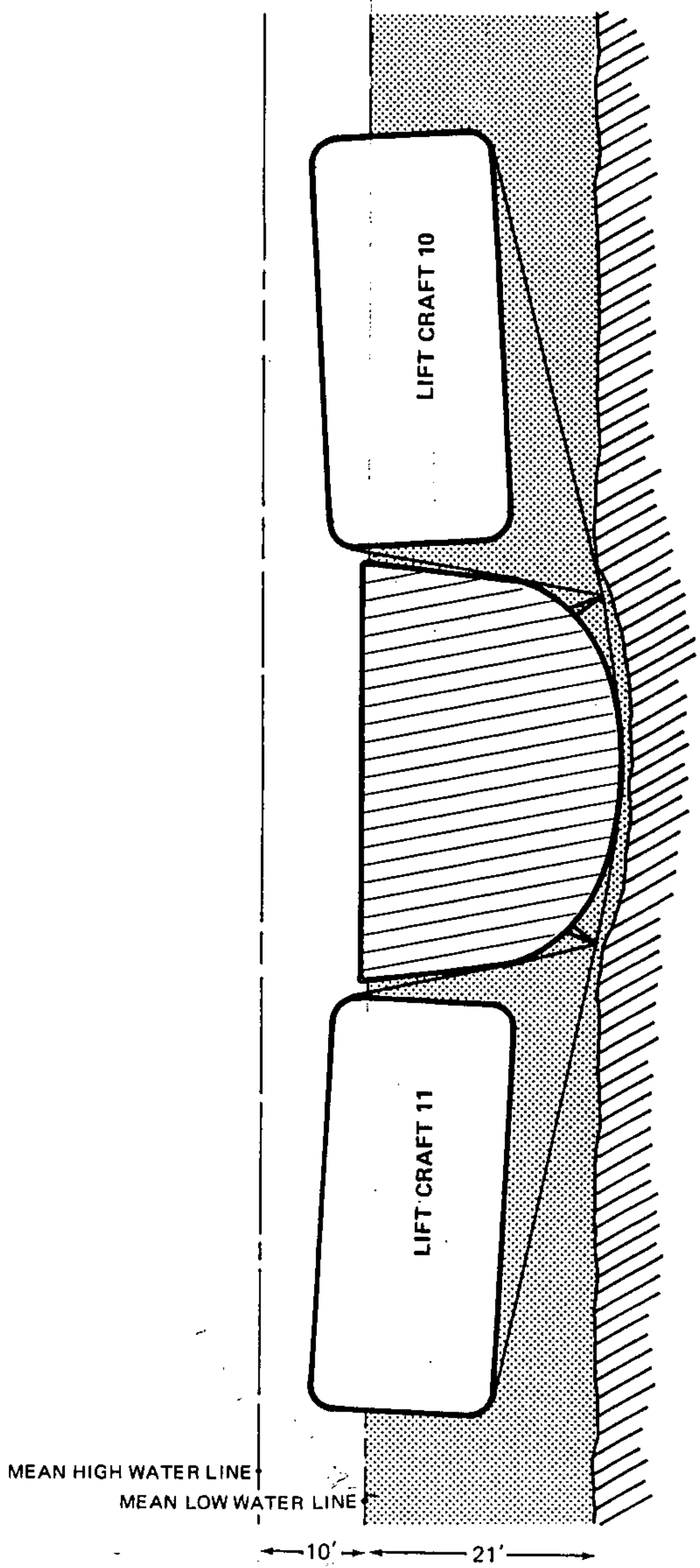
The unit slowly worked around approximately 50 degrees to starboard, and gradually increased to full speed, making straight for the area lying between two buoys laid the previous day. The flood was slightly on the starboard quarter and the speed was reduced by half when there was sufficient way in the unit.

Engines were kept going at half ahead until the wreck grounded and were stopped periodically to allow the tide to make the last few inches. Between 1430 and 1500 the tide rose another four inches and an advance of 50 and 100 feet resulted, but little more could be expected. (See Fig. 2, No. 8 for Position D.) The tide was ten feet six inches, two inches above prediction, and orders were given to flood down and unpin in readiness for the next lift during low water at 2037.

BARRINGTON and *BARILLA*, were laid off to the northwest and closed to within hailing distance. Two anchors with backers had been laid out on the bank ahead of the unit a few days previously, and the *BARILLA* recovered the wires and passed them to LC 10 and 11 to hold them up against the strength of the ebb. The breast mooring was also laid out on the port side of LC 11. *BARRINGTON*, with stern anchors down, passed her main winch wires to LC 23 on the port quarter and *SUCCOUR* was positioned to assist in holding the unit against the flood tide when coming afloat.

Soundings were taken ahead and astern of *MAILLÉ BRÉZÉ* and over her decks. These were reduced to low water from a tide gauge reading at 1645 of eight feet six inches, and showed that the bank had a declivity of two feet six inches in 430 feet of water. With depths of 21 feet at the stern and 18 feet six inches at the stem, the wreck had sunk only about three feet six inches into the mud.

The spacing pontoons had been removed immediately after the wreck grounded, as there was now ample depth of the ship's side for the lift craft to bear against on pinning down for the final lift.



CROSS SECTION OF THE LIFT IN POSITION "D".
FIG. 2 NO. 8

By 1915 preparations were complete and orders were passed to pin down at 1930. At 2030, seven minutes before predicted low water, the tide gauge reading was plus seven inches to datum and at 2105 pinning down was complete. The discharge of ballast water started immediately and the tide rose fast.

At 2330 the wing tanks in all the lift craft were practically dry and *MAILLÉ BRÉZÉ* was off the ground for the whole of her length. The head gear was tightened up on LC 10 and 11; *SUCCOUR* on the lee side was put to slow ahead to keep the unit up to the wind. This proved effective and at 2345 *BARGLOW* started to come ahead on her engines thus keeping the wreck nudged up to the bank and slightly to windward of the beaching position.

At 0030 the tide had risen six feet nine inches and shortly after all ships were stopped and the slack in the moorings was taken in. The time had come to carry *MAILLÉ BRÉZÉ* over the bank; after this, the tide would rise more slowly each hour and with careful timing the beaching position could be reached and flooding down commenced at least an hour before high water. The order to discharge the 1,270 tons of water ballast was given at 0041 and all ships were put half ahead once more. *BARILLA* and *SUCCOUR* eased away their stern moorings and LC 10 and 11 hove away steadily on their head anchors. Soundings were taken at 0056 and showed depths of 19 feet, six inches aft and 16 feet, six inches amidships, M.L.W.

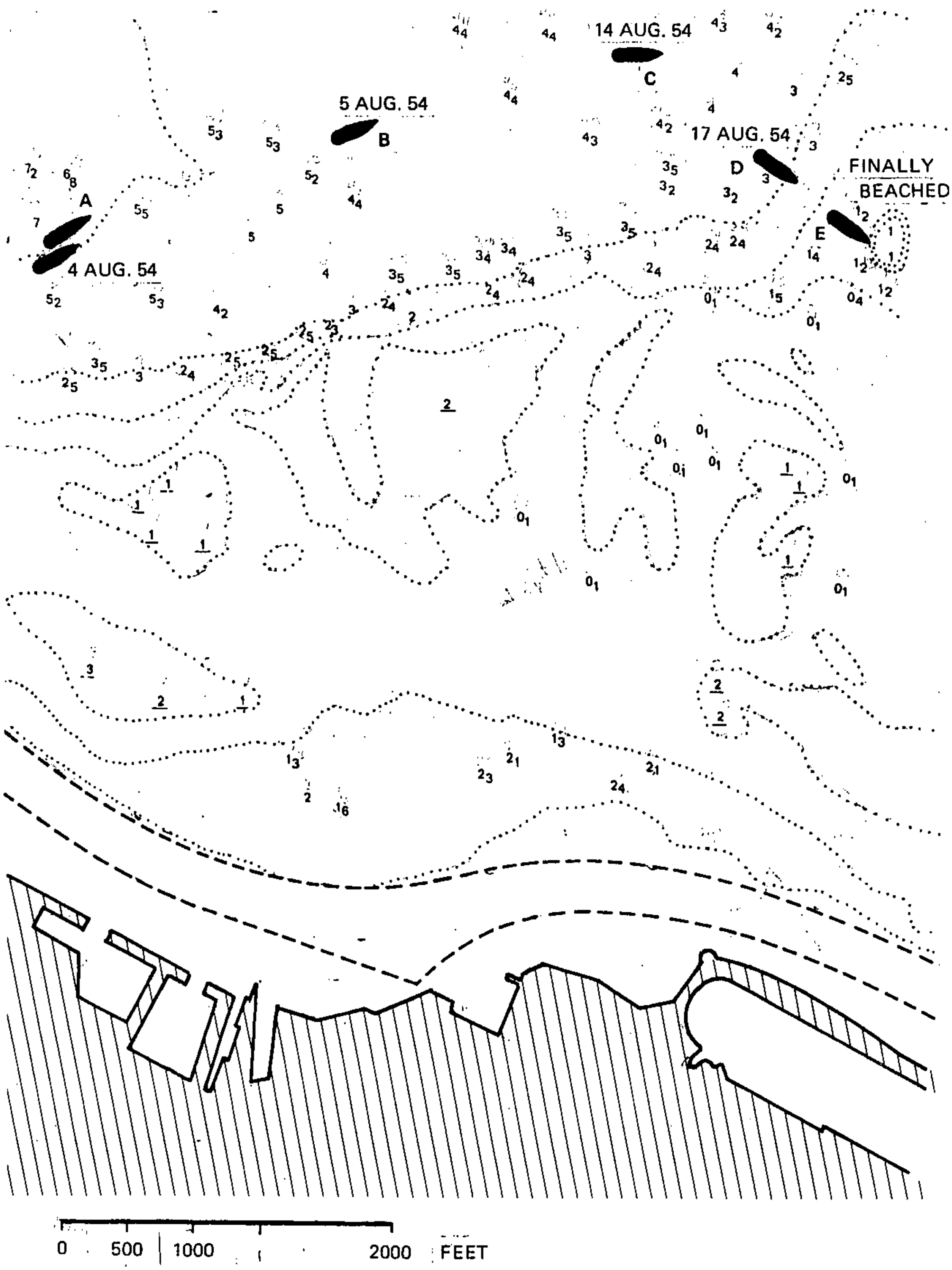
MAILLÉ BRÉZÉ moved slowly ahead and at 0125 the port breast lines were leading well abaft the beam. At this time a report from LC 10 and 11 warned the unit was too far to windward. The lift craft were at maximum buoyancy and the wreck was more than half way over the bank. *BARGLOW* was therefore ordered to increase speed while the two ships on the lee side eased down until the unit had worked from windward to the correct line of approach. From this point the engines were used only as necessary to maintain position while moving steadily ahead.

At 0149 the sounding at half length of *MAILLÉ BRÉZÉ* was 22 feet and at 0156, within a few feet of the intended position, flooding down of the center tanks was commenced. This process usually took 40 minutes, but in order to expedite matters the flooding of the wing tanks was also begun. Taken in conjunction with the rise of the tide for the last hour, this was too fast for LCs 23 and 24, and flooding of only the center tanks was resumed temporarily. At 0230 when the soundings gave depths, reduced to M.L.W. of 12 feet forward, 14 feet amidships and 17 feet aft, flooding of all tanks together was possible again, and the *MAILLÉ BRÉZÉ* was allowed to come to rest before the predicted high water. (See Fig. 2, No. 9 for Positions A through E).

MAILLÉ BRÉZÉ was now lying fore and aft with the main strength of the flood and ebb tides. She was sunk about five feet in the sand and shingle, and at low water had a freeboard at springs of four feet aft and nine feet at the stern.

2.14. REFLOATING

When the operation was planned the large lift craft were to be kept alongside the wreck until she was ready to be towed to the shipyard. The next few days were spent clearing water from the main



MOVEMENT OF "MAILLÉ BRÉZÉ". POSITIONS "A" TO "E".
FIG. 2 NO. 9

compartments with the aid of the lift craft and *SUCCOUR*. Six inch flexible suctions were rigged from the LCs to No. 1 and No. 2 enginerooms and No. 2 boiler room, which were then pumped down. At the same time, men with high pressure jets washed down silt, mud and shingle from the turbine casings, boilers and auxiliary machinery. A portion of this debris was carried away in suspension by the suction, but the heavier material found its way down into the engineroom plates and bilges.

During the lightening of the ship the removal of depth charges presented a problem. They were carried in enclosed chutes below the upper deck on each quarter; there was only a small access door at the loading end. The quickest and easiest method of getting to them was to burn a strip of deck plating out for the full length of the chute, thus exposing all the depth charges, which would then be lifted out singly by hand. It had to be done when there was a little tidal water over the deck to dampen the sparks and cool the plate edges as the deck plating was burned away. The salvors were often burning within inches of the charges, 16 in all.

Two eight-inch and three six-inch pumps were placed onboard the wreck to deal with No. 1 boiler room, the after accommodation, forward and after magazines, wardroom and other compartments. A number of four-inch Johnson and Snorer pumps from *SUCCOUR* were used as backup and to drain the lower compartments.

After this was accomplished the unbreached compartments could be pumped out to bring the ship afloat; additional buoyancy could then be gained by installing a patch over much of the damage.

Sufficient buoyancy was recovered in the forward and after ends of the ship to justify bringing her afloat on her main compartments, No. 1 engineroom, and No. 2 boiler and enginerooms.

By bringing the ship afloat she could be hove ahead some 250 feet into shallower water thereby enabling a light shield of 3/16 inch plate to be placed over the lower portion of the damage in No. 1 boiler room. By extending this some six feet above the low water mark, sufficient time could be gained for the pumps to have effect against the rising tide, and thus secure additional buoyancy to bring *MAILLÉ BRÉZÉ* to a reasonable draft for the tow to the salvage yard.

This was done on the afternoon of 1 September and patching the lower end of the damage and the positioning of an additional eight-inch pump in this compartment commenced before dark.

Her draft on coming afloat was 20 feet six inches forward, and 21 feet eight inches aft.

By jettisoning mud, patching and pumping, and the removal of ammunition, together with the recovery of buoyancy in the forward boiler room, the wreck was in good trim and draft for towing. Drafts were 14 feet nine inches forward, and 15 feet six inches aft. At this point there was little to be gained by removing the mud and silt below the engine bed plates or in the lower compartments for there was no need for a further reduction of draft.

On 15 September 1954, the ship was handed over for delivery to the salvage yard.

3. EMPRESS OF CANADA

3.1. BRIEF

Fire broke out aboard the passenger liner *EMPRESS OF CANADA* while docked at Liverpool undergoing repairs. Attempts to contain the fire failed and the ship steadily listed until she sank at the dock. As she was blocking one of the most valuable berths in the harbor she had to be removed. Extensive preparations were made to right and refloat her, which combined internal and external, mechanical and static forces. The entire operation, though successful, took almost two years.

3.2. DESCRIPTION OF THE SHIP

The dimensions of the ship were 581.9 feet long, 75.25 feet wide, and 24.0 feet deep, with a gross tonnage of 20,021 tons. From the floating drafts her displacement immediately prior to the fire was 18,680 tons, and after subtracting the amounts of water, fuel, etc., this figure substantially agreed with the stated light ship displacement of 15,562 tons.

3.3. HOW THE SHIP SANK

On the afternoon of Sunday, 25 January, 1953, the *S.S. EMPRESS OF CANADA* (Fig. 3, No. 1) was lying in No. 1 Branch Gladstone Dock when an outbreak of fire was discovered in the passenger accommodation, B deck. She had moved from a graving dock two days previously but her repairs were still in progress and about 290 workmen were on board.

The fire was discovered on board at 1610. The alarm was telephoned to the fire brigade at 1617, but at the official inquiry it transpired that smoke had been seen coming from portholes in B deck at between 1525 and 1530, 40-45 minutes before any alarm was given. The fire brigade arrived two minutes after the alarm at 1619 and by that time the fire had obtained a firm hold and was spreading aft and upward with such rapidity that all that could be done was to attempt to "box" it. The number of fire pumps was eventually increased to thirty, supplemented by hoses from the Mersey Docks and Harbor Board's vessel *SALVOR.*

The Board's officials arrived shortly after 1700 and immediately investigated the stability of the ship. The officer of the day managed to recover the tank statement from the ship's office which gave amounts of fuel, water, and stores on board, and the estimated metacentric height (G.M.). There was no cargo. Although access to the ship's data and plans was not possible, fortunately a sister ship – the *EMPRESS OF FRANCE* – was lying in the next berth. Using the plans and data of the *EMPRESS OF FRANCE,* the G.M. obtained with the stated amounts of fuel, etc., for the *EMPRESS OF CANADA* agreed with the G.M. of 3.5 feet calculated the previous day by the chief officer of the latter vessel. This check showed that it was reasonable to use the *EMPRESS OF FRANCE's* data for further calculations.

Estimates were made of the amount of water entering the vessel through the fire hoses and the areas where it was being applied, the quantity of water that would drain to a lower level by way of staircases, etc., and the loss of weight due to combustion of wood paneling and fittings. On this basis it was calculated that when the vessel reached a list of 17-18 degrees the G.M. would be less than six inches, as the bulk of the water would be in the upper decks; there would be no righting moment left at a list of 22 1/2 degrees. An examination of the plans showed that with a list of 17 degrees, the portholes on D deck would be below water level, but as all these were fixed ports of 1¼-inch glass and no repairs were in progress below C deck, no leakage was anticipated.

Consideration was given to moving the vessel but there were not sufficient tugs available to tow her with safety, and the possibility of blocking the only entrance to the North system of docks had to be weighed.

At the commencement of the fire the draft of the vessel was 18 feet 2 inches forward and 25 feet 2 inches aft; 21 feet 8 inches mean. The depth of water in the berth was 48-49 feet and this level could not be lowered as the tide was rising. This precluded any hope of successfully grounding the ship by flooding. It was therefore decided to continue to fight the fire until the list reached 17 degrees, and then to suspend fire fighting until the list reduced by the burning out of top weight and the reduction in weight of water by drainage and evaporation.

As the bridge was in the fire area, a pendulum was rigged and a scale marked on the after end of the deckhouse on A deck aft to enable the list to be measured. A number of holes were cut with oxyacetylene torches in the shell plating at the level of B deck to drain that deck.

The list steadily increased, and at 2035 hours it reached 17 1/2 degrees. The firemen inside the ship were withdrawn and fire fighting was confined to cooling the upper deck where surplus water would run overboard and to protecting the shed alongside which the vessel was lying.

Meanwhile, detailed plans of the vessel had been obtained from the Canadian Pacific Company's head office and these were examined by their naval architect to see if it was possible to improve the list by counterflooding.

A pipe tunnel ran on the center-line from the boiler room forward through No. 2 and No. 3 holds to a height of six feet above the hold overhead. From the plans it appeared practicable to flood the starboard side of No. 3 hold, but after a short time it was found that most of this water was draining to the port side through a cross-over pipe under the tunnel which was not shown on any of the plans. The pumping was stopped.

The ship continued to increase her list and draft aft. At 2345 hours the list was 21 degrees and the draft 18 feet 10 inches forward and 25 feet 10 inches aft. About 0100 hours the masts and funnels came into contact with the dock shed and she finally sank on her side at 0138 hours on 26 January (Fig. 3, No. 2). At the official inquiry, which was held before the vessel was salved, the probable cause of the steady increase of list was attributable to the ingress of water through ports in D and C decks broken by the heat and through the galley refuse chutes in C deck. When the vessel was righted

however, it was found that the port oil fuel filling door on D deck level was open, providing an aperture three feet by 2 feet 3 inches which would be submerged at a list of 15 degrees and this was undoubtedly the major factor in the loss of the vessel. There was no reason for the door to be open and the fact that it was open was unknown to anyone in authority. Also, as the door was below the level of the quay, it could not be seen when operations were in progress. It is not normal practice for such doors to be opened except when bunkering is in progress, and the starboard door through which the vessel had bunkered the previous day was properly closed and watertight.

The vessel sank on her port side, her masts and funnel resting on the quay and shed, lying at an angle of 89 degrees to the vertical. The bed of the dock consisted of sandstone overlaid with two to four feet of soft mud; the original excavation of the rock was at a level of 22 feet below low water of equinoctial spring tides. She was lying at an angle of 2.3 degrees to the face of the quay; the bow was about 35 feet farther from the quay than the stem.

3.4. METHOD OF SALVAGE

The *EMPRESS OF CANADA* was launched in 1928 and, in view of her age and the damage she had sustained, it was probable that she would be a constructive total loss when salved. She was blocking a valuable berth but it was also important in planning her removal to cause as little interference as possible with the remainder of berths in the dock. The two alternatives were to cut her up where she lay or to right and refloat her.

The level of the dock water could only be lowered on rare occasions, if the remaining eleven deep-water berths were to continue in use. The greater part of the cutting would have had to be done by divers, and even if the restrictions on the use of the dock were accepted, a third of the hull would always be submerged. Previous experience in the removal of the remains of a small war casualty in the docks suggested that a period of three to four years would be occupied in this method because of the difficulties caused by lack of visibility underwater. The cost of building a dam around the vessel, to enable her to be cut up dry, and the subsequent removal of the dam was prohibitive.

It was therefore decided to right the vessel and then refloat her. Preliminary calculations allowing for the removal of a large part of the superstructure showed that a total righting moment of about 350,000 foot-tons would be required initially, decreasing as she turned and becoming zero at about 45 degrees. Detailed planning to provide this force proceeded.

Meanwhile work proceeded on the removal of the masts, funnels, bridge, deckhouses, lifeboats, davits and cargo winches, each item being listed and weighed after removal. Owing to losses caused by locking operations, the level of the dock water fluctuated over a range of ten feet, occasionally being as low as 40 feet. Over 50 per cent of this material had to be cut away under water by divers working under conditions of very low visibility. The low visibility was due to particles of clay, organic matter, etc., suspended in the water, and although conditions in the enclosed docks were somewhat better than in the river, because the heavier particles have time to settle out between tides, visibility was still restricted to a few inches.

NOTE: Experiments with a number of different types of underwater lighting have been carried out for many years but even a lamp with a high-intensity mercury-vapour light source was of little use more than 10-15 feet below the surface.

The vessel had on board at the time of the casualty over 1,250 tons of diesel and boiler fuel oil. The leakage from air vents, etc., from the various tanks produced a serious fire risk, and added considerably to the difficulties of diving; the effects of the oil rendered a diving dress useless in less than a week. The removal of the oil from the surface of the water was made more difficult by its admixture with floating debris, and after numerous experiments, the only satisfactory way was to remove it with large hand scoops. To reduce the contamination of the diver's dresses, a pipe was led from an air compressor with the open end secured to the diver's ladder about five feet below the surface of the water. The resulting turbulence created an oil-free area on the surface of about 10-15 feet diameter.

The straight side of the vessel extended for a length of 230 feet amidships. Allowing for a certain amount of cushioning by the mud overlaying the rock, a pressure of about 65 tons per square foot would develop as the vessel rolled on her bilge. A detailed examination of the scantlings showed that the strength of the structure in this area would be sufficient to prevent collapse of the bilge.

A detailed examination was also made of the interior of the vessel and the dock was run down at low water to enable as much of this survey as possible to be done dry. Even so, over one-third of the survey had to be done by divers. To assist the divers, a sectional model to a scale of 1/8 inch to 1 foot was made. This model was constructed so that each deck could be lifted off. All steel bulkheads, doors, etc., were built up in plywood, but wood bulkheads, fittings, and machinery were shown in plan only on each deck. The plan was marked up as the survey proceeded. The model proved of great value in the survey and in the subsequent work of isolating various compartments.

3.5. SOURCES OF RIGHTING MOMENT

The righting moment was obtained from a combination of four forces, one mechanical and three static, as follows:

1. sixteen shore purchases each nominally 100 tons, pulling on wires led over tripods erected on the starboard side;
2. eleven salvage pontoons submerged along the port deck edge;
3. six salvage pontoons partly filled with water as counterweights along the starboard bilge;
4. internal buoyancy in eight compartments in the hull.

The south quay of No. 1 Branch dock had a three-story concrete shed, the upper floors carried on concrete pillars, the sides consisting mainly of large sliding doors. On the quayside of the shed was a

40-foot wide apron with rail and crane tracks, and behind the shed, a service road 77 feet wide. A large railway siding was south of the road. To enable this berth to remain in use as long as possible, the anchorage for the purchases and seating for the winches was situated in the rail sidings about 150 feet south of the shed. The positions of the tripods on the wreck and the anchorage of the purchases were arranged so that the lead of the hauling wires was at right-angles to the wreck and clear of the shed pillars. With the large door area, only one reinforced concrete panel had to be removed from the roadside wall of the shed. The arrangement of the winches, wires, etc., is shown in Fig. 3, No. 3.

3.6. ANCHORAGE BLOCKS

Three reinforced concrete blocks were constructed to anchor the purchases and provide seating for the sixteen steam winches, carrying four, eleven, and one winch, respectively.

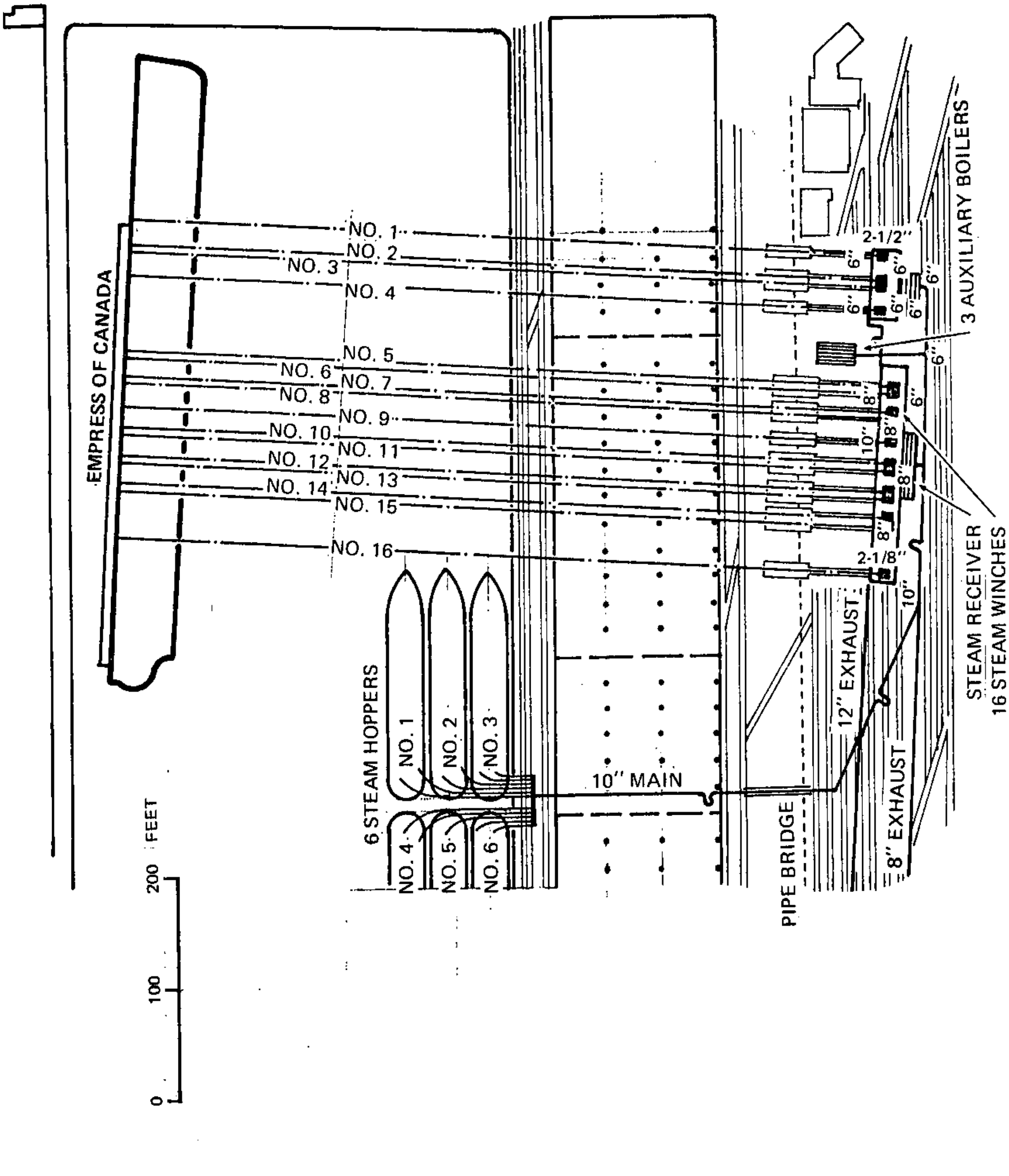
The first block measured 23 feet 3 inches by 68 feet, weighing 936 tons; the second 23 feet 3 inches by 176 feet, weighing 2,420 tons; and the third 23 feet 3 inches by 16 feet, weighing 220 tons.

In the design, a pull of 1,920 tons, or 120 tons on each purchase, was allowed. The blocks were roughly wedge-shaped in section (Fig. 3, No. 4). They were 12 feet deep at the rear end, six feet deep in front, with a two-foot base step 16 feet from the front. The center of gravity was 1 foot 6 inches off center towards the rear. The maximum ground pressure when at rest was 0.869 ton per square foot at the rear edge, and under full load it was 0.941 ton per square foot at the front edge. The tendency was for the block to slide about a slip circle of approximately 54 feet in radius, giving a factor of safety of only 1.17, taking the shear of the soil at 0.1 ton per square foot. This factor of safety could not be increased economically by deepening the blocks, so a sheet-steel piling 30 feet long was driven in front of the blocks throughout; the top of the piling was secured by heavy bolts at the top of the blocks.

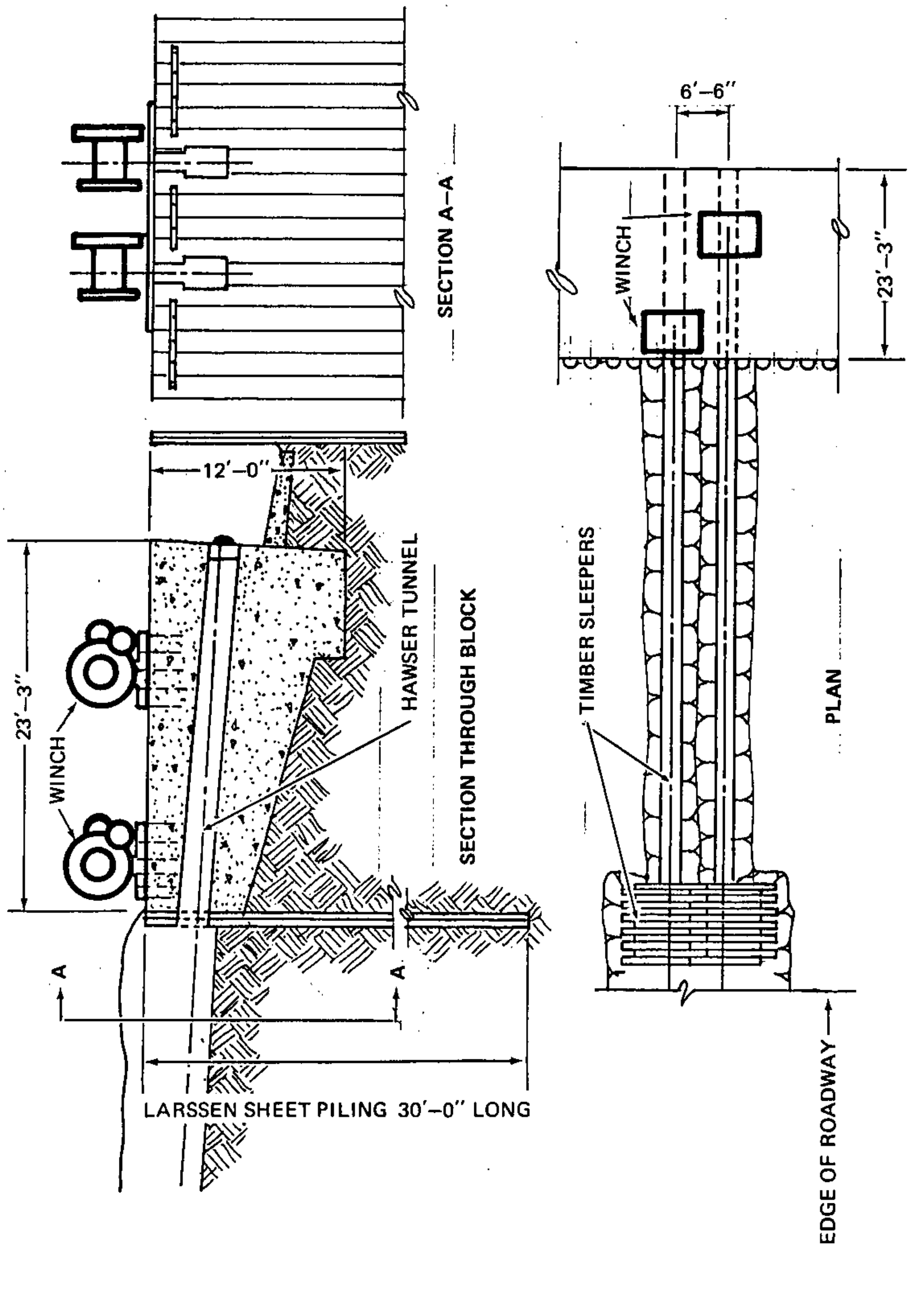
The concrete blocks were constructed of eight to one mix, and laid in sections, the joints having shear locks throughout. Each joint was suitably reinforced with old steel rails. The first lifts were laid six feet six inches deep forming the sloping bases.

To position the winches, openings 9 feet by 6 feet 6 inches by 2 feet 3 inches deep were left on the top of the blocks (Fig. 3, No. 5). Two old steel rails were then temporarily fixed over each opening and leveled. The winches were lowered on to these supports with the holding-down bolts suspended into the openings. Concrete was then laid and leveled-off two inches from the top face and the winches were removed, leaving the bolts concreted into position. Hardwood pads were fitted and leveled, and the winches bedded into position.

Trenches were then excavated to provide a passage for the anchorage pendants to the tunnels in the block sloping from the roadway level to a depth of five feet at the block (Fig. 3, No. 6). Each purchase was anchored by a nine-inch wire pendant and shackled to the rear block of the purchase. The pendant was led through a tunnel cast in the block and secured by a six-inch diameter carbon-steel toggle pin bearing against two steel girders cast in the rear face. An inspection passage for the rear toggle pins was provided at the rear face, with the earth retained by light sheet-piling.



GENERAL ARRANGEMENT OF WINCHES AND PULLING WIRES.
FIG. 3 NO. 3



BLOCKS USED TO CARRY WINCHES.
FIG. 3 NO. 4

Over 1,000 yards of railway track had to be lifted to clear the site before excavation commenced. The surface level of the concrete blocks was arranged so that the railway tracks could be relaid across the top of them when the site was reinstated.

3.7. WINCHES AND STEAM SUPPLY

The heaving power was provided by sixteen steam winches of nominal 12-ton pull, loaned by the Admiralty, Royal Navy. Each winch possessed cylinders 10 1/2 inches in diameter by a 12-inch stroke. Although the size of the main drums was not ideal, the delivery period of specially built steam or electric driven winches was so long that the restriction on the amount of purchase wire that the main barrels would accommodate had to be accepted.

The main steam supply was from six of the Board's dredging craft moored on the south quay, capable of supplying 120,000 pounds of steam per hour, at 180 pounds per square inch (Fig. 3, No. 7). It was desirable to use these vessels for as short a period as possible. Therefore, to provide steam for all the preliminary testing and rigging of the gear, three portable oil-fired water-tube boilers, supplying 5,000 pounds of steam per hour were positioned near the anchorage blocks in a temporary shelter. These boilers also supplemented the steam supply from the ships during the main operation.

The steam from the oil-fired boilers of the moored vessels was led through three-inch bore flexible copper pipes to two 12-inch bore headers placed horizontally on the quay. Each header was fitted with twelve three-inch stop valves to receive the flexible pipes (Fig. 3, No. 8).

An eight-inch pipe rose from each header to the apron of the first floor of the shed, where they joined into a ten-inch bore main pipe. To leave the road clear for traffic, the ten-inch pipe was laid across the first floor of the shed. It was carried over the roadway on the south side of a temporary steel bridge. It then dropped to about six feet above ground level and was laid with a slight gradient to the rear of the blocks, where it was connected to a steam receiver of 380 cubic feet of capacity. The supply from the portable boilers was connected to the same receiver (Fig. 3, No. 9). At the mid-length of the receiver the steam passed through a ten-inch control valve to the sixteen winches.

When heaving, the stop valves at the winches were fully opened and the steam supply was controlled from the main valve at the receiver to ensure that the pull of all the winches was as far as possible balanced.

The headers, steam pipes, and receivers were lagged with two-inch magnesia sections, canvas-covered, and finally covered with 3/8-inch "Bitulac" composition. Bradford-type steam traps and hand drains were fitted at various points in the system.

The three-inch exhaust pipes from each winch were led into a common exhaust line laid along the north face of the blocks (Fig. 3, No. 10). To keep the steam clear of the operating area, these pipes exhausted to air at a distance of 250 feet from the most westerly winch. This pipe was of eight-inch bore at the eastern end and, at the fifth winch, increased to ten-inch bore, finally increasing to 12-inch bore to the outlet.

3.8. PURCHASES AND HAULING WIRE

Each purchase was comprised of a pair of six sheave blocks rove with 3½-inch circumference steel-wire rope. The rear block was shackled to a nine-inch steel-wire pendant 100 feet in length, passing through the tunnel in the concrete anchorage and secured with a six-inch diameter toggle pin at the rear face.

The outer or moving block was shackled to a nine-inch wire pendant, 60 feet long, which in turn was shackled to the main wire (Fig. 3, No. 11). The travel of the moving block was limited to about 75 feet; this was governed by the maximum amount of 3½-inch wire which the barrels of the winches could accommodate. A travel of 75 feet would produce an alteration in the angle of heel of the wreck of about 45 degrees.

Since at this list the wreck would still require power to move her towards the upright position, the 60-foot pendants enabled the purchases to be fleeted out and reshackled to the main wire, as necessary, during the operations.

The hauling part of the purchase wire ran from the outer block to the winch barrel; the other end was shackled to the same block using a "Talurit" alloy clamp to secure the wire around the thimble. The use of this type of clamp instead of a conventional splice permitted the blocks to be brought much closer together at the end of their travel.

The main nine-inch wires were led across the dock over the heads of the tripods and secured at the base of the vertical leg of the tripods. The nine-inch wires were of 6 x 61 construction with a breaking strain of 267.3 tons, similar to the wire used for lifting operations with pontoons. The 3½-inch diameter wires were of 6 x 37 construction with a breaking strain of 43.5 tons.

The ground over which the purchase blocks traveled was carefully swept, and steel plates were laid where necessary to obviate the risk of grit and stones being picked up by the moving wires.

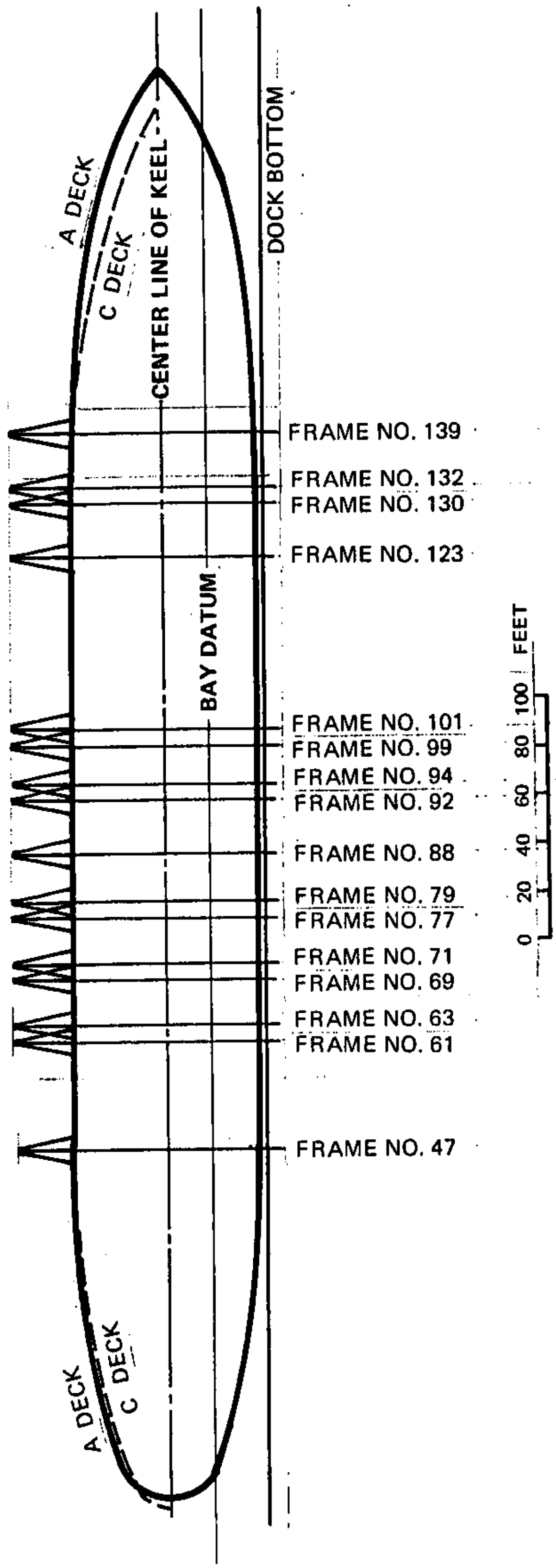
Short lengths of old rail were secured at right angles to the moving blocks to prevent any tendency to twist under load.

The distance from the heads of the tripods to the rear face of the concrete anchorage varied from 708 to 735 feet. The total length of nine-inch wire was about 11,000 feet, and 24,000 feet of 3½-inch diameter wire were required for the purchases.

3.9. TRIPODS

Sixteen tripods were constructed on the starboard shell plating, four single and six double. Their positions were governed by the positions of the pillars in the south shed and by the condition of the ship's structure (Fig. 3, No. 12).

POSITION OF TRIPODS.
FIG. 3 NO. 12



The positions of the tripods were as follows:

single tripods – frames 47, 85, 123, 139.

double tripods – frames 61-63, 69-71, 77-79, 92-94, 99-101, and 130-132.

The vertical leg of No. 1 tripod was at A deck, with the remainder at the promenade deck. The tripods were fabricated from 28-32 tons per square inch weldable mild-steel plates and sections.

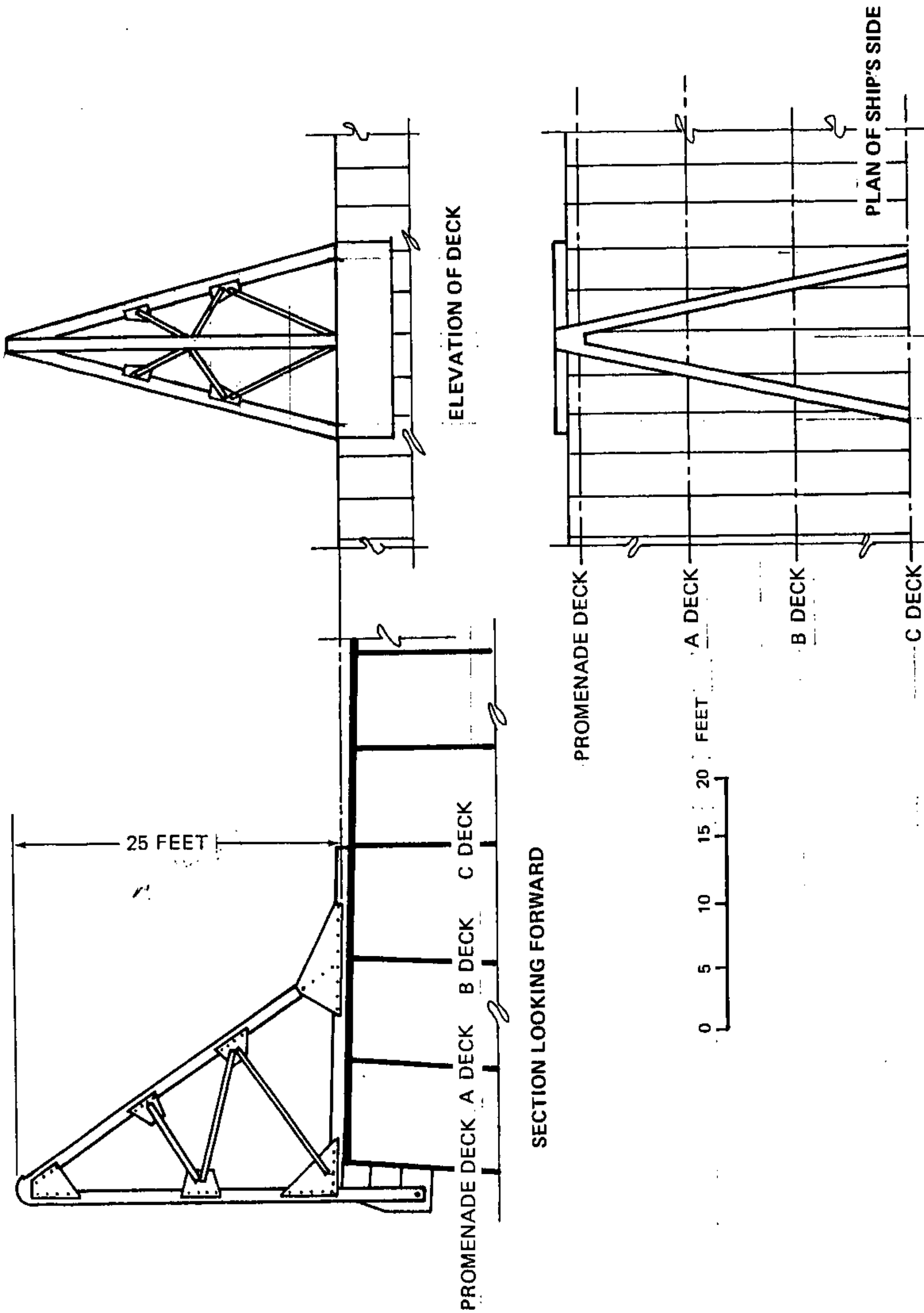
The vertical leg consisted of two 8-inch x 3½-inch x 5/8-inch angles welded to the back of a 12-inch x 4-inch x 4-inch x 0.40/0.60-inch channel forming an 8-inch deep trough for the wire. Each back leg was made from two similar channels back to back, with a 12-inch separation connected at intervals by 12-inch x 12-inch x 5/8-inch plates. The curved bearing plate at the head was rolled from 1-inch plate and the legs were braced with 6-inch x 4-inch x 5/8-inch angles.

The lower ends of the vertical legs extended 6 feet 6 inches below the shell over the face of the deck. They were welded to three vertical plates one inch thick, which were in turn welded to the deck extending fore-and-aft over five deck beams (Fig. 3, No. 13). The base of the single tripods consisted of two fabricated girders in the form of a "V" extending over four decks and seven frames, the rear legs connected to the base at the third deck.

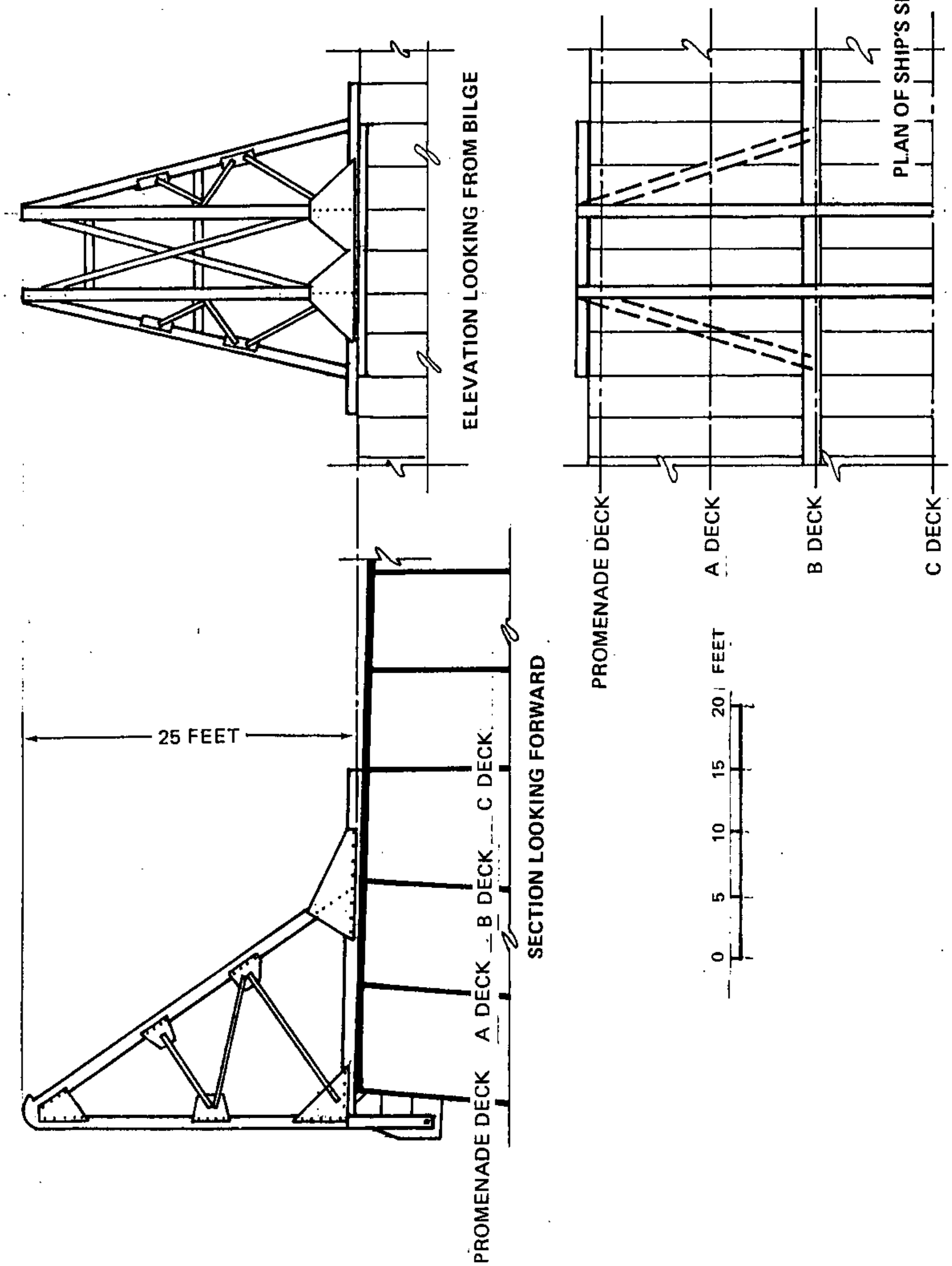
Each base girder consisted of two 15-inch deep plates, 3/4 inch thick, 12 inches apart. The plates were continuously welded to the shell plating with a 4-inch x 3/4 inch strip welded to the upper edge to form a flange; heavy tripping brackets were fitted at each deck. To ensure that the lower edge was in continuous contact with the shell plating, a pattern had to be made for each plate, and the plate cut to allow for landings and the distortion caused by the fire (Fig. 3, No. 14). The double tripods had two similar base members fitted parallel to the frames extending over four decks with similar girders at right-angles, extending fore-and-aft over nine frames at the line of the third deck.

The nine-inch wires were led over the curved bearing plate at the apices of the tripods down between the girders of the vertical legs. The ends of these wires were secured by six-inch diameter toggle pins fitted in the side plates at the bases of the legs, and through the thimbles spliced in the ends of the wires (Fig. 3, No. 15). The pins were held in place by keeper plates.

The main parts of the tripods were fabricated ashore, placed in position by floating crane and welded in place. Fig. 3, No. 16 shows a completed single tripod. After completion each structure was tested by reeving a temporary nine-inch wire from the anchorage over the bearing plate and down over the bilge where it was made fast to a pontoon. The pontoon was then partially flooded to produce a load on the wire equivalent to a horizontal pull of 150 tons at the head of the structure and deflections were checked. The maximum depression at the heel of the rear legs was 3/8 inch. (See Fig. 3, No. 17).



TYPICAL ARRANGEMENT OF A SINGLE TRIPOD ON THE SHIP'S SIDE.
FIG. 3 NO. 13



TYPICAL ARRANGEMENT OF A DOUBLE TRIPOD ON THE SHIP'S SIDE.
FIG. 3 NO. 14

3.10. BUOYANCY PONTOONS

Eleven Admiralty salvage pontoons, A.S.P.'s, were secured at the port side of the deck close to the dock bottom, providing an upward buoyancy force of 880 tons. These pontoons are cylindrical in shape, each 33 feet long by 13 feet diameter, subdivided by internal bulkheads and fitted with connections for blowing and venting. When fully submerged and blown they have a buoyancy of 80 tons each. To take the securing wire or chains, they are fitted with a tube passing through the diameter about 8 feet 6 inches from each end.

Five pontoons, two forward and three aft, were secured by wires passing around the hull from the port deck edge, under the bottom, and up to the starboard side.

With the six pontoons in way of the boat deck it was not possible to pass the securing wires around the hull. Therefore, they were secured by the bight of each wire being led through a heavy shackle in a six-inch wire strap around the base of a Welin boat davit on the port side. The wire was then led up the face of the deck to the starboard side.

The wires were seven inches in circumference, 6 x 61 construction, with a breaking strain of 161.2 tons. The six-inch wire strap was of 6 x 37 construction with a breaking strain of 130.3 tons.

Each pontoon was held by two 7-inch wires. The end of each wire was secured to the pontoon by a toggle bar through the eye in the wire resting across the mouth of the chain pipe, passing down through the pipe and thence under the wreck; or through the six-inch strap and made fast with a carpenters stopper bearing against a specially constructed tabernacle welded to the shell plating (Fig. 3, No. 18).

Each pair of pontoons was blown or vented from a control panel on the quayside through one-inch diameter flexible hoses, two per pontoon.

3.11. COUNTERWEIGHTS

Six A.S.P.'s were suspended on the starboard bilge (Fig. 3, No. 19). They were partially filled with water to bring them to the weight of 115 tons each, a total of 690 tons, and positioned and ballasted so that they would float clear when the vessel reached an angle of 50 degrees to the vertical.

Each pontoon was suspended by two 7-inch wire pendants (Fig. 3, No. 20), cut and spliced to exact lengths. The outer ends of the wires were shackled to short lengths of chain passing through the hawse pipes of the pontoons. The inner ends were secured by six-inch pins in special tabernacles, welded to the shell plating where they would be above water when the vessel righted.

3.12. INTERNAL BUOYANCY

In the original planning it had been intended to obtain the internal buoyancy by building internal bulkheads and pumping out the requisite amount of water. Following the divers' survey and a close examination of the condition of the decks above water, and taking into account the number of watertight bulkheads to be constructed, and the amount of shoring of the decks that would have to be done underwater, it was decided to attain the required buoyancy by the use of compressed air. This would reduce the amount of underwater work; most of the necessary tasks required, to make the spaces airtight, were above water.

Eight separate compartments were made airtight as follows (Fig. 3, No. 21).

No. 1, No. 1 hatch trunk, between deck and hold (frames 168-184).

No. 2, No. 2 hatch trunk, between deck and hold (frames 149-168).

No. 3, forward crew accommodation spaces in B, C, and D decks and the deck house on A deck.

No. 4, passenger accommodation space on A, B, and C decks between frames 68 and 139.

No. 5, after promenade deck and A deck house (frames 1-23).

No. 6, No. 6 hatch trunk, between deck and hold (frames 31-48).

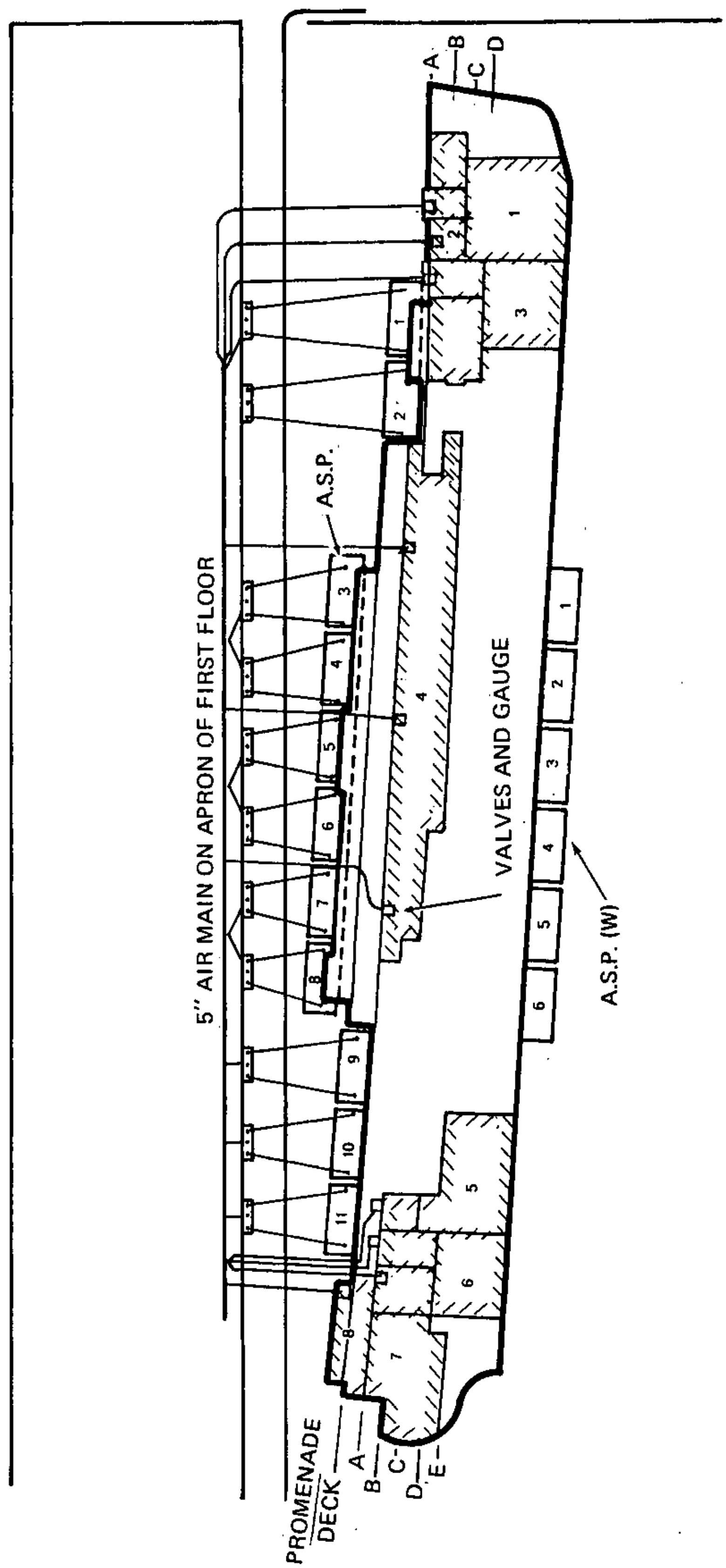
No. 7, No. 7 hatch trunk, between deck and hold and the steering-gear compartment.

No. 8, after passenger accommodation space on B, C, and D decks (frames 1-36).

With the water expelled to the centerline of the ship, a total buoyancy of 4,700 tons would be obtained from these compartments at an air pressure of 6 pounds per square inch. This buoyancy in conjunction with the other forces, provided a total righting moment only about five per cent in excess of the original estimated required moment. In view of this small margin all spaces were made tight to a level about nine feet below the centerline. This provided an extra 3,900 tons of buoyancy at a pressure of 10 pounds per square inch.

A further advantage gained by the use of compressed air was that as the wreck altered its angle to the vertical, air would spill and the compartments reflood in the later stages of the operation, thus preventing the presence of excessive buoyancy when the vessel was righted.

Compressed air was admitted to the compartments through valves bolted to the starboard side. Release valves and individual gauges were fitted for each compartment. The gauges were arranged so that they could be read from the central control position.



BUOYANCY COMPARTMENTS AND PONTOONS' AIR SUPPLY.
FIG. 3 NO. 21

A large amount of work was involved in making these compartments airtight, particularly in the sections involving accommodation. For these sections, it was necessary to strengthen the boundary bulkheads, locate and seal all service piping, ventilation ducts, etc., and strengthen the deck pillars as the decks were designed for external and not internal pressure.

The upper deck was steel originally planked with three-inch teak, practically all of which had been burnt on the starboard side. It was necessary to cut out many thousands of the bolts which had held the deck planking, and to plug the holes.

All openings, portholes, doors, scuppers, etc. in the starboard side were closed with welded plates throughout, whether needed for the air compartments or not, in order to reduce the work needed to seal the hull before the final refloating.

3.13. COMPRESSED AIR SUPPLY

In addition to the compressed air required for the pontoons and the eight compartments, compressed air was used to minimize the suction between the mud and the ship's port side in the initial movement.

To introduce this air, the divers shot a number of "Temple Cox" air bolts through the port shell plating from inside the ship at D and E deck levels, each bolt being individually supplied by a 3/4-inch hose from the quay. In addition, a number of open-ended 3/4-inch air hoses were placed by diver between the shell plating and the bottom. This was achieved by attaching the open end of the hose to a semi-flexible sectional drain rod, which was pushed from the deck edge under the ship to the required distance by a diver sitting on the dock bottom.

To supply the compressed air, a five-inch bore pipe was laid on the first-floor apron of the dock shed, with 2½-inch connections to the pontoon control panels. Individual connections operated from apron level to the eight buoyancy compartments and connections were made to the anti-suction fittings (Fig. 3, No. 22).

The compressed air main was supplied from a battery of 14 portable compressors in the shed. Additional connections were made at the west end to the compressors on the two salvage vessels in case a larger supply was required if undue leakage occurred.

All air pipes from the quay to the wreck were of sufficient length to allow the wreck to right without breaking the air supply. The excess pipe was coiled on the quay and secured with light twine stops.

3.14. CALCULATIONS

A fully detailed schedule of all items of weight removed was prepared and the position of each item relative to the vertical and longitudinal center of gravity was measured from the plans. Similar schedules were prepared for amounts of wood bulkheads, paneling, furnishings, etc., burnt, and stores burnt or removed. These schedules covered several hundred items.

Schedules were also prepared for weights added by the construction of the tripods, and shoring and stiffening of bulkheads, amounting to 350 tons of steel. The tripods accounting for 270 tons of this total.

Allowances were made for mud settled inside the ship based on divers' measurements in various spaces, and for trapped water. Allowances were made for the reduction in weight of structure and fittings below water level in the capsized position.

The summary of these figures is given in Table 3, No. 1. The accepted values were:

Weight of wreck	=	14,500 tons
Center of gravity above keel	=	33.5 feet
Longitudinal center of gravity	=	21.1 feet abaft center

The wreck lay at an angle of 89 degrees to the vertical, and the turning point was assumed to be initially at the point on the shell where the flat side joined the curved bilge plate. The lever about the turning point in this condition was 22.7 feet, giving an initial upsetting moment of 329,150 foot-tons. (See Table 3, No. 2).

The upsetting moment and the righting moment from each of the righting sources was calculated for each ten degrees up to 40 degrees from the vertical. When the vessel had a righting moment of 97,150 foot-tons, the upsetting moment would become zero at 50 degrees. The results of the calculations are shown in Table 3, No. 3 and plotted in a graph in Fig. 3, No. 23.

It was appreciated that as the wreck rolled on her bilge the soft mud overlaying the rock would be squeezed in front of the curved plating. This mud had an average depth of five feet and it would have been possible to dredge it away, but it was decided to leave it as a cushion to retard the movement caused by the ship's own weight from about 45 degrees inclination onwards. This would minimize the risk of damage to the bottom shell plating which would have complicated the subsequent refloating operations.

The center of the tripod pull was 14.5 feet abaft the longitudinal center of the ship, and therefore 6.6 feet forward of the longitudinal center of gravity, thus giving a moment tending to twist the wreck horizontally. The pressure on the port shell plating in contact with the ground was estimated to be 0.8 ton per square foot which appeared to be a reasonable ground pressure to resist twisting or sliding on the initial pull. As an additional precaution, three wires four inches in circumference were secured at each end of the vessel about 180 feet each side of the center length at the deck level on the starboard shell plating. These wires were then passed around the hull under the ship. They were secured to bollards on the quay side.

The south quay was occupied on 10 February 1954, and the rigging of the wires across the dock commenced. The weight pontoons were previously placed in position by floating crane. Fig. 3, No. 24 shows the lead of wires and positions of pontoons.

SUMMARY OF SCHEDULES
TABLE 3 NO. 1

TABLE I. SUMMARY OF SCHEDULES

ITEM	WEIGHTS, TONS	CENTRE OF GRAVITY ABOVE KEEL, FEET	V MOMENT	LONGITUDINAL CENTRE OF GRAVITY, FEET	MOMENT, AFT, FT.-TONS	MOMENT, FORWARD, FT.-TONS
LIGHT SHIP WEIGHT (MODIFIED)....	15,562-0	34-00	529,108-0	24-0 A.	373,488-0	–
ITEMS TO BE ADDED	2,100-0		88,830-0		6,650-0	–
	17,662-0		617,938-0		380,138-0	
ITEMS TO BE REMOVED............	3,242-0		135,127-0		76,360-5	–
ADJUSTED WEIGHT	14,420-0	33-42	482,811-0	21-07 A.	303,777-5	–

TABLE 2. EMPRESS OF CANADA

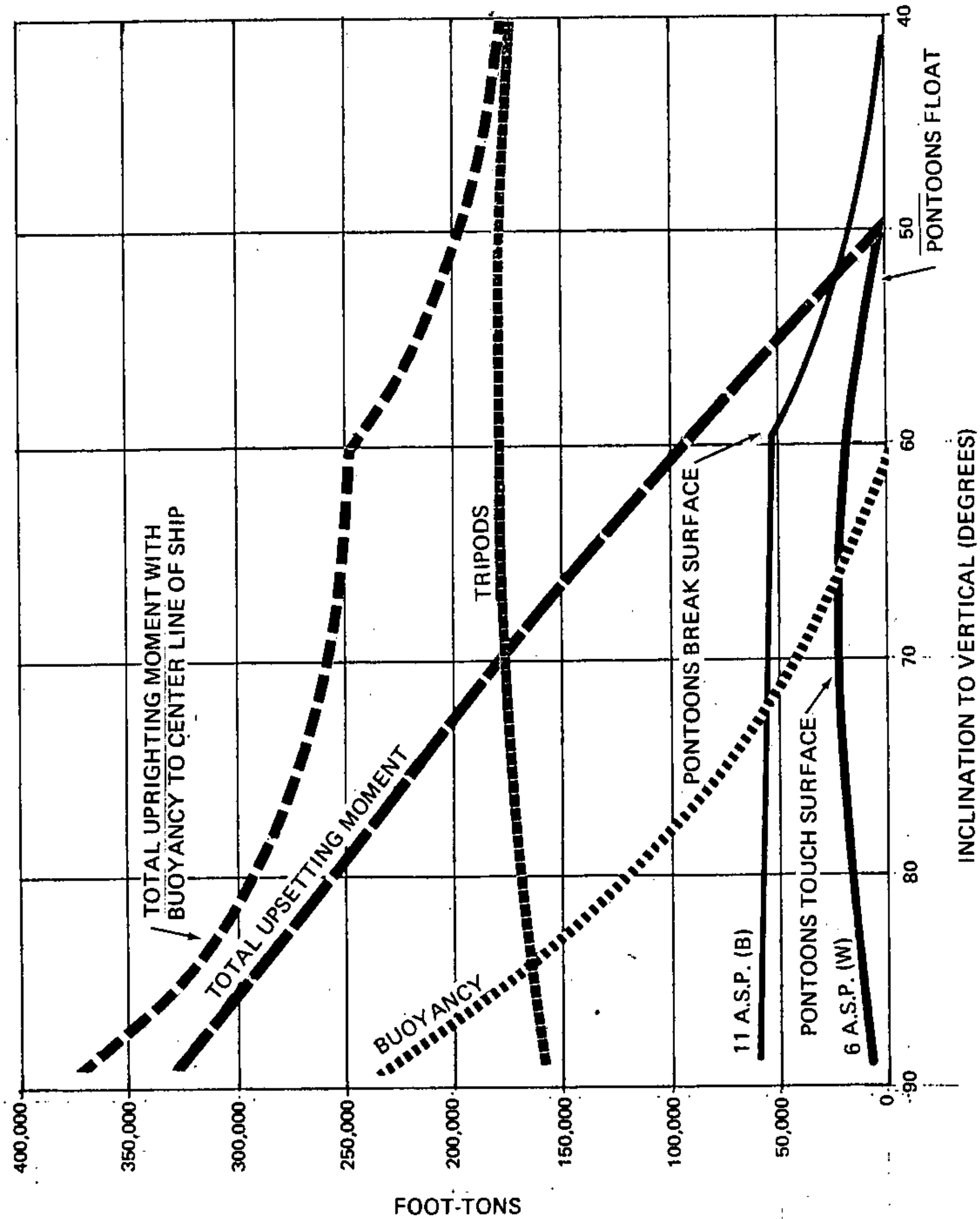
NO.	ITEMS	NOMINAL FORCE, TONS	INITIAL CONDITION, DEG.			ANGLE OF SHIP TO THE VERTICAL, DEG.		
			89			80		
			FORCE, TONS	LEVER, FEET	MOMENT, FT.-TONS	FORCE, TONS	LEVER, FEET	MOMENT, FT.-TONS
			ANGLE OF TRIPOD WIRE TO THE HORIZONTAL 4 DEG.			4½ DEG.		
1	16 TRIPODS EACH AT 100 TONS PULL (RESERVE OF 20 PER CENT)	1,600	1,596·20	101·0	161,216·0	1,595·04	107·75	171,865·6
2	11 LIFTING PONTOONS A.S.P. (L.) 80 TONS EACH	800	880·0	67·80	59,664·0	880·0	66·90	58,872·0
3	6 COUNTER-WEIGHT PONTOONS A.S.P. (W.) 115 TONS EACH	690	690·0	16·20	11,178·0	690·0	25·80	17,802·0
4	8 COMPARTMENTS WITH INTERNAL BUOYANCY TO THE CENTRE-LINE OF THE SHIP NOMINAL AIR PRESSURE 6 LB. PER SQ. IN.	4,700·0	4,700·0	30·60	143,820·0	1,819·4	24·00	43,665·6
5	TOTAL UPRIGHTING MOMENT				375,878·0			292,205·2
6	TOTAL UPSETTING MOMENT	14,500·0	14,500·0	−22·70	−329,150·0	14,500·0	−17·70	256,650·0
7	EXCESS UPRIGHTING MOMENT				46,728·0			+35,555·2
8	PERCENTAGE EXCESS MOMENT OF MOMENT REQUIRED				14·2%			13·8%
9	PERCENTAGE EXCESS MOMENT OF MOMENT AVAILABLE				12·4%			12·2%

CONDITION SUMMARY.
TABLE 3 NO. 2

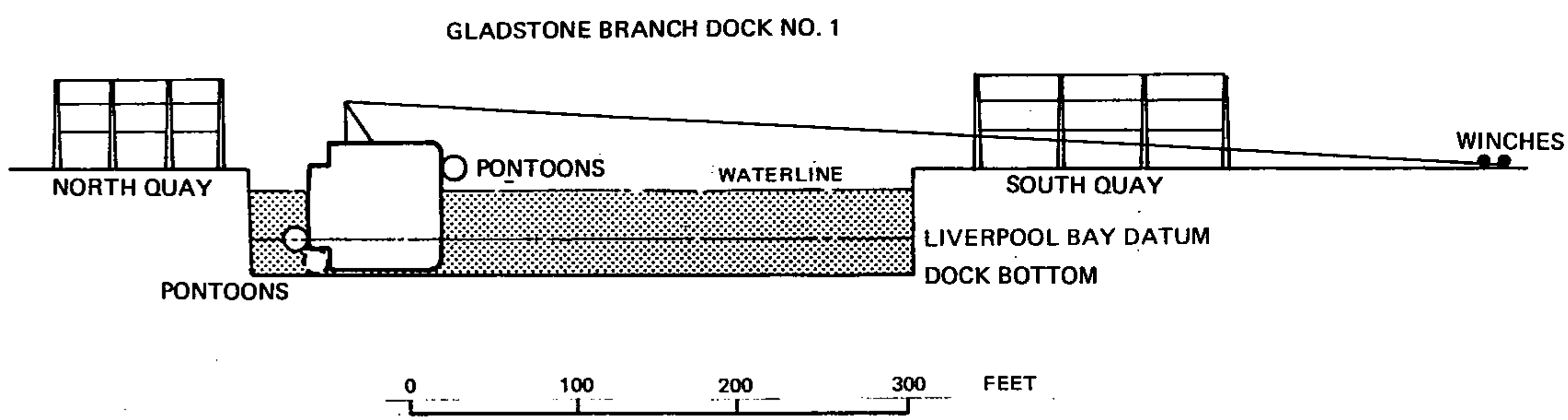
FINAL PROGRESSIVE MOMENT TABLE

ANGLE OF SHIP TO THE VERTICAL, DEG.											
70			60			50			40		
FORCE, TONS	LEVER, FEET	MOMENT, FT.-TONS	FORCE, TONS	LEVER, FEET	MOMENT, FT.-TONS	FORCE, TONS	LEVER, FEET	MOMENT FT.-TONS	FORCE, TONS	LEVER, FEET	MOMENT, FT.-TONS
ANGLE OF TRIPOD WIRE TO THE HORIZONTAL											
5 DEG.			5½ DEG.			5 DEG.			4½ DEG.		
1,593·92	112·20	178,837·8	1,592·64	113·30	180,446·1	1,593·92	112·00	178,519·0	1,595·04	107·30	171,147·8
880·0	64·70	56,936·0	880·0	60·50	53,240·0	400·0	45·00	18,000·0	106·0	35·80	3,794·8
690·0	35·00	24,150·0	450·0	42·50	19,125·0						
		259,923·8			252,811·1			196,519·0			174,942·6
14,500·0	–12·30	–178,350·0	14,500·0	–6·70	–97,150·0	14,500·0	0·0	0·0	14,500·0	+6·70	+97,150·0
		+ 81,573·8			+155,661·1			+196,519·0			+272,092·6
		45·7%			151·0%			∞			∞
		31·4%			61·5%			100·0%			

FINAL PROGRESSIVE MOMENT TABLE.
TABLE 3 NO. 3



UPSETTING AND UPRIGHTING MOMENTS.
FIG. 3 NO. 23



POSITION OF PONTOONS AND WIRES.
FIG. 3 NO. 24

All work on the wreck, including the testing of the air compartments and the placing of the buoyancy pontoons, was completed by the end of February.

The buoyancy pontoons were sunk into position, secured, and blown to full buoyancy to test the fastenings and stretch the wires. They were then vented and the securing wires were retightened and finally secured. All winches were tested under steam for an extended run, and bearings adjusted where required.

The six vessels supplying steam were brought into position 48 hours in advance of the operation, and all piping and connections tested under pressure.

The main control position was situated on the first floor of the shed on the north quay and connected by temporary telephones with subsidiary operational positions. The telephones were supplemented with portable high frequency radio equipment. From this position all the tripod wires could be sighted and the gauges on the air compartments read with binoculars.

A large pendulum with a scale graduated in degrees was erected on the starboard side forward of No. 1 tripod and observed from the east quay. From this point readings were telephoned to the central control (Fig. 3, No. 25).

To ensure simultaneous action by the individual winch operators, a revolving order board was erected on the south side of the south shed, in a position clearly visible from all the winches. Orders such as "Brakes off" were painted in letters two feet high and operated on telephoned instructions from the officer-in-charge at the main stop-valve.

The operation was timed for 1230 hours on 6 March 1954. By 0800 hours all air compartments were blown to 6 pounds per square inch and the pontoons blown to full buoyancy. The winches were declutched, and the main drums held on the brakes and run light to ensure that they were properly warmed through and all water was cleared from the steam lines (Fig. 3, No. 26).

Operating personnel were closed up at their various positions and checked. Emergency parties of fitters, burners, etc., with their equipment were sited at suitable points and the fire brigade and first aid detachments were in attendance.

The order to start heaving was given at 1235 hours. The wreck commenced to turn as soon as the wires tightened. She continued to turn steadily (Fig. 3, No. 27), reaching an angle of 45 degrees in 14 minutes at 1249 hours. At this time heaving on the wreck had to be stopped because the purchase blocks had come together.

No. 7 purchase was overhauled, the nine-inch pendant unshackled and the outer block connected to the main wire. Heaving with this one wire recommenced at 1315 hours. The wreck started to roll again, with a pull of about 80 tons, finally coming to rest at nine degrees from the vertical at 1347 hours (Fig. 3, No. 28).

The six buoyancy pontoons amidships had now been lifted out of the water, and as their weight was opposing the righting force, they were released. The pontoons weighed 42.5 tons each.

The vessel was resting on the bank of mud squeezed towards her starboard side, and this amount of list was considered large for the refloating apparatus. As soon as the hauling wires were removed a grab dredger removed the mud from alongside the starboard bilge. Two pontoons were then moored under the tripods, and each was secured by four 9-inch wires to the tripod heads. By flooding the tanks of the pontoons a weight of 800 tons was applied and the list reduced to 5½ degrees. A pontoon is shown in position under the tripods in Fig. 3, No. 29.

3.15 REFLOATING

The refloating problem was to bring the ship afloat in a stable condition and at a draft and trim convenient for drydocking. The level of the bottom towards the center of the dock is 23 feet below datum, and the level of the keel resting on the mud was 21 feet below datum, the datum being the mean level of equinoctial spring tides. The calculated draft of the ship after removal of mud and debris in the upper decks and with all tanks full was 21 feet 9 inches.

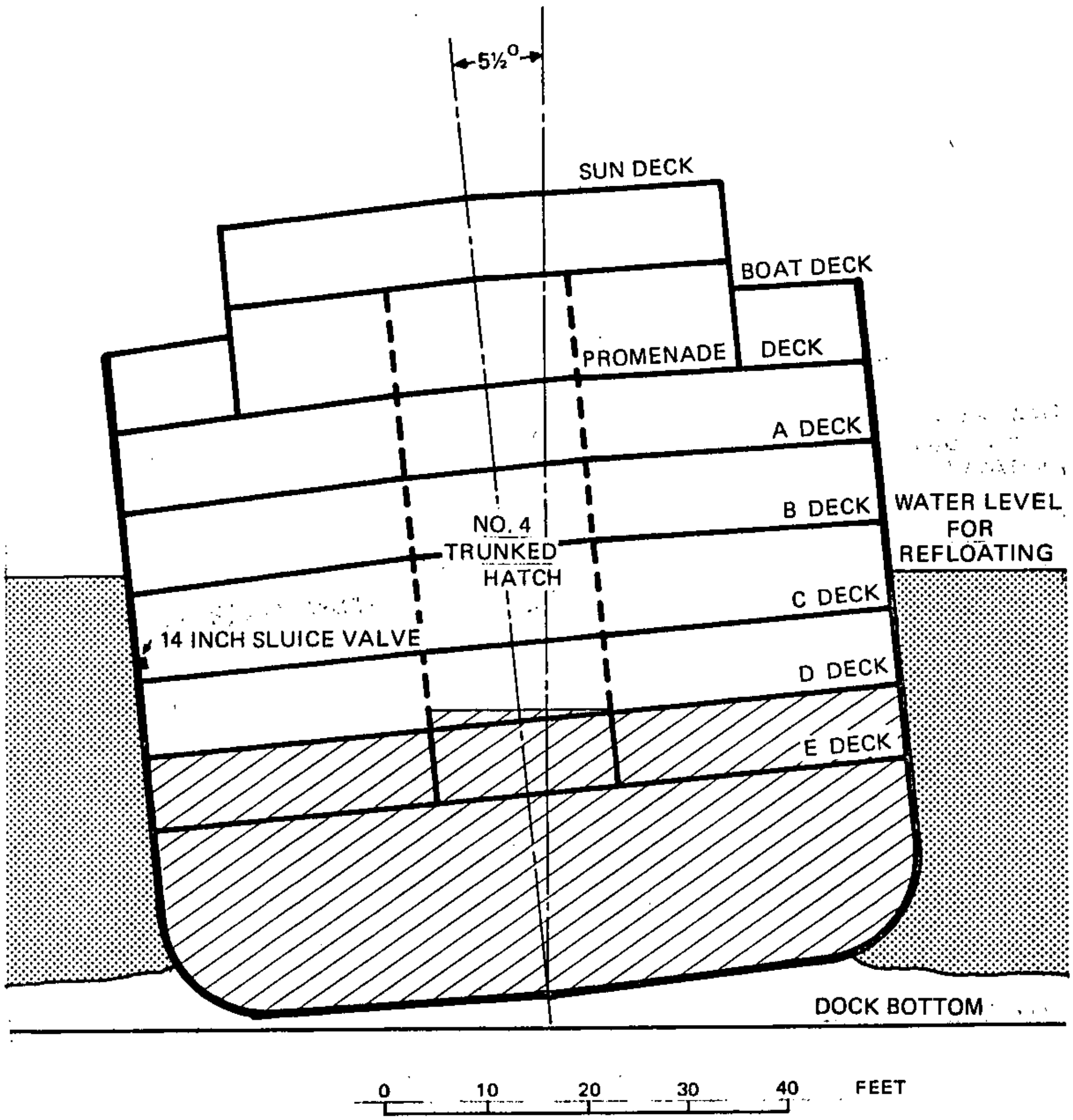
The range of a spring tide falling to datum level at low water would be 31 feet; the elapsed time from low water to high water, only 5½ hours. Over the low water period the level of water in the dock would be at or below 21 feet 9 inches for only one hour because there was no means of retarding the entry of the rising tide. It was not possible to pump out the ship and ensure the removal of all loose water in the time available, and there would have been a serious risk of the ship capsizing again.

The method adopted was to ballast the ship to a refloating draft of about 44 feet. This would give a period of six to seven days during neap tides when the dock water-level could be maintained at that height. Ample time would be gained for correcting list and trim before drydocking, without the risk of capsizing, as the ship need not be more than one foot clear of the dock bottom.

A weight of 29,000 tons of ballast would be required in the ship to bring her to the required draft. Solid ballast would have had to be discharged before the vessel could be drydocked. This would have been a long and costly operation, but by ballasting with water these difficulties would be removed.

The plan adopted was to keep the lower holds and E deck flooded to the lower side of D deck (Fig. 3, No. 30), with the engineroom and boiler room flooded at the same level. By keeping the water level two feet above D deck in the hatch trunks and sealing off the whole of D deck, the calculated metacentric height was eight feet, giving a reasonable margin for eventualities. The only large area of free surface was in the engine and boiler spaces.

With the water level in the ship up to D deck, the weight of water would be 24,900 tons, giving a mean draft of 41 feet 8 inches and a trim of 9 feet 6 inches by the head. This unbalance was due to the sheer of D deck, the main deck. The height of this deck above the water level was 28 feet 3 inches amidships, 37 feet 6 inches at the forward end of No. 1 hold, and 32 feet 3 inches at the after end of



REFLOATING DIAGRAM.
FIG. 3 NO. 30

the after hold. To correct the trim and to counteract the anticipated list to port, 2,000 tons of washed gravel were to be placed in B and C decks on the starboard side aft to give a draft of about 43 feet 6 inches on an even keel.

The first operation was to seal all the openings, portholes, doors, scuppers, etc., on the port side, as all openings on D deck and a large number on C deck would be submerged at a draft of 43 feet 6 inches. To reduce the amount of diving work, the dock was run down to low water level for two tides, and blanks were welded over 184 portholes. Two shell doors in C deck and the oil fuel filling door in D deck were also welded.

The dock water level was liable to fluctuate in normal operation by as much as ten feet, and a fall of ten feet would cause an additional 11,000 tons of water to be retained in the ship. To permit rapid equalizing of the interior and exterior waterlevels, eleven 14-inch sluice valves were fitted in C deck controlled by rod gearing extending up to A deck.

The amount of mud and debris was considerable, and over 3,000 tons were discharged by hand into barges for dumping at sea. This work was rendered more difficult by the presence of quantities of oil.

The upper decks to B deck were above water level for the greater part of the time but work on the lower decks, including the sealing of D deck, had to be done compartment by compartment to avoid the wreck becoming too buoyant. Fig. 3, No. 31, Fig. 3, No. 32 and Fig. 3, No. 33 give an idea of conditions inside the vessel.

D deck was the main deck for classification purposes and was therefore a watertight deck. The spaces in the deck at the ship's side around the frames had been sealed with cement chocks, and a large number were broken and loose as a result of the fire. This deck would have to withstand a water pressure from the underside of up to 4-5 pounds per square inch. Since it was essential that there should be no leakage into D deck, it was necessary to weld fitted plates around each frame after clearing the loose concrete. This work had been completed along the starboard deck edge while the ship was on her side, but the whole of the welding on the port side had to be done in sections by pumping out the compartment, cleaning, and welding.

The tripods were left in position and four empty pontoons were placed on the tripods for the initial refloating attempt. The width of the entrance to the Gladstone graving dock was sufficient to enable the ship to enter with the tripods in position.

A pendulum 18 feet in length, terminating in a heavy plumb-bob with a pointer, was placed in what had been one of the public rooms on the promenade deck amidships. The deck was marked out so that list and trim could be read directly. This central control position was linked by temporary telephones to the various pumping stations.

The initial trial was made on 23 June but it was found that there was an excess of weight to starboard. The pontoons were lifted off, the tripod legs burnt through, and the tripods removed.

On 27 June, seventeen months after she sank, the ship was refloated with a list of two degrees to port and trimmed two feet by the stern. With the removal of 200 tons of the shingle ballast, and adjustment of water levels, she was brought to an even keel on a draft of 42 feet 1 inch with a list of one degree to port.

In the early hours of 1 July she was towed to the graving dock and landed on the blocks (Fig. 3, No. 34). Her displacment in this condition was 40,250 tons. To avoid excessive pressure on the keel and bilge blocks, the water in the graving dock was pumped down to 27 feet over the blocks and then lowered concurrently with the water being pumped out of the holds and engine and boiler rooms.

The examination of the hull showed that the only damage caused in the righting had been to the port bilge keel; 60 feet of the keel had been torn off and the remainder bent back flat against the shell plating. The vessel was sold to shipbrokers, and after removal of the propellers and various other work to prepare her for towage overseas, she left the port on 1 September, 1954 (Fig. 3, No. 35).

4. USNS MISSION SAN FRANCISCO

4.1. BRIEF

The *USNS MISSION SAN FRANCISCO* sank, partially blocking a major North American waterway, the Delaware River; if not removed quickly the wreck would have caused economic disaster for the industries dependent on the waterway commerce. The wreck was successfully removed after several major setbacks, in a lengthy operation involving the use of explosives to cut her down into manageable sections, easily retrieved and transported from the wreck site.

4.2. DESCRIPTION OF THE SHIP

The *USNS MISSION SAN FRANCISCO* (T-AO-123) was a T-2 class, turbo-electric powered tanker. The ship's characteristics were:

Displacement	5,738 tons (light)
Displacement	22,300 tons (full load)
Dimensions:	
Length	523.5 feet (oa)
Beam	68 feet
Depth	30.8 feet (max.)

4.3. HOW THE SHIP SANK

The *MISSION SAN FRANCISCO* and the *SS ELNA II* collided mid-channel in the Delaware River shortly after midnight of 7 March 1957, four miles below the Delaware Memorial Bridge. The weather was soupy, visibility was poor and *MISSION SAN FRANCISCO* was light, but not completely free of gas. The point of collision occurred at the tanker's bridge structure, starboard side, and was followed by violent explosions in the cargo tanks forward and aft.

After the collision the tanker was carried across the channel where her bow grounded in shallow water outside the west edge of the channel. She sank in 45 feet of water, channel depth, resting across the channel at a 60 degree angle. In this position the wreck blocked 375 feet of the 800 foot channel.

4.4. CONDITION OF THE WRECK

Because of the apparent magnitude of the job and the difficulties involved, Merritt-Chapman and Scott were contracted for the salvage work. The salvage vessel *CURB* arrived on 19 March 1957, and an examination by divers and salvage personnel ensued.

The bow section was flooded, however the stern section, housing the machinery spaces, was still buoyant. The forward engineroom bulkhead, at frame 46, held against the sea with only minor leakage.

The after cargo pump room, frames 46-47, had burned out and was open to the sea, and the starboard bunker fuel tank was open to the sea below the waterline. This tank had burned and caused severe warping in plates and frames as far aft as its after extremity, frame 33. A severe fire had also occurred in the forward starboard end of the engineroom as a result of the starboard fuel tank burning out. All the main transformers and switchboards located in the area were burned out, but otherwise there was no major damage to machinery. The water eventually rose to a point approximately three-quarters up the main motor and covered all lower level pumps. The main propulsion generator, two ship service generators, and miscellaneous other machinery in the engineroom were not damaged. Except for bricks fallen out of the boilers, there was essentially no damage in the fireroom. The port bunker fuel tank did not burn or explode but was holed near the bottom. It was eventually used to control buoyancy by applying air pressure to it via the tank's top fittings. Fire had also burned out most of the crew staterooms on the main deck, and a few on the 01 deck. The worst damage from heat buckling was forward all the way athwartship, at frame 46, and on the starboard side aft to approximately frame 25, over the engineroom's electrical equipment which had burned.

Considerable wreckage had settled in the channel from the explosion. While early salvage operations were conducted on the *MISSION SAN FRANCISCO*, the U.S. Army Corps of Engineers conducted cleanup operations in the eastern half of the channel, which was soon open to traffic.

The *SS ELNA II* did not sink as a result of the collision, but drifted clear, grounded west of the channel downstream, and was subsequently floated free and towed away.

4.5. CLEARANCE METHODS

Initial efforts were concerned with the salvage of equipment from the bow section, dewatering, and making the stern section watertight. The heavy lift derrick, *MONARCH*, was used to bring up cargo and transfer salvage equipment. On 1 April *MONARCH* unsuccessfully attempted to hoist the bridge structure off the wreck.

By mid-April, divers' examinations established that the bow section could not be salved as a unit. The dewatered stern section rose and fell with the tide, apparently still connected to the remainder of the ship by plating or the keel beam. A stability study was made of the stern section and it was decided to cut it free and float it. The plan was to cut the steel plates by using a heavy chain sling and two cranes on either side of the wreck, working saw-like, up and down. Two-hundred tons of pig iron were placed in the bilge of the forward section of the engineroom, and cribbed in as low and as far forward as possible.

On 27 May, just after the ballast was placed and prior to the completion of the cutting sling, the problem was uniquely solved. At 2300, in soupy weather, the *SS COSMIC*, inbound up the Delaware, struck the stern section of the *MISSION SAN FRANCISCO*.

The stern broke free and floated upriver, grounding west of the channel directly off Newcastle, Delaware. Fortunately, the collision occurred after the ballast had been placed.

After the second collision, the salvage operation was simplified to two sub-operations; maintenance for eventual sale of the stern section, and salvage of the remainder of the ship in order to clear the channel.

4.6. SALVAGE OF THE STERN SECTION

Only minor damage occurred to the stern section in the second collision. Damage included holes in the skin of the ship, high and aft in the after peak tank; torn and holed plates aft on the steering engineroom; rudder palm blots sheered and the rudder hanging and wedged against a blade of the propeller, which as a consequence was bent.

The holes in the after peak tank were quickly patched with concrete, and an athwartship steel bulkhead was constructed in the steering engineroom aft of the rudder post. No work was necessary on the rudder. A diver's inspection of the stern section near the break revealed no downward projections. Examination of the forward portion of the stern section disclosed that there was an apron of bottom plating about 50 feet forward of frame 46 on the post side. This apron was an irregular diagonal, tending aft and to starboard, and terminating just forward of frame 46 on the starboard side plating. After the collision, the stern section was retrieved by the *CURB*. The section, heavy by its "bow", was towed to Philadelphia Naval Shipyard. To obtain maximum control of the list and trim for towing, a cofferdam was built on the starboard deep fuel tank, and a six-inch electric submersible salvage pump was semi-permanently installed. Air lines were rigged and maintained in the port deep tank. A portable generator, portable air compressor, and a volume tank were installed and kept on board.

By pumping the starboard deep tank, and putting air on the port deep tank, the stern section could be easily controlled. On an even keel the stern's draft was 29.5 feet. The tow was completed 1 June 1957.

4.7. CHANNEL CLEARANCE

On 19 April the salvors began to recover scrap from the river bottom. The pieces of wreckage thrown clear by the explosions had to be removed so two-way traffic could be re-established. To accomplish this digging and pickup work, the derrick *COMMERCE* was rigged with a 17-ton three-section orange peel bucket.

On 7 July the actual salvage operations were begun. Using a four anchor moor the derrick barge was placed over the forward end of the wreck and began the search and pickup on the wreckage. The orange peel bucket, with a span when opened of 16 feet, was lowered to the bottom, closed and hoisted, bringing steel and/or mud with it to the surface. No diving was attempted because of the heavy tidal current, short periods of slack water, zero visibility, and the dangerous scraps of steel on

the river bottom. All searching was blind, accomplished either by sounding, dragging or random search with the bucket. The salved steel was lowered onto the derrick deck and subsequently transferred to Navy YCs. Pieces retrieved in this manner ranged from a few pounds to 30 tons.

In order to cut the steel hulk on the bottom, blasting charges were made by tying dynamite sticks, 90% gelatine, to a manila line and snaking the charge over the hulk, again working blind from a small boat on the surface. Later in the operation these charges were replaced by Navy demolition explosives.

Initially individual charges of only 180 pounds were used because of the close proximity of the Delaware Memorial Bridge and the smokestacks from a refinery, both less than five miles away. After inspection these structures showed no signs of effect from the explosives. The original accident explosion caused a tremendous shock, which though felt for many miles, apparently did no damage to the bridge and surrounding installations; this factor supported the use of heavy explosives on the job. The charges were eventually raised to 400 pounds of dynamite each. When the Navy demolition charges were substituted, 500 pounds of dynamite equivalent were used.

On 24 September the Army Engineers conducted a detailed echo sounding and prepared a chart to permit the analysis of the effectiveness of the work as far as it had progressed.

Having started from tank No. 9 area and working forward, the derrick reached tanks No. 4 and 5 when the work was halted for the winter period on 24 December 1957.

4.8. NEW PLANS

No salvage work was possible during the winter months, so during this time consideration was given to the various means of removing the bow section, which was relatively intact and somewhat west and outside the edge of the channel.

Floating the bow was not feasible because of the list, accumulation of silt, and attachment of the bottom plates and structure aft.

Since the bow section was still intact, it could be employed to the salvors' advantage in another approach. Using the divers inside and on the deck to strategically place large explosive cutting charges, would be more efficient and quicker than the random search method and snake charges used previously. A detailed study of the ship's bow structure was made from plans, and a cutting plan was prepared and presented to the contractor on 27 March.

The plan called for the use of two large charges, placed inside the hulk by divers, to cut the bow horizontally at the second deck level and vertically at the forward pump room. The steel sections could then be lifted out. Before the plan could be agreed upon, a diver examination of the bow had to be made to check its feasibility. The major deterrent was the strong tidal current over the wreck and the impracticality of conducting diving operations for periods longer than an hour at slack water.

On 10 and 12 April the examination was made. The bow had a port list of about 25 degrees with the port side deck edge 28 feet underwater; the starboard side at the after end of the forecastle head deck was at surface during low water. The cargo hatch was closed and the depth from the port side deck edge to the mud line was 29½ feet. The tidal current was so strong that diving was extremely hazardous and entry into the hull was not attempted.

On 16 April it was decided that the extensive diving necessary to place the required charges could not be done safely unless a cofferdam-like trunk were fitted to the cargo hatch in order to get inside the wreck. In view of the bow's list, which produced structural problems, and the current, this was not considered a good plan. As long as the bow remained reasonably intact, the divers would be used to place and sandbag the deck charges.

A series of crisscrossing charges on the forecastle deck, and a large charge on the forecastle bulkhead, main deck junction, were planned. Larger charges than were used the previous year, about 500 pounds dynamite equivalent, were agreed upon. The possibility of transmission of the shocks to the nearby Delaware Memorial Bridge or the refinery was a problem, so the bridge test borings were checked. The test borings were made to about 180 feet, with random 250 foot bores; no rock was reported. As a result, charges as large as 1000 pounds TNT equivalent were considered safe in regard to shock hazards, and this was later confirmed by actual charge detonation.

In planning any phase of the salvage operation it was important to know as much about the wreck's position as possible. The Army Corps of Engineers devised an effective method of doing this. First they set up target ranges ashore; then laid the wreck area out as a grid chart. By this means, and the use of a sextant angle, the derrick was effectively spotted over the wreck area high spots. As a result the work was substantially hastened, and it is recommended that this method be adopted in similar clearance tasks in the future.

4.9. OPERATIONS

On 21 April 1958, work on the removal of the bow's stern section recommenced; using two divers working from a launch. For each cutting charge divers placed a manila line along the intended cut line, secured the line with partially filled sandbags and then laid the explosive charge, made up as a snake line, and sandbagged it down. Except for two exploratory dives all work entailed the use of two divers on the bottom; one laying the charge or sandbags and the other passing gear from the downline. A total of 38 dives were made during 21 April to 9 May, working a seven day week. A total of ten cutting charges were laid; nine of them were deck charges and varied in weight from 270 to 523 pounds, mixed C-4 and tetrytol. The tenth charge was 840 pounds tetrytol at the deck and bulkhead on the after end of the forecastle.

Foul weather prevented the derrick, *COMMERCE,* from commencing work until 9 May. As the channel was open to navigation 200 feet west of the centerline, the derrick had to moor to the west of the wreck, coming over the bow in an easterly direction. The diver-placed charges proved very effective, and the derrick was able to retrieve large pieces of the bow. The work of sounding, placing

charges from the surface, and picking up the pieces of steel progressed rapidly and by 4 June the bow had been cleared. On 9 and 10 September, sweeps were made over the wreck area which indicated the job was complete. A total of 738 long tons of scrap were recovered.

4.10. DEMOLITION METHODS

In general, cutting charges were made up in snakes of varying lengths up to 80 feet by marrying the TNT or C-4 blocks to a manila line and using a primacord trunk line. The blocks were butted end-to-end, and in those instances where both TNT and C-4 were used, the two types were alternated. The Mk-14, 55-pound blocks were used as pounding charges on particularly obstinate high spots and on the bow. In a few instances full cases of C-4 were used as pounding charges. A supply of Mk-8 explosive hoses was available, but none was used as they were too stiff to drape over the jagged wreckage.

A total of 86 charges were placed during the period of 24 April to 4 September. Five misfires were experienced, attributable to "blowouts" on the primacord and in one instance to a cap misfire. In all cases the charges were either refired, or a second overlapping charge was placed, and the first fired sympathetically.

Table 4, No. 1 provides a breakdown of the explosives expended.

DESCRIPTION OF EXPLOSIVE	EXPLOSIVES EXPENDED
1. CHARGE DEMOLITION M5A1, 2.5 POUND BLOCKS, COMPOSITION C-4	6192 EACH, (15,480 POUNDS)
2. CHARGE DEMOLITION M-1, CHAIN OF EIGHT 2.5 POUND BLOCKS OF TETRYTOL ON PRIMACORD TRUNK LINE	672 CHAINS (13,440 POUNDS)
3. CHARGE DEMOLITION Mk 14-1, 49 POUND BLOCK OF TNT	40 BLOCKS* (1,980 POUNDS)
4. OUTFIT DEMOLITION Mk 133-1, CHAIN OF EIGHT 2.5 POUND BLOCKS TNT ON PRIMACORD TRUNK LINES	395 CHAINS* (7,900 POUNDS)
5. CHARGE DEMOLITION OUTFIT Mk 8-0, 25 FEET RUBBER HOSE FILLED WITH TNT	NONE
6. CORD, DETONATING, WIREBOUND (PRIMACORD)	2,250 FEET

* Five Mk 14 and Mk 133 used the previous fall are included here.

USE OF EXPLOSIVES.
TABLE 4 NO. 1

5. VASA

5.1 BRIEF

On her maiden voyage in 1628, the Swedish man-of-war *VASA* capsized and sank in Stockholm Harbor. She was built top heavy with little apparent regard to her stability. Three hundred and thirty-three years later with the aid of modern salvage technology and techniques, she was relocated, raised and preserved. The lifting process and dewatering was complicated by the concurrent archeological excavations of the ship. This included the preservation of her wooden hull and all salvable artifacts, and the imposition of a time table as a result of the tremendous public interest aroused by the discovery and salvage operations. As the oldest identifiable ship ever salved she has proven to be invaluable as a source of information on the maritime history of that period.

5.2. DESCRIPTION OF THE SHIP

The *VASA* was a 64-gun Swedish man-of-war, built in 1628. She was carvel-built of black oak with sides 13 inches thick. She was about 200 feet long, 38 feet in breadth and displaced 1300 tons. To give an idea of her bulk, the *VASA's* foremast had been 80 feet long and 30 inches in diameter at deck level. When fully rigged she would have carried approximately 13,000 square feet of sail. She was designed for 437 crew members; three officers, 12 petty officers, 12 artisans, 90 seamen, 20 gunners and 300 soldiers. She was lavishly decorated with wooden carvings and figureheads, and ornately painted; a ship fit for a king. (See reconstructed drawing of *VASA*, Fig. 5, No. 1.)

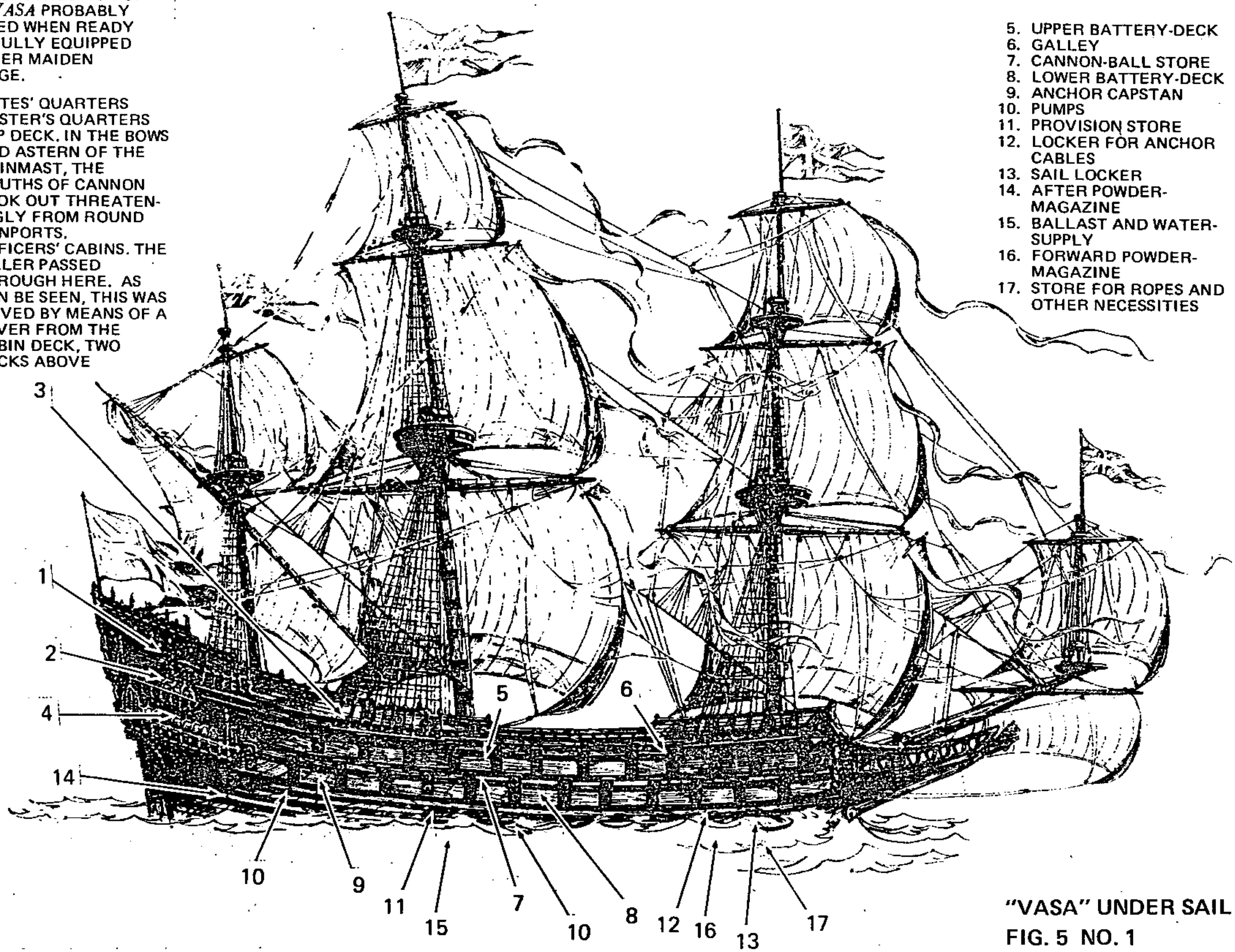
5.3. HOW THE SHIP SANK

In the spring of 1628 the King of Sweden's latest and grandest war fleet addition, the man-of-war *NY WASSAN* as she was originally known, lay at moor awaiting her maiden voyage.

She was very large by the standards of her time and very ornately decorated. Many dignitaries, both civilian and military, had been invited aboard with their families, and along with the crew were to enjoy this first brief cruise. *VASA* left her berth just below the royal palace. After being warped up against the light southwesterly wind until she was south enough to have a clear course through the inlet to Stockholm, the topsails and mizzen were stretched. She moved ahead under sail and the two-gun parting salute was fired as the light wind pushed her very slowly. She had traveled about a half mile when she caught a stronger gust of wind, and those on shore saw her heel over sharply. The *VASA* righted herself and cast loose the topsail sheets. Another gust of wind sent her heeling over again. The list increased further and further until water started rushing into her gun ports. With flags flying and sails set, she went to the bottom of the harbor in some 17½ fathoms of water, taking 50 of her crew with her.

A RECONSTRUCTION OF HOW *VASA* PROBABLY LOOKED WHEN READY AND FULLY EQUIPPED FOR HER MAIDEN VOYAGE.

1. MATES' QUARTERS
2. MASTER'S QUARTERS
3. TOP DECK. IN THE BOWS AND ASTERN OF THE MAINMAST, THE MOUTHS OF CANNON LOOK OUT THREATENINGLY FROM ROUND GUNPORTS.
4. OFFICERS' CABINS. THE TILLER PASSED THROUGH HERE. AS CAN BE SEEN, THIS WAS MOVED BY MEANS OF A LEVER FROM THE CABIN DECK, TWO DECKS ABOVE
5. UPPER BATTERY-DECK
6. GALLEY
7. CANNON-BALL STORE
8. LOWER BATTERY-DECK
9. ANCHOR CAPSTAN
10. PUMPS
11. PROVISION STORE
12. LOCKER FOR ANCHOR CABLES
13. SAIL LOCKER
14. AFTER POWDER-MAGAZINE
15. BALLAST AND WATER-SUPPLY
16. FORWARD POWDER-MAGAZINE
17. STORE FOR ROPES AND OTHER NECESSITIES



"VASA" UNDER SAIL
FIG. 5 NO. 1

5.4. EARLY SALVAGE METHODS

A court of inquiry was set up immediately but was unable to come to any conclusions as to why the ship sank, except that she had seemed by most accounts to be top heavy and her design hinted at initial instability.

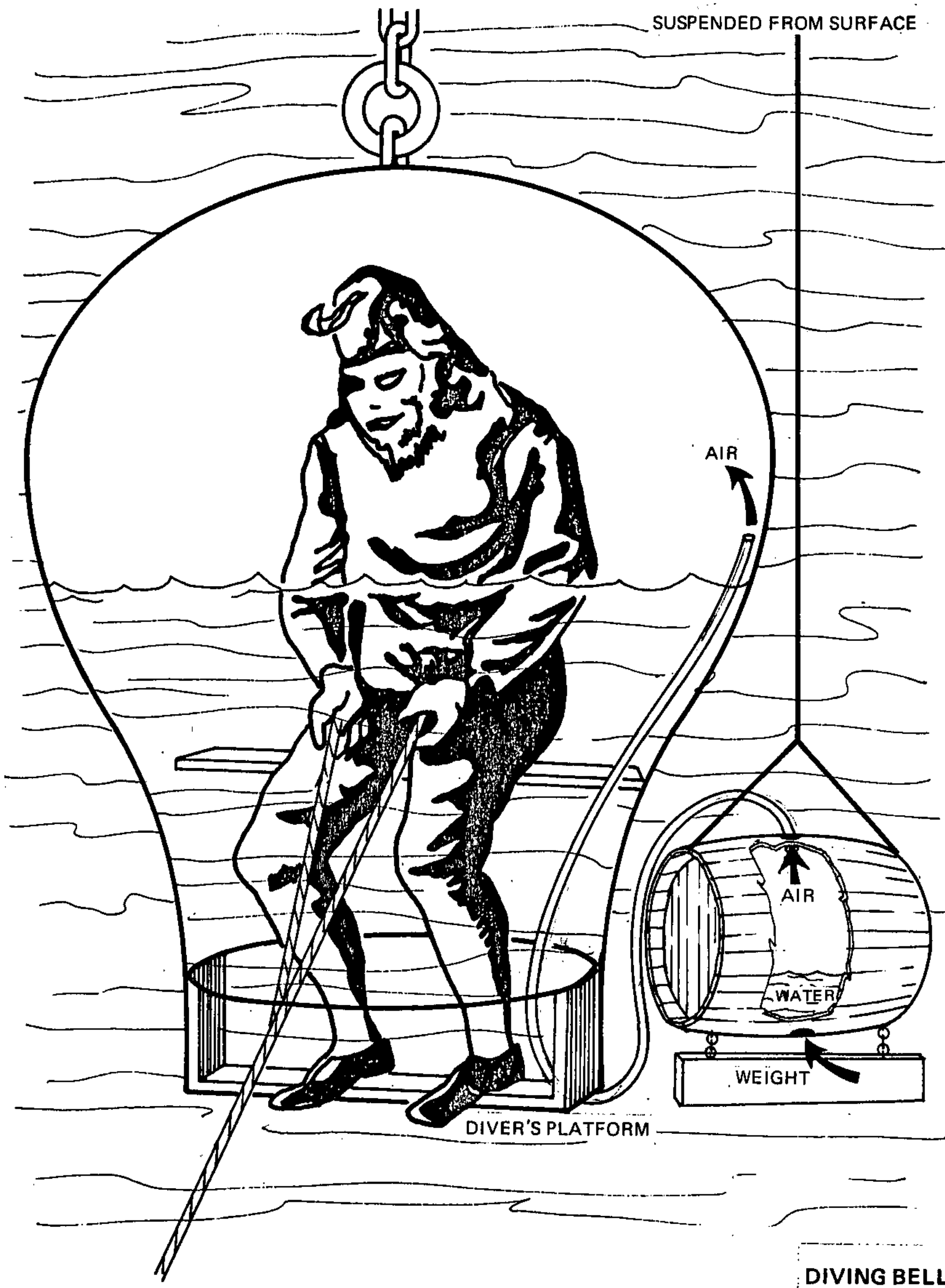
The loss of the *VASA* was critical from an economic as well as a militaristic standpoint for the Swedes, and the King was anxious to recover the ship somehow. News of the catastrophe traveled fast and within three days an English salvor was granted a salvage patent, the first in the history of Sweden. His reports indicated that she was lying in about 108 feet of water, without a list. The efforts of this first salvage team were concentrated on trying to raise her using grapnels and hooks attached by lines to windlasses, which would drag her up; the attempts were unsuccessful. In every case the cables broke, or sufficient power was not available.

Attempts continued with varying degrees of failure for the next 36 years, mostly by profiteers who were after her marketable cargo and fittings.

In 1663 a new salvage expert appeared on the scene, Andreas Peckell and his partner Albrecht von Treileben. They were especially interested in *VASA's* guns which were of value, though they had not abandoned altogether the hope of raising her. The plan was to salvage the guns first, and then try to remove the ballast, which they thought would lighten her enough so that the rest of the task of raising her would be easy. To get at the second layer of guns they had to tear off the main deck beams, which they surprisingly were able to accomplish. They were aided by a new invention, the diving bell. The bell was made of lead, about four feet high and shaped somewhat like a church bell. A diver stood on a platform about 1½ feet down under the bell. He breathed the air which had become entrapped in the topmost portion of the bell as it submerged and the water and pressure equalized. In addition to this supply there was a special air supply in a barrel which had a piece of piping leading to the inside of the bell. (See Fig. 5, No. 2.) In this manner the diver could stay down for 20-25 minutes. There were no lights and the water in the harbor was so muddy the work was done in almost total darkness. The diver had only the protection of leather clothing in the icy water. His movements were restricted by the awkward position and lack of space, as was the kind and number of instruments he could use in the bell. Despite all this, Treileben and Peckell and their crew were able to recover over 50 guns which were sold all over Europe. In 1665 their venture ended, all serious work stopped on *VASA*, and she was forgotten until 1920.

5.5. RENEWED INTEREST

In 1920 a Swedish historian published some records he had found concerning the *VASA* and her fate; they attracted little attention. However, the report was read by Anders Franzén, a marine archeologist, and it drew his attention. He had worked for the Museum of Maritime History for many years, locating and investigating wrecks of interest in the Baltic sea. The Baltic Sea was the scene of much maritime commerce and many sea battles in European history and is full of wrecks. Its brackish water is the only place in the world that will not support marine borers, especially the shipworm, Teredo



DIVING BELL.
FIG. 5 NO. 2

navalis, to which so much damage to old wooden ships has been attributed. Franzén studied historical documents and old maritime reports trying to discover a lead to where the *VASA* was sunk, as knowledge of her position had been lost in the many years she had been forgotten. For four years he researched and made special charts and maps, trying to pinpoint her exact location. In 1956, by a process of elimination, he had finally narrowed down the area to a large hump on the bottom, just outside a well-used dock in Stockholm Harbor. After several dragging attempts in this area, he managed with a special core sampler to bring up a small plug of blackened oak from the spot. It was not very conclusive evidence, but it was enough to warrant further testing and investigation. Divers were sent down to the hump and discovered *VASA* lying almost covered with some 300 years of mud and harbor refuse.

At this time, 1957, the following was known about the *VASA:*

1. *VASA* was built of black oak and in all probability the more important parts of her hull were still intact.
2. She was a royal ship and had sunk on her maiden voyage in 1628 with all her equipment.
3. She had gone down very quickly, quite undamaged.
4. She was on an even keel in firm clay.
5. She seemed to have been well preserved by layers of mud.
6. She had never been exposed to the deteriorating effects of ice pressure, swell, vegetable or animal life, short wave light rays or free oxygen.
7. She had been armed with 48 24-pound guns of bronze, which would not corrode.
8. She lay close to the naval dockyard, whose considerable resources could be used on her independently of wind and weather.
9. She could be identified with absolute certainty.
10. In all probability she was the oldest ship found so far in such good condition, that could be dated and identified. She would prove invaluable, if she could be raised, for gathering information about the maritime history of that period.

5.6. PRELIMINARY INVESTIGATIONS

A special *VASA* committee was set up in February 1957 in order to examine the technical and financial aspects of salving the ship. No one had, at that time, even the vaguest assurance that the task was possible. First *VASA* had to be examined and measured, as there was no information available on the ship at all. The examination proved to be difficult. The depth of water over the *VASA's* keel was just over 118 feet, 94 to 98 feet of water on the port side and 100 to 104 feet of water on the starboard side. The bottom of the harbor was firm clay covered with a layer of mud and slime six to ten feet deep. There was debris and garbage in the area from the harbor business. Visibility was very poor as no light could penetrate the muddy waters below 16-22 feet; every time a diver moved, great clouds of mud were stirred up. Divers were limited to one half hour's work underwater at a time. No one during the salvage saw *VASA* in her entirety until she was drydocked in 1961.

As all operations underwater had to be carried out blind, a true picture of the ship was impossible. It was evident that some means of measurement and observation was needed. This was done by divers afixing markers on the wreck; plastic cords were used to mark the hull off in meters from the bow to the stern along both rails. The process of marking and measuring took one whole month.

The next step was to examine all of *VASA's* beams. The success of raising the ship rested on the strength and solidity of the original oak beams. The beams also had to be marked to ensure each was examined and accounted for; this was done by painting very large numbers on them. The gun ports were counted next; divers found 12 on either battery and two ports in the lower battery stern. The salvors had intended to examine the interior of the ship also, however, large quantities of mud and debris had to be pumped off the main decks in order to do this. They found the interior so choked with mud that an inspection was impossible. It was August before all these tasks could be accomplished, and the committee then published the first known facts and tentative sketches of the *VASA*. According to their calculations she was about 162 feet long; the largest deck beams were 26 feet between rail posts, the sides bulged an additional six feet, and the rail thickness added even more; she totaled 39 feet in breadth at her widest part. On the basis of these measurements her displacement was estimated at some 1,300 tons.

From diver investigations it was known that *VASA* was in good condition, but she had been put together with iron bindings and hinges as well as wooden nails. The iron had long since disintegrated and it was not known the number or location of the areas which had these iron fastenings, so the salvors could not guess how much their loss had affected *VASA's* strength.

The questions still to be answered before a salvage attempt could be conceived were numerous. Would *VASA* stand up to the strain of being lifted? Would the lift wires squeeze her hull in or cut her to pieces. Would she come free of the clay she was embedded in? Would it be better to disassemble her and reassemble her after she had been brought up?

Opinions and information were gathered from all quarters. The Institute of Timber Research made tests proving that the oak would still withstand considerable strain to horizontal pressure as it should only have lost 40% of its original strength; its ability to withstand vertical pressure was reduced to a quarter of what it was when new. After interpreting and coordinating all information, the committee recommended trying to raise the *VASA* as she lay.

5.7. SALVAGE METHODS

The next step was to determine a method of salvage. Suggestions ranged from using large synthetic rubber inflatable balloons in the hull, to the conventional method of using pontoons and caissons.

The balloon method would have been very simple but calculations showed the hull would not withstand the force of the pressure exerted from within. This plan was discarded.

The next consideration was to use either sunken pontoons and lift wires, or caissons. Three principle variations were possible. The ship could be raised by large air cylinders, filled with water, then sunk alongside the wreck, and fastened with wires and chains. Compressed air would be used to deballast the cylinders which would rise to the surface and bring the ship up with them. It was a one stage operation with little control over anything which went on under the surface.

Another alternative was to use big lift pontoons. The pontoons would be ballasted down to water level, and lift wires passed under the wreck and fastened around the pontoons so that the pull would be distributed evenly along the wreck's hull. Then the water would be pumped out of the pontoons and that force would lift the ship. The whole rig, pontoons and submerged wreck, would be towed to shallower water and the process repeated as often as necessary to move the hull into the desired depth and position.

The third variation of the lift method was to use hoisting gear or screw jacks to do the actual lifting. Pontoons would be fitted with stands for the screw jacks, and have wells in the center through which the chains would run. The chains would be shackled to attachments on wires and made taut with powerful screw blocks. The ship would then be pumped up in one stage.

Whatever method was used, the ship had to be put down on the bottom when nearing the surface to remove the pontoons. Each of the methods had disadvantages but the successive lift method using lift wires drawn under the hull through tunnels was decided upon because it gave more room for control of the hull, even though it would be difficult to find a clear safe bottom area in which to set the hull down after each successive lift. There was a question still to be resolved with the method chosen as to whether the first lift would clear the wreck from the hole into which she had dug herself. However, each of the other two methods had the distinct drawback of leaving considerable overhang of the stern and bow, and it was not known whether the hull could withstand this unsupported pressure; it could very easily have broken off.

5.8. TUNNELING EFFORTS

While the techniques and methods were being discussed, work on the wreck continued. Toward the end of August 1959 an experimental tunnel was begun under *VASA*. Work was continually interrupted by ship traffic as the wreck lay outside of Stockholm's largest drydock. Each time a ship came or went the work had to be stopped and all craft cleared out of the way. In the tunneling operation the mud had to be pumped off before the clay could be tackled. Many loose objects were unearthed and had to be carefully removed before the tunneling could continue. Divers tunneled into mid-December when work had to be stopped for the winter. The tunnel had only advanced as far as the keel, but the progress was sufficient to convince the salvors that the task of raising the *VASA* was at least technically possible.

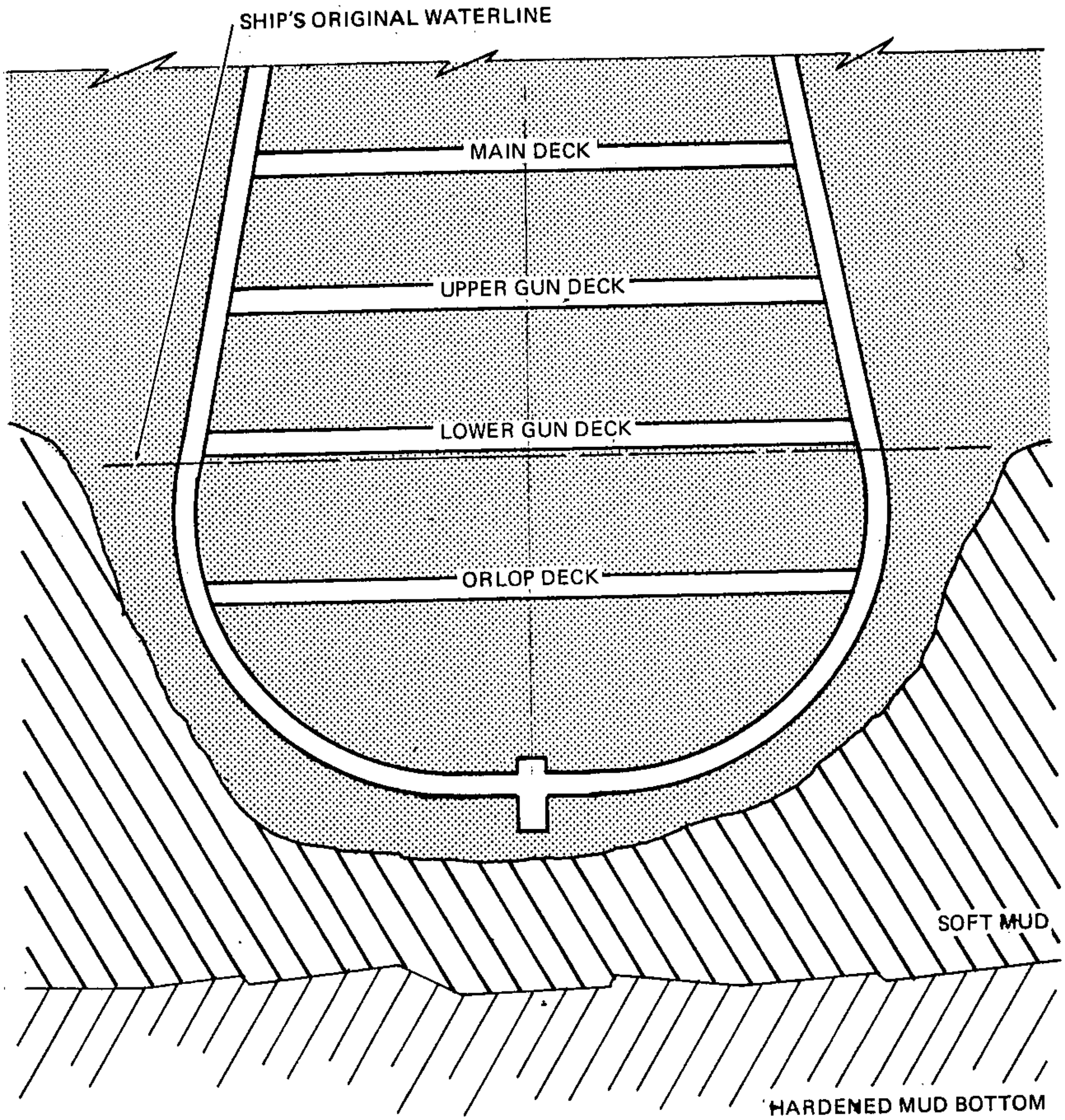
In mid-April work resumed on the tunnel. One man worked on either side of the ship, tunneling toward the middle in carefully calculated paths to insure the tunnel's connection in the middle. They worked in total darkness with Zetterström nozzles and evacuation pumps, much like vacuum cleaners. The pressure nozzles drilled out the mud and clay, and the evacuating pumps sucked it from the tunnel through rubber hoses. Since they worked at depths over 100 feet, they had to wear cumbersome deep sea diving rigs as a protection against the cold. They were forced to lay prone in the tunnels with 700 tons of ship directly above them. (See Fig. 5, No. 3.)

Six narrow tunnels from one side of the ship to the other had to be made in this manner, each approximately 80 feet long; a total of nearly 500 feet of tunnel. The lift wires would then be passed under the keel of the wreck, through the tunnels, and attached to the pontoons, one on either side of the ship. (Fig. 5, No 4.) Work again stopped on 16 December 1958 for the winter. By this time some 1000 descents by divers had been made since the spring of 1957. The third spring tunneling efforts continued.

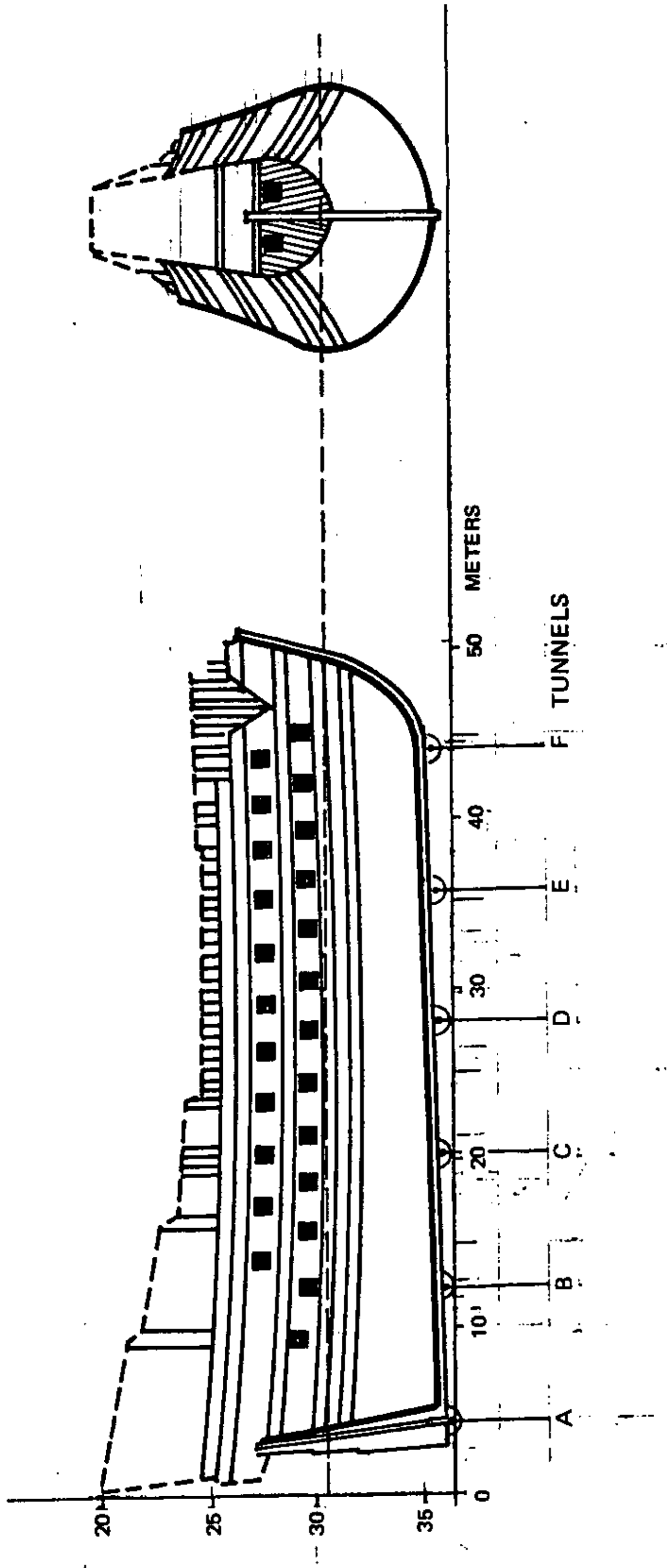
The uniqueness of this salvage operation should be discussed as it illuminates the extent of the job undertaken. Normally a salvage team works from diagrams, charts and reports which give them enough information to accurately judge the ship's characteristics and peculiarities and to know how to approach the salvage operation. Nothing was known about *VASA* except for what partial historical documents revealed and the information the divers were able to contribute from their observations in the murky water. It was impossible to examine *VASA* from the inside because she could not be entered. No plans were made when she was built, and the rough estimates of her dimensions were barely adequate. She could not be lightened very much as her stone ballast was inaccessible. No guess could be made as to where her center of gravity was located, or even her exact weight. Everything taken into consideration, the unknown factors tended to restrict the salvors' efforts in that they had to make the most conservative estimates and take the safest possible choice in every instance of the operation at a sacrifice to time and cost.

5.9. THE LIFT

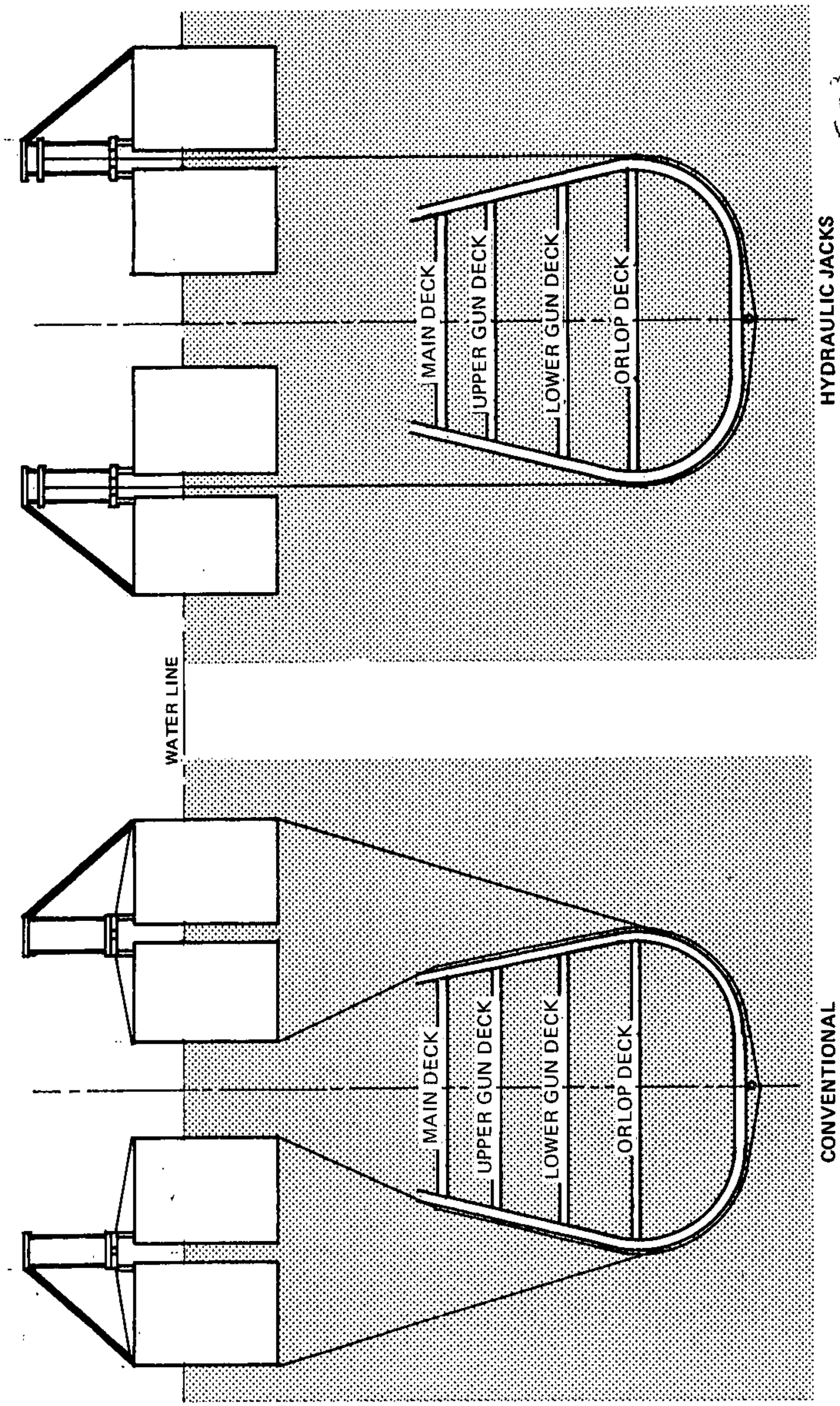
On 13 August 1959 units of the salvage fleet, all of which had been donated, began to arrive. The Royal Swedish Navy supplied divers, for on-the job training, for the operation, and the Neptun Salvage Company donated the equipment and salvage craft. *ODEN* and *FRIGG*, two large pontoons with a combined lift capacity of 2,400 tons, were to be used for the lift. The lift wires which had been positioned earlier, were to be taken up one by one and fixed to the pontoons to ensure even distribution along the length of the ship. The two inch diameter lift cables were 390 feet long, and had the capacity to withstand a strain of as many tons. (See Fig. 5, No. 5.)



TYPICAL TUNNEL UNDER "VASA".
FIG. 5 NO. 3



POSITION OF TUNNELS.
FIG. 5 NO. 4



LIFT PONTOONS.
FIG. 5 NO. 5

The first lift began on 20 August. Divers made one last underwater check. The pumps began to ballast down the pontoons and for an hour nothing happened. Then the port pontoon listed slightly and the two pontoons had to be moved closer together. In four hours the pontoons had been ballasted to a sufficient potential lift capacity of 700 tons, roughly the weight of the *VASA*. A half hour later the pumping was stopped. The pontoons should now have been able to lift her. Bubbles had started to break the surface which was an indication that water was seeping between the wreck and the clay bottom. Suddenly the ground lines slackened and the floats bobbed. A diver was sent down to check and reported that *VASA* had lifted 18-20 inches off the bottom. Eight hours after the pumping began the ship was out of the hole. She was moved athwart the hole and towed for 100 yards until she touched bottom and was gently set down. This process of lifting and moving went on for 28 days and *VASA* was transported 600 yards. During this time she had been turned around so that she traveled stern first; her stern drew considerably less draft than her bow which had grounded often in moving and dug into the soft bottom. On 16 September the first stage had been successfully completed. *VASA* had come through in fine condition with only superficial scratches from the lift wires, and a few broken bulwark posts. The next stage was given the go-ahead in view of the success thus far, but all work had to be stopped in December for the winter months.

In May 1960 the final preparations were started. Of the many things still to be done, one was to clear the upper battery deck which had caught 29 anchors in the course of 300 years. The anchors had damaged the top structures to some extent; the sterncastle was gone and the afterport was demolished. *VASA* also had to be made watertight and that involved building a new after-peak section the size of a small barn, and attaching it to the ship. The hull had to be strengthened and this was done by passing iron rods, shackled in threes, through the opposite gun ports where they were secured to the hull. Four of these sets of rods were used along the length of the hull. The gun ports had to be closed and made watertight. The thousands of holes left by the decomposed iron pins and bolts had to be located and filled. These preparations continued into the winter of that year when work was again stopped. By this time, urging from public interest and enthusiasm in the salvage operations made it necessary to establish a time table projecting that the *VASA* would be raised the week of 20-27 April 1961.

By March 1961 all the holes, some 6,000, had been patched. The most expedient plan seemed to be to raise *VASA* quickly so that pumping and archeological investigation could be begun while she was still in her wire cradle, instead of waiting until she drydocked. In order to raise her more quickly, the lift pendants had to be moved to the side of the pontoons, enabling them to lift the ship in one operation; she would have to be lifted up through the well between the two halves of the pontoon this way. *ODEN* and *FRIGG* were filled and sunk over the wreck. The two inch diameter wires from the previous lifts were attached to the pontoons. As the water was pumped out *VASA* was raised about 13 feet. A diver's inspection showed that sometime since the last lifting operation *VASA* had slipped her wires approximately 30 feet so that the stern rested unsupported. The only possible solution was to set her down again and have divers dredge around the stern until a new set of wires could be passed under her. This was done with some difficulty and as an extra precaution, rubber pontoons, each having a lift capacity of 20 tons, were fitted around the stern for more support.

At this time a bottom inspection was made to determine if *VASA* had been holed or sustained bottom damage otherwise. The bottom passed inspection; the planks were very hard and the only damage was minor scratches from the wires.

Because hydraulic jacks were going to be used for the next lift, the old two inch wires had to be replaced by thicker 2-3/4 inch wires coupled to jack lift chains. Work on this and the hull patching continued.

24 April was the date set for the final lift. Coupling 2-3/4 inch wires to the jack's chains proved easy and on 14 April, 14 manual jacks were manned, two men to each jack. Inch by inch the *VASA* was drawn up. She was down to 400 tons weight after divers had removed a lot of heavy objects from her, including one gun, some tons of stone, several cubic yards of mud and a number of pieces of watersoaked oak. The lift was successful and that evening *VASA* lay securely on the jacks with her upper portion only a few feet under water.

On the day of the final lift preparations were begun at 0500. At 0900 the jacks began to haul her up, and a few minutes later the first piece of black 17th century oak broke surface. For the duration of the lift *VASA* came up at the rate of 18 inches per hour.

5.10. PUMPING PHASE

The next morning *VASA* and the two pontoons were towed to shallower water by two tugs. In this location she was 13 feet off the bottom in 32 feet of water with her afterpart just touching at 39 feet. Before the archeologists and pumping could begin, she had to be raised an additional 18 inches. As soon as this was accomplished with the hydraulic jacks, the pumping began with transportable pumps that had a capacity of ten tons per minute. The pumping operation was a delicate job and called for extreme care and precision. The pumping had to be synchronized with the rate the ship rose on the jacks; the water level inside the ship could never be allowed to rise higher than the level outside, or the sides would be exposed to abnormal strain from the pressure within the ship. The iron strengthening rods would be some prevention, but having progressed this far, the salvors could not take any risks. The pontoons had to be continually trimmed as *VASA* rose and her water weight decreased, to ensure that she had plenty of support from the lift wires. Two pumping shafts had been prepared, one forward and one aft, and into these the Flygt pumps were lowered. As preparations got under way some 4,500 gallons of water a minute poured out of the ship. While pumping was progressing divers were plugging small leaks and cracks in the hull. While doing this the divers discovered an open gun port, dislodged by the lift wires, which was letting water into the ship faster than it could be pumped out. By evening this was fixed, the holes were patched and the pumps started to gain on the water. The next day the pumps gained more of an advantage and the ship began to rise slowly. At the same time the archeologists were unloading the cargo and all removable artifacts. Each piece had to be logged, photographed, cross-referenced and cleaned, and then transported carefully to waiting preservative baths until they could be thoroughly examined and treated. Everything inside the ship was clogged with mud and slime, sometimes many feet thick. The mud had to be washed out and screened so as not to lose anything of value. The work was painstakingly slow especially since a deadline had been set, and even the archeologists' work had to be synchronized to the pumping and raising. To complicate the situation, as the ship rose each new piece that became exposed had to be kept wet so that the wood would not dry out too fast in the summer air and warp or split. Those areas which could not be kept sprinkled had to be wrapped in plastic and watered down occasionally. So much more was involved in the salving of this old ship than most salvage jobs, that it is a wonder it was ever completed.

5.11. DRYDOCKING

The final step was to move *VASA* into a drydock where she would rest on a special pontoon made for her; this pontoon would serve as her permanent bed and as the floor for the proposed *VASA* museum. A bed of gravel was prepared in the large drydock for the pontoon and as soon as it was completed it was moved into the drydock. The drydock was then flooded in readiness for *VASA*. However, *VASA* in her present condition was not light enough to clear the threshold of the drydock. The clearance was 31 feet, but there was an extra 13 feet to negotiate to get onto the special pontoon. *VASA* could not draw more than 18 feet of water if she was going to make it onto her pontoon.

There was much more mud and slime to be removed than was anticipated so a special dredging pump had to be brought in for the job. The pump was a model originally designed for clearing choked up lakes, and it was able to suck eight tons of mud per minute from the ship.

The ship was lightened through pumping and cargo removal until she was able to float on her own, but she was still too deep to clear the pontoon. The mud was only one factor which held her down; her own wooden hull was waterlogged from the time at the bottom and from the water baths she had to have to keep her from drying out. This extra weight made it impossible for pumping alone to turn the trick.

A solution was found that entailed docking her in two processes. She was first to be docked on the drydock floor astern of the special pontoon, where she would be cleaned out until she was light enough to be moved up on her pontoon.

Before she could be towed into drydock on 4 May her slight list was corrected using ten tons of ballast in the starboard upper battery deck. Next she had to be turned around so that she pointed bow first into the dock. Then at two knots she started for the drydock. Just outside, the pontoons had to be released as they could not accompany her. This was tricky since a wire could foul on her anywhere while the pontoons were being cut loose, and another gun port cover could be dislodged and send her quickly to the bottom despite pumping efforts. However, she glided into the drydock with only minor difficulties, and was safe for the moment.

Once in drydock it was easy to see why she had sunk 300 years before: the waterline was only four feet below the lower gun ports; tall rigging and enormous superstructure made her top heavy; heavy armament and weighty carving and ornamentation placed high, also unbalanced her. The remains of her stern section ended almost 55 feet above her keel, and the rudder was more than 32 feet high and probably weighed some three tons. She was very top heavy, not at all stable and quite cumbersome.

Once in drydock the excavations were continued and even though progress was made, it was evident *VASA* was not going to reach her pontoon. She would be drawing too much water, and to complicate matters further, the harbor water level had been unusually low. Operations were behind schedule and no solution was in sight, so the Salvage Master was recalled to help solve the problem.

The Salvage Master decided to try a small lift inside the drydock to raise *VASA* to her pontoon. Four cylindrical pontoons were obtained to fit beside her in the dock. However, the water level was so low that even this was not going to solve the problem. Things had reached an impasse. As luck would have it, one evening the water suddenly rose for a short time and quickly taking advantage of this, the lift proceeded. *VASA* was hauled onto her pontoon with less than a half inch to spare at her stern before the water again subsided.

It was not until 26 July that *VASA* was sufficiently clear of mud, slime, and precious artifacts to be moved from her drydock. She was then towed to another site where further archeological excavation was carried out in preparation for the day when she would be completely restored and moved to her own museum for exhibition.

On 16 February 1962 the *VASA* Dockyard and *VASA* Museum in Stockholm were officially opened to the public. The 333 year old ship and her artifacts and treasures are preserved in the museum exactly as they would have been three centuries ago. The exhibit shows an accurate portrayal of the life of the mariner, his ship, and his trade in the 17th century.

6. M/V FEDERAL EXPRESS

6.1. BRIEF

The *M/V FEDERAL EXPRESS* was struck, while at her dockside mooring in Montreal Harbor, Canada, by a freighter out of control. She was torn from her moorings and sank as a result of a hole ripped in her port side during the collision. The sunken wreck was a major navigational hazard, and unless removed before winter, might have broken up from ice pressure and forced the closing of the Port of Montreal and the St. Lawrence Seaway in the following spring — major economic disaster would have resulted.

To effect her removal, with all speed and surety, she was broken up with explosives and salved piecemeal by lift craft. Because of the close proximity of piers and other installations, an air curtain had to be constructed to minimize underwater shocks from the explosives. A steel deflector wall was also built to divert the forceful current in the channel, and reduce the speed of the current over the wreck so that divers could work around her safely. The operation of removing the *FEDERAL EXPRESS* was successfully accomplished in six months, thus averting economic disaster in the area.

6.2. DESCRIPTION OF THE SHIP

The *M/V FEDERAL EXPRESS* was a World War II vintage Canadian corvette converted for coastal trade. Her dimensions were:

Length	120 feet
Beam	30 feet
Displacement	800 tons

6.3. HOW THE SHIP SANK

On the evening of 5 May 1960 the Swedish freighter *POLARIS* experienced steering gear failure entering the 3.6 knot St. Mary's current in Montreal Harbor, Canada. In the grip of the current she struck the port bow of *FEDERAL EXPRESS* while she was at her dockside mooring. The impact ripped a large hole in the port bow of the ship, below the waterline, and tore her from her mooring. She was forced into the Danish ship *HILDA MAERSK*, being taken in tow by the tug *MATHILDE*. *MATHILDE*, realizing that *FEDERAL EXPRESS* was sinking, tried to push her over to the south bank of the channel; however, she was sinking too rapidly. The tug rescued the 18 men on board as *FEDERAL EXPRESS* sank in 56 feet of water, 800 feet from the Laurier Pier.

6.4. IMPORTANCE OF IMMEDIATE CLEARANCE OPERATIONS

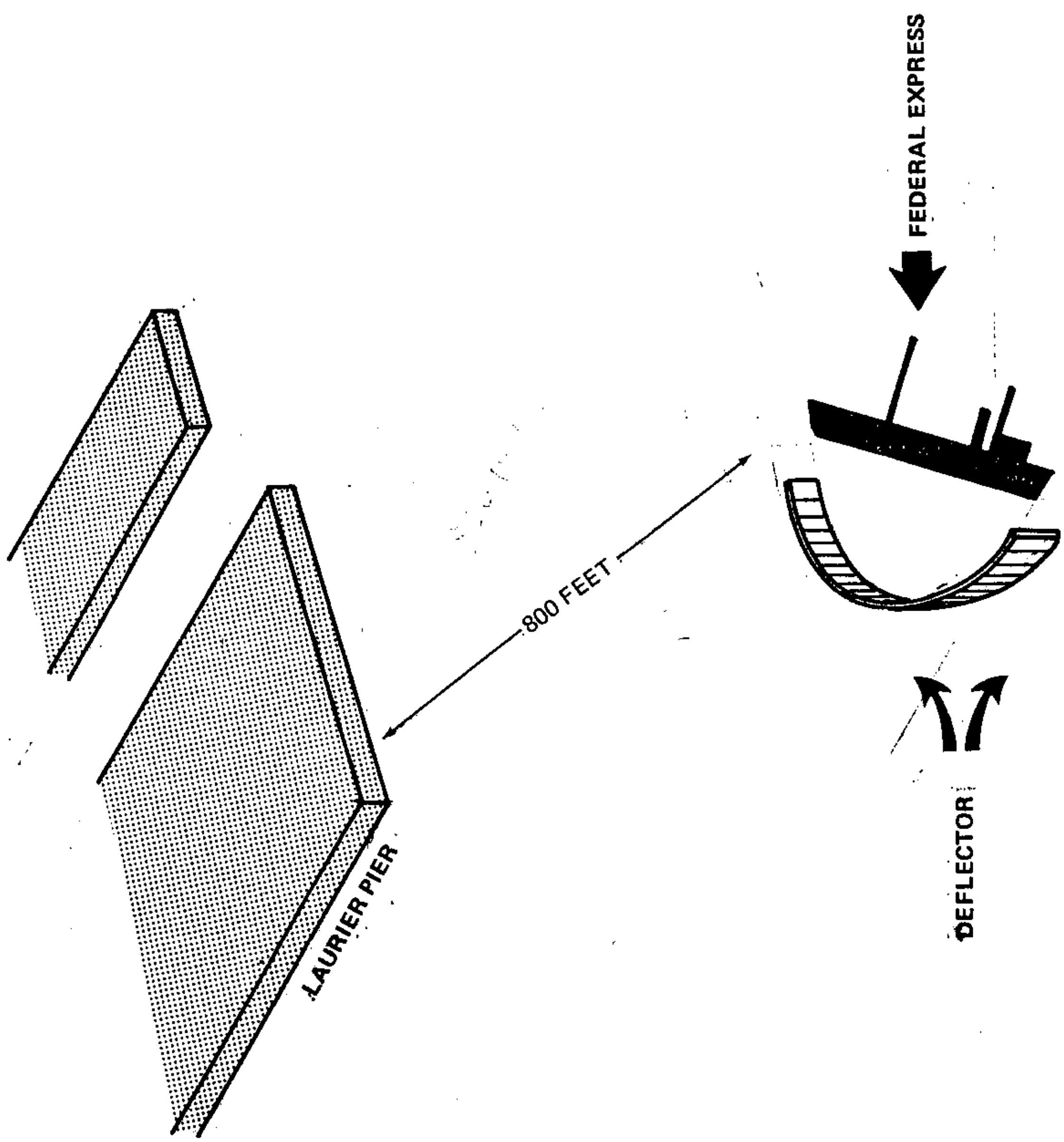
The accident had taken place in a matter of minutes. The Montreal Harbor Authority stopped all channel traffic to locate and mark the wreck. By noon, 6 May, a single lane of traffic had resumed. The wreck sank in the middle of the main shipping channel to upper Montreal Harbor at the intersection of the harbor channel and the St. Lawrence Seaway. The channel at this point was only 1,200 feet wide with unusually strong, tricky currents. *FEDERAL EXPRESS* became a major navigational hazard and unless she was cleared before winter arrived, there was imminent danger of her breaking up from ice pressure or shifting in such a way as to close the Port of Montreal and the Seaway in the spring. This would result in economic disaster for the area. Clearance efforts had to proceed quickly and in a manner which would pose no possibility of another accident or delay which could further disrupt channel and seaway traffic.

6.5. METHOD OF SALVAGE

Two solutions to the problem of salvage were examined; either refloating the vessel or cutting it down into manageable sections which could be easily brought up by crane. Initial inspection by divers confirmed they could not work on the wreck as she lay. The 3.6 knot river current was much too swift. Examination of the problem resulted in the innovation of a giant steel deflecting wall, which when placed upstream from the wreck, would divert the current and reduce its speed over the wreck.

Further consideration was given to the exact method to be used in conjunction with the deflector, in removing the wreck. Two methods of salving the wreck in one piece were available: the use of injected compressed air, or lifting by means of pontoons. Refloating and salving in one piece would have been the fastest method, but if the first try failed the job may not have been completed by winter. Furthermore, by trying to lift the ship in one piece there was the danger that after leaving the shelter of the deflector the current might produce another accident resulting in resinking. The deflector would have to be relocated with a great loss of time, and it could be endangered or swept out by winter ice. Despite the greater time and expense it was decided the *FEDERAL EXPRESS* should be broken up on the bottom and taken up in pieces.

The method adopted for breaking up the wreck was to detonate a series of explosive string charges along a preselected line between bulkheads. Two inch diameter cartridges of 95% "Submagel Explosive," a modified underwater blasting gelatine, were strung along a length of primacord, which is a detonating fuse with a high explosive core of PETN and a firing velocity of 20,000 feet per second. The string charges, about 20 feet in length, were fastened to the wreck by studs driven into the hull with power drivers. The charge was detonated electrically from aboard the *SCARBORO*. On this particular hull the charges were sufficient to cut through the frames and other connections of the wreck without having to use underwater torches. Torches were used only to make holes for shackling slings during the lifting operation and to remove some of the superstructure.



POSITION OF THE DEFLECTOR:
FIG. 6 NO. 4

Meanwhile a preliminary investigation was underway to determine the position of the wreck, the depth of water over it, and to get an idea of the area surrounding it. Since diving was impossible, echo sounding equipment and sextant fixes were used. It could not be ascertained if the ship was lying on her port or starboard side, facing up or downstream because the echo sounder was not accurate enough to locate the ship's funnel or mast. A guess was made that she was on her port side with keel facing upstream, and this was later confirmed.

6.6. THE DEFLECTOR

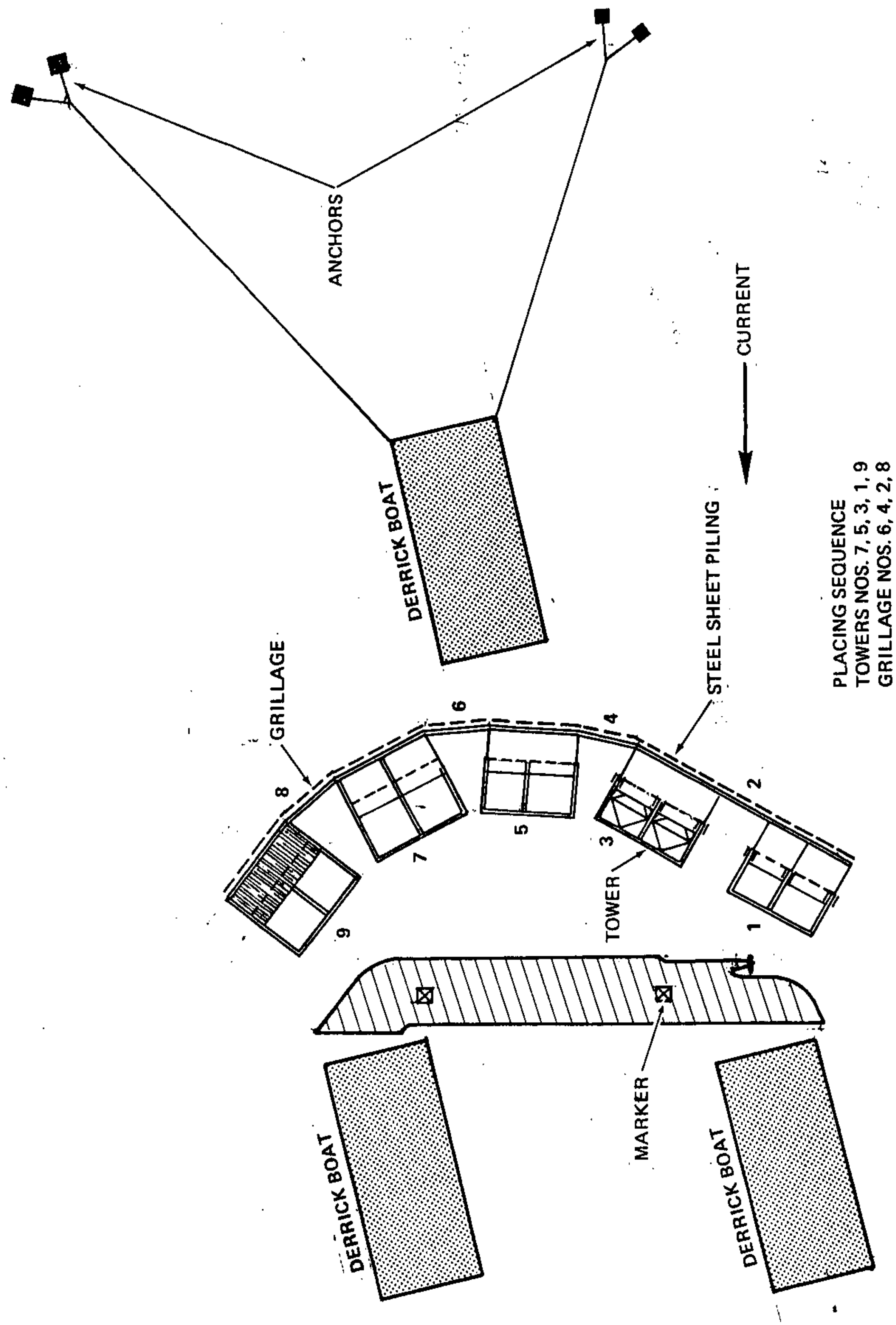
The deflector design had to meet the following requirements. It had to be large enough so that salvage work could proceed at all locations at roughly the same time. It had to be effective in reducing current velocities from 3.6 knots to 1.3 knots. It had to be simple enough so that it could be built, installed and dismantled quickly. The design had to incorporate the maximum amount of prefabrication, since it had to be erected in the middle of the river with no protection against waves or weather, and no fixed point of attachment on the river. The salvage operation was complicated by the congested shipping traffic which could not be interferred with.

The most feasible plan, taking into account all considerations, was to build the deflector around a core of five towers which could be prefabricated, floated to the site and then erected.

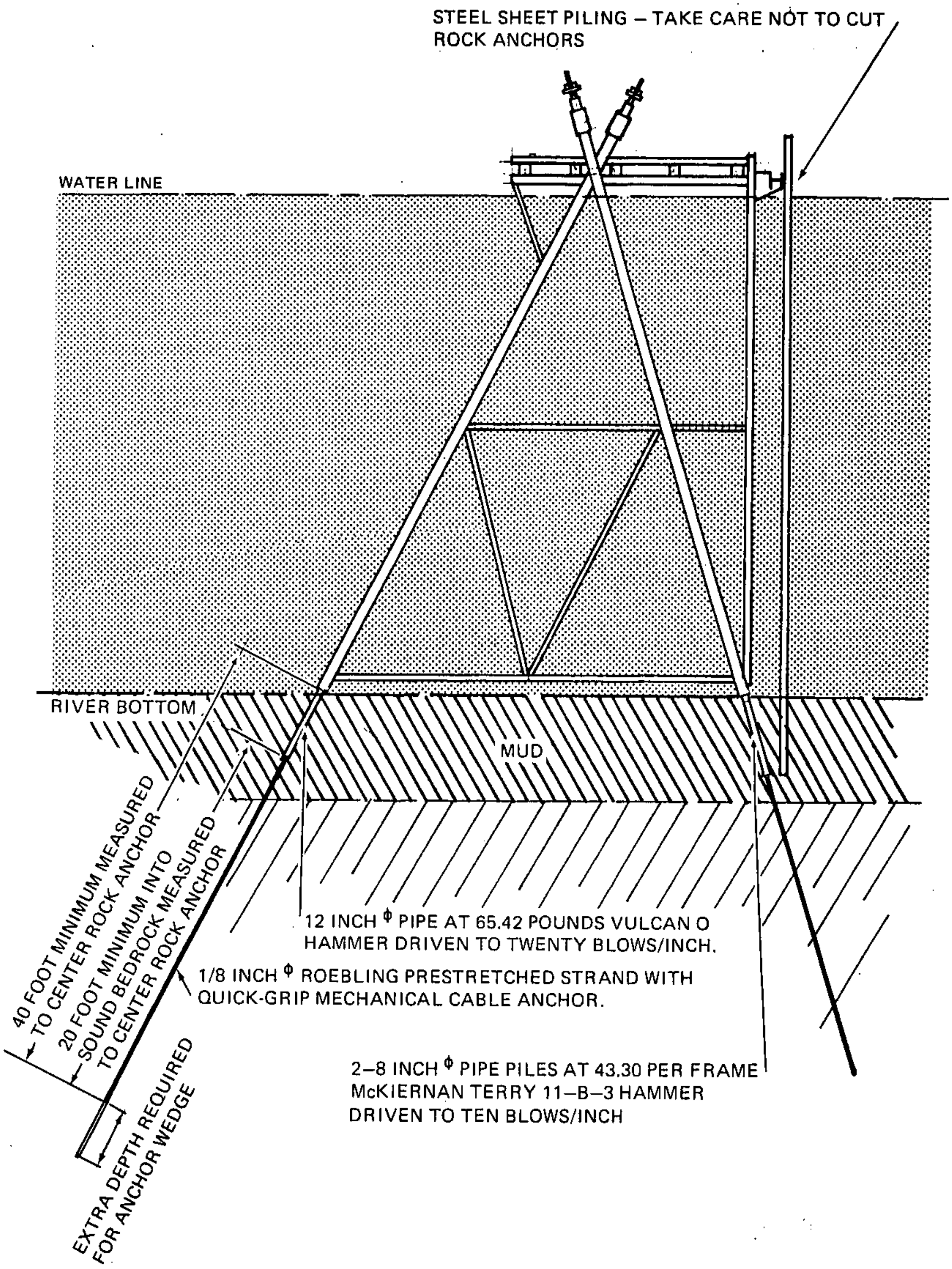
The time element permitted no mistakes in the design and placement of the deflector, so hydraulic model studies were conducted beforehand.

Precautionary tests proved invaluable as several important discoveries were made. Had the deflector been of solid construction, the area of the wreck would have been swept by back-eddies having a velocity greater than the original current. The model revealed where to leave gaps in the wall to achieve the best results and indicated a need for an increase in design loads allowed for the deflector. Pressures were at a maximum at the center of the deflector and gradually decreased as they approached the ends.

A special technique had to be developed to anchor the steel deflector. The deflector wall had to be 50 feet high in the water, about 300 feet long across the river current, and capable of withstanding a total force from the waves and currents of some 1500 tons. Conventional marine anchors and cables could not deal with such loads without impairing the already reduced channel traffic. An anchorage method previously used for the strengthening of dams was eventually adopted. The five towers were anchored to the river bed shale rock by steel cables. To place these cables a hole was diamond-drilled at least 40 feet into the river bed through each pipe pile, and underreamed at the bottom. A bridge strand wire rope cable, 1½ inches in diameter, was attached to a patented expanding rock anchor, and lowered through the pipe pile to the underreamed portion of the hole. There the anchor was expanded by using a tiny explosive charge to cut a retaining pin inside the anchor. In this way some of the anchors were placed up to 130 feet below the water surface. (See Fig. 6, No. 6)



CURRENT DEFLECTOR IN POSITION.
FIG. 6 NO. 5



DEFLECTOR TOWER IN ANCHORED POSITION.
FIG. 6 NO. 6

When the anchor and cable were in position, each upstream cable was stressed against its pile to a load of 50 tons, and secured. Each downstream cable was stressed to 38 tons; thus each tower was held down by a prestressed force of 414 tons. The deflector towers themselves, essentially large cubes of space framework, were about 55 feet high, 50 feet long and weighed 45 tons each. After the core towers were placed and anchored, sheet piling was driven five feet into the river bed along the upstream side of the towers to form the deflectors. (See Fig. 6, No. 5 and No. 7.) The deflector was completed and full scale diving operations were commenced on 1 August 1960.

6.7. DIVING OPERATIONS

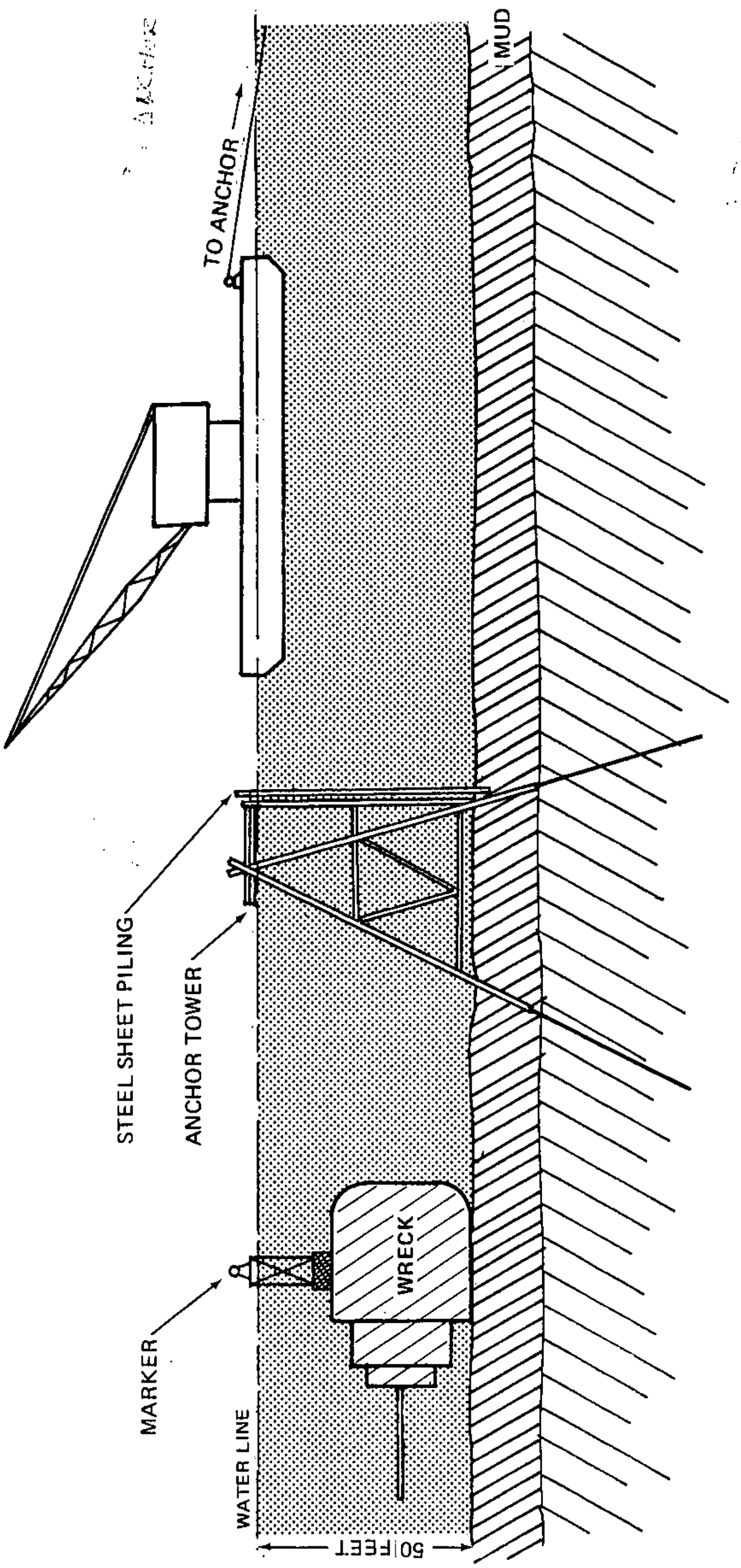
As soon as the first part of the deflector had been erected, providing some protection, a temporary small deflector wall was positioned topside of the wreck. It consisted of strong wooden boards held together by steel beams and secured firmly to a barge. Behind this, divers were able to make as thorough an examination as possible in the 18 inch visibility of the murky water, using underwater television cameras.

The diving operations were crucial to the success of the salvage task. Early in the operation it was determined that the swiftness of the current precluded the use of a conventional diving rig. More flexible wear was needed, so the divers were equipped with light weight suits and fins instead of the deep sea diving suit and heavy boots. In this light outfit a diver could work horizontally swimming head-on into the current with only his head, shoulders, and feet offering resistance.

The divers established quarters in the channel, working double crews at a time and rotating the diver/attendant positions. Diving five to six hours per crew, they located gases trapped in the hold and perforated the many cargo holds with special underwater guns to let the gas escape. Sixty tons of the cargo was comprised of carbide drums which were damaged when the ship sank. Calcium carbide when in contact with water, releases highly flammable acetylene gases, explosive under some conditions. Since the wreck had listed to her side, it was necessary to cut large openings with arc-torches to remove the cargo. Whenever the sparks contacted the gases, minor explosions occurred. Divers proceeded to lighten the ship, although an error could have been catastrophic. As long as the carbide drums remained underwater they posed no serious problems; once at the surface they would attain such a degree of incandescence that the paint would begin peeling off of them. Several of the drums burst into flames on the barge deck. Although safety precautions were observed, the divers were operating under a calculated risk.

6.8. THE AIR CURTAIN

Because of the time element involved, it was evident that explosives would have to be used for the salvage of the wreck. Without adequate protection for offshore installations less than 800 feet away, the blasting would be far too dangerous. Underwater charges large enough to cut the ship's plates would produce shock waves so strong they would crack foundations, damage pier footings and possibly spring hull plates on vessels anchored nearby. A water hammer could enter the intakes of ships and do damage to their engines.



CURRENT DEFLECTOR IN POSITION PROTECTING THE WRECK.
FIG. 6 NO. 7

In order to minimize danger from the shock waves a protective air curtain was devised to absorb the pressure waves from the underwater explosions. The general principle behind the air curtain follows; water, being a homogenous material, creates a heterogenous mass when air bubbles pass through it or emulsifing takes place, and this mass absorbs shock waves from explosions nearby.

The air curtain consisted of four-inch aluminum perforated pipes laid on the river bed, through which compressed air was released during the blasting. The air rising to the surface formed a solid wall of bubbles in a curtain 150 feet long. Before the curtain was installed underwater pressure measured on a sensitive oscilloscope at the end of the Laurier Pier was recorded at 18 to 20 pounds per square inch. After the curtain was installed the pressure was too small to record.

Another air curtain was installed to protect the derrick, *SCARBORO*, which because of the time element, had to remain close to the site of the wreck during most of the blasting operations. Again this curtain was found to be completely effective in preventing damage.

6.9. LIFTING OPERATIONS

The floating derrick, *SCARBORO*, equipped with shear legs, a large revolving crane, and having a lift capacity of 280 tons, was used for the wreck removal operation. Wires from the arm of the crane were attached to each section to be removed. Diving crews cut hull openings to pass wire rope messengers. The ends of the messengers were fitted with connecting shackles secured to the main hawsers. The trick was to find areas of sufficient strength to support the pull of the wires, and the weight of the wreck.

The stern section was the first to be removed. It totaled almost 170 tons; 120 tons of actual ship and 50 tons of weight from silt and waterlogged timbers. Once *SCARBORO* lifted the stern section above water, harbor tugs towed her to a pier where another crane received the stern and deposited it on the dock.

The wreck's bow was the next section to be removed, and the final stage was the removal of the superstructure and the remaining cargo decks and compartments.

In order to completely clear the area of the wreck debris, a crane equipped with a clam was used to rake all debris left on the bottom by the blasting operation. By 5 October 1960 the channel had been completely cleared.

6.10. DISMANTLING THE DEFLECTOR

One last task remained — the dismantling of the deflector. This was a difficult operation as the anchor cables had to be severed at the river bottom and the whole structure lifted out. It was accomplished

by inserting shaped explosive charges inside the hollow tubes of the deflector frame, and sliding them down around the cables to the river bed. Each charge contained a 1¼ ounce mixture of TNT and PETN, a powerful explosive used mainly in making blasting caps. Since no machines existed which could make these specially shaped charges, they were hand-made and poured in the laboratory. Detonating each charge separately severed the anchor cables and permitted the towers to be withdrawn.

By 15 October 1960 the operation was complete and the channel clear of obstructions.

7. M/V MONTROSE

7.1. BRIEF

The cargo ship *M/V MONTROSE*, while in Detroit Harbor, collided with a cement barge. Her hull was ruptured and she sank resting on her port side. During salvage operations an extensive timber shoring system had to be installed, transferring the pressure from the weather deck, which had become analagous to the ship's side, to the second deck. The hull rupture was sealed with a concrete patch, and after the ship was made watertight, she was successfully pumped out and dragged to shallow water with beaching gear.

7.2. DESCRIPTION OF THE SHIP

The *M/V MONTROSE* was a cargo ship possessing the following characteristics:

Length	420 feet 7-3/4 inches (bp)
Breadth	58 feet 9 inches
Depth	35 feet 9 inches
Draft	27 feet 4 inches
Tonnage	4,993 tons (gross)
Tonnage	5,600 tons (DW)
Speed	15½ knots
Propulsion	5 cylinder Diesel, 6,300 BHP

7.3. HOW THE SHIP SANK

On the evening of 30 July 1962 the Canadian cargo vessel *M/V MONTROSE* left the Detroit Harbor Terminals pier and collided with a cement barge. The hull of *MONTROSE* was pierced through the port side forward, at holds No. 1 and No. 2. The ship sank in 2½ hours, coming to rest on its port side in 45 feet of water. No casualties were reported.

7.4. CONDITION OF THE WRECK

Salvage crews from Merritt, Chapman and Scott arrived late in August 1962 and found *MONTROSE* lying on her port side in 45 feet of water. She was directly under the Ambassador Bridge, 400 feet from shore; the bow pointed upstream at approximately a 20 degree angle to the shore. The ship listed 85 degrees to port; the starboard side projected 14 feet above the surface at mid-ship. (See Fig. 7, No. 1)

Surface current at the wreck site was from four to five knots; bottom current outside the hull was also swift. Divers found that a thorough external damage survey was impossible.

All but 300 tons of cargo had been unloaded prior to the collision, but most of the remaining cargo cascaded down the port side covering the damaged hole. Before an internal examination could be made, dunnage, sweat boards and cargo had to be removed. Divers reported that a hull rupture about 34 feet long, and of varying widths up to three feet extended approximately 18 feet forward into hold No. 1 and 17 feet aft into hold No. 2. No. 5 weather deck hatch cover and a lower hatch cover were missing, as was a door between holds No. 2 and No. 3. Many vents and ventilators were open. Some of the double bottom tanks were filled, but the deep tanks were slack.

7.5. THE SALVAGE PLAN

No simple procedure could be applied to right and raise the ship. The obvious method of righting was the use of offshore anchors and pulling tackle. Examination revealed that this method would interfere with river channel traffic and the plan was abandoned.

An alternative plan was formulated as follows:

1. Move as much salvable cargo as possible, especially cargo contributing to capsizing moment;
2. Remove deck and cargo winches and booms, lifeboats and other gear contributing to capsizing moment and preventing close positioning of derricks;
3. Seal the hull rupture using a reinforced concrete patch piped from within by a tremie funnel; anchor the patch firmly to the hull side and tank top;
4. Close or replace watertight doors in the hold and locate and repair No. 5 hatch cover;
5. Seal all ventilator openings in the hull; wedge tight all hatch covers;
6. Rig five ten inch salvage pumps;
7. Rig chains under hull for use in beach gear dragging and derrick lifts;
8. Provide approximately 13,000 foot-tons of righting moment with booms and concrete block weights;
9. Provide a derrick lift of 180 to 200 tons at the port rail to counteract the weight of the concrete blocks and booms and to furnish approximately 6000 additional foot-tons of righting moment;
10. Flood all double bottom and peak tanks;
11. Flood port and center deep tanks to prevent listing buoyancy from trapped air and vapor, and to guard against overturning to starboard should the wreck float with considerable free liquid surface and negative metacentric height;
12. Pump down all five cargo holds;
13. Drag the hulk shoreward by means of beaching gear.

A major operational problem hindered the initial salvage operations. With the ship on its side when the hold pumping began, the weather deck became analagous to the ship's side. The weather deck was too weak to withstand hydrostatic loading as a bulkhead. The deck would be loaded with a head equal to the difference between inside and outside water levels. The deck stiffening framework was not strong enough to withstand the head necessary to provide the buoyancy, so an extensive system of timber shoring was installed (See Fig. 7, No. 2), transferring the pressure from the weakened weather deck to the second deck. It was still necessary even after these precautions to limit the hydrostatic head to 11 feet. After the ship had rolled, and more than half the deck emerged, the loading pattern was triangular and the limit was relaxed. The hatch covers were firm enough to withstand the pressure and needed no shoring.

7.6. EQUIPMENT

RIGHTING GEAR

The righting gear consisted of five stiff leg booms approximately 90 feet long, stepped near the turn of the starboard bilge and supporting 30 to 40 ton concrete blocks suspended on fixed pendents from the tips. The booms were stayed with wire rope. One turnbuckle was provided in each backstay to allow lateral adjustment of the boom tips to equalize the shear stresses in the heel pins. Boom steps were designed and located so that the boom thrusts were carried by transverse bulkheads in the tank top region. (See Fig. 7, No. 3).

DRAGGING GEAR

Beaching gear for dragging consisted of nine-part tackles, connected to the wreck with two inch wire rope at one end and to dead man anchors at the other end (See Fig. 7, No. 4). Six sets of gear, each capable of a 50 ton pull were installed. Later, the difficulty of pulling the stern forward necessitated the addition of a seventh set of beach gear. Power was supplied to the purchase tackle by barge-mounted winches and a shore crawler crane.

7.7. PRELIMINARY WORK

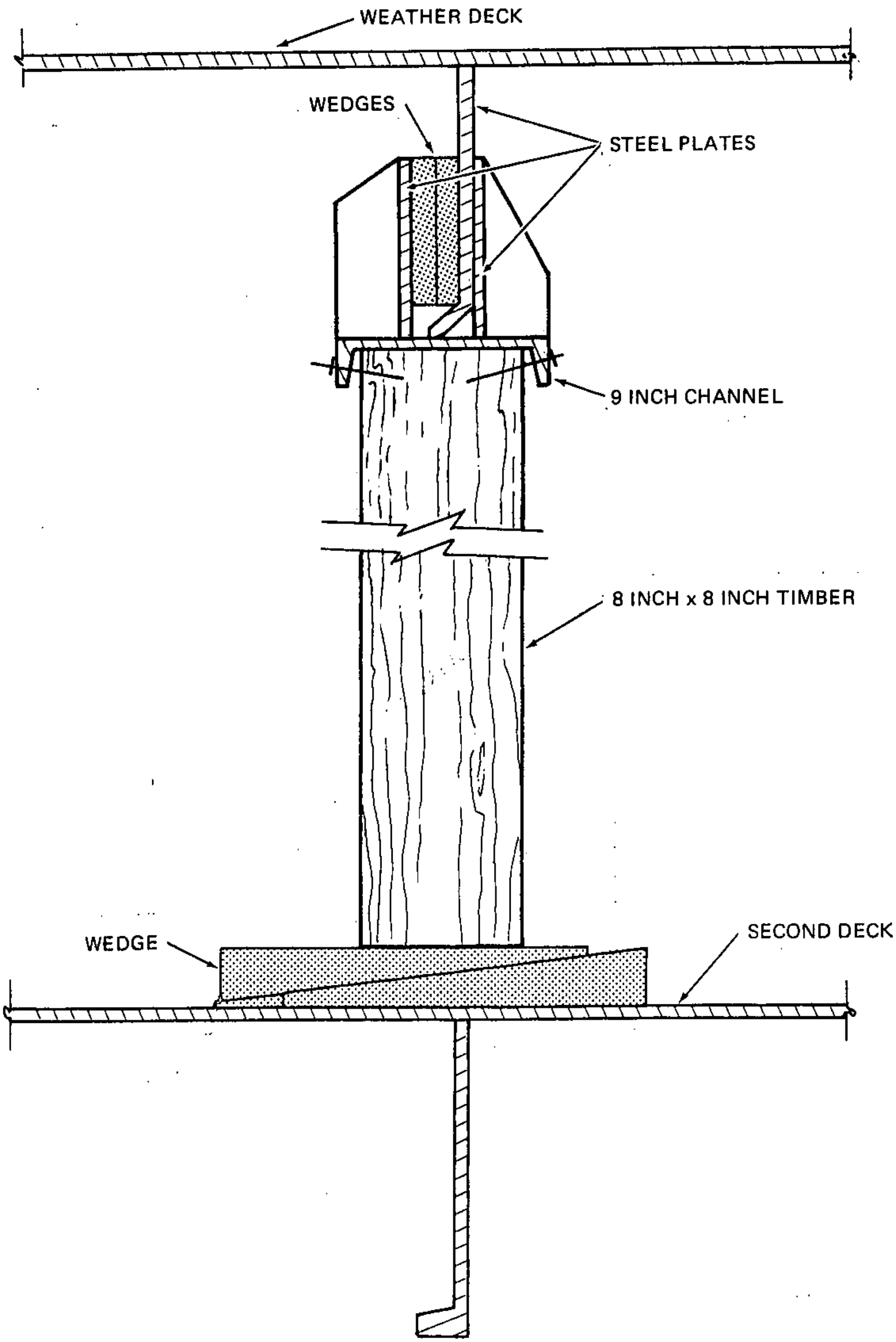
The first task before any righting effort could be made, was to shore the weather deck and patch the rupture.

Shoring the weather deck:

Typical framing of the weather deck consisted of steel plates welded to deck plates. Sixty-eight timber shores, fitted with channel caps were used. The channel caps were designed to be slipped over the bulb, with lateral wedges driven against the side of the bulb plate. The shores were then set in a preloaded condition by driving home the base wedges. (Fig. 7, No. 5)

Patching the rupture:

The rupture was initially patched by bolting steel plates from the inside over the opening. The toggles were cut from steel plates and sheet piling through which bolts had been passed. Anchors for the concrete were made with long bolts passed through the shell plating and the frames. Plate washers were fastened at the inner end.



WEATHER DECK SHORING DETAIL.
FIG. 7 NO. 5

The concrete was kept in place with wood, steel or sandbags, depending on the situation. The concrete mass had to be shored against the tank top to prevent becoming dislodged as the ship righted. Both sides of the bulkhead between holds No. 1 and No. 2 had to be patched in this manner. Concrete was poured through a tremie pipe and hopper which was mounted over an access hole cut in the starboard side. The hole straddled bulkhead 136 which separated holds No. 1 and No. 2.

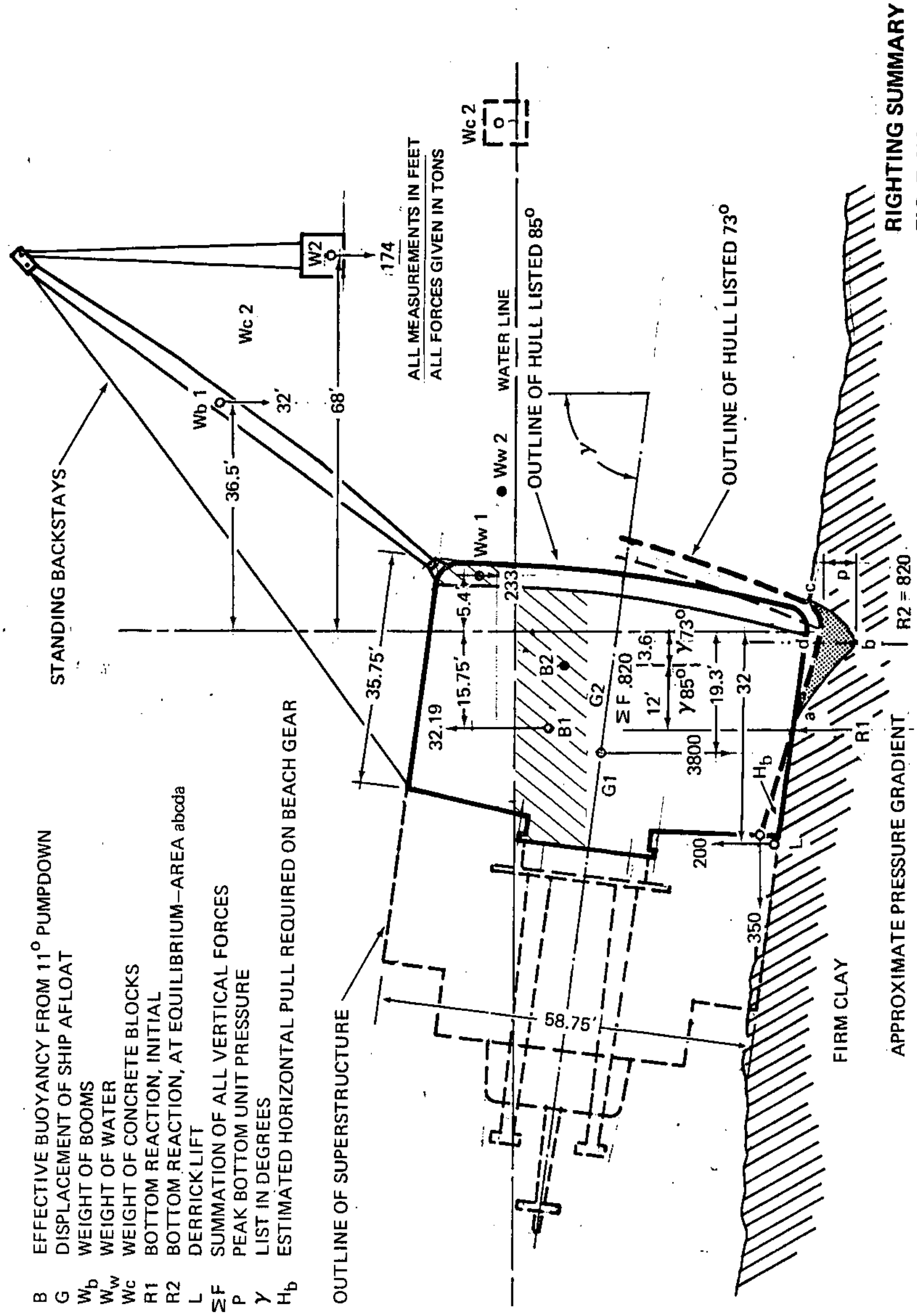
Divers guided the tremie spout underwater. The concrete was transit truck-mixed, transported in concrete buckets and deposited by floating derrick. (See Fig. 7, No. 6) A total of 98 cubic yards of concrete were used in the patch. Under these conditions the patch could not be expected to be 100% watertight. In hold No. 1 it was successful in stopping the leaks, but in hold No. 2 it created further caulking problems which extended throughout the pumping phase.

7.8. PRELIMINARY RIGHTING

In order to facilitate dragging and minimize superstructure damage, the ship had to be partially righted. This would lift the superstructure and port rail from the channel bottom. The righting study concluded that the righting moment from pumping down alone would not be sufficient. The center of buoyancy was to the right of the center of gravity of the ship, and pumping would only add listing moment. Booms and weights, and the lifting force of available derricks, furnished the additional righting moment. On the assumption that the river bottom was firm clay, the plan called for five concrete blocks totaling 174 tons and derrick lifts of 200 tons. This assumption proved incorrect and the tonnage estimate was much too large. It took only two of the five blocks to right the ship 12 degrees, and one of the two blocks submerged during the operation.

NOTE: It is difficult to measure the modulus of bottom reaction as it effects the righting of a ship. Variations in bottom shape, moisture content, and graduation of materials, make a complicated problem for a plane foundation mat on land. The lines of a ship make the problem complex since the shape causes local displacement of soil in search of firmer strata on which to locate the fulcrum.

Consideration of the movement of reaction R will show how a softer bottom diminishes the righting moment required (Fig. 7, No. 7). R lies somewhere between points e and L before the righting moment is imposed. If the bottom is infinitely hard and the ship sufficiently stiff, the pressure gradient will assume the classic triangular shape with the reaction through its centroid. (In this case the Detroit River bottom was composed of clay, and the hull had to be displaced in order to bring the sharper hull outline to harder soil and allow for the rotation of the ship.) The reaction at R moves progressively to the right, to a point near R_2, where the rotation moments will balance. The ship now rests in a trench as defined by adc. As the ship rolls in a righting direction, the boom weights become more effective. The center of buoyancy moves to the right from B_1 to B_2, but the center of gravity also moves from G_1 to G_2; the W series moves to the position of the reaction. This calls for another readjustment in the position of the reaction. Eventually a condition of equilibrium is established with the reaction in the vicinity of R_2, provided an excessive amount of righting has not been imposed.



RIGHTING SUMMARY
FIG. 7 NO. 7

Control of the righting moment was handled by two methods: first, the boom pendents were cut to length so as to enter the water before the ship righted to a critical angle; total immersion would lessen the moment of the weights to 60%; second, the amount of derrick lift could be calculated with reasonable accuracy by rating the trim of the derrick hull, a scow of rectangular shape. The derrick hull was first pulled down and the hoist brakes set. With this procedure, one righting rotation of the wreck would automatically lessen the lift until the derrick hull was again pulled down for another lift.

7.9. PUMPING OPERATION

One ten-inch pump was rigged in each of the five holds, and an extra six inch pump was rigged in hold No. 1 where the most serious leakage occurred. The pumps were gasoline engine driven, self-primed, high delivery, low discharge-head type. The capacity of the ten-inch pumps was 840 tons per hour, at a 15 foot static suction lift. They were mounted on platforms opposite holes cut through the high side of the deck. The platforms were adjustable, enabling them to be leveled during the ship's righting. As the holds were dewatered and the ship righted considerably, the pumps and platforms were reinstalled inside at a lower level to reduce suction lift. (Fig. 7, No. 8)

7.10. THE DRAGGING OPERATION

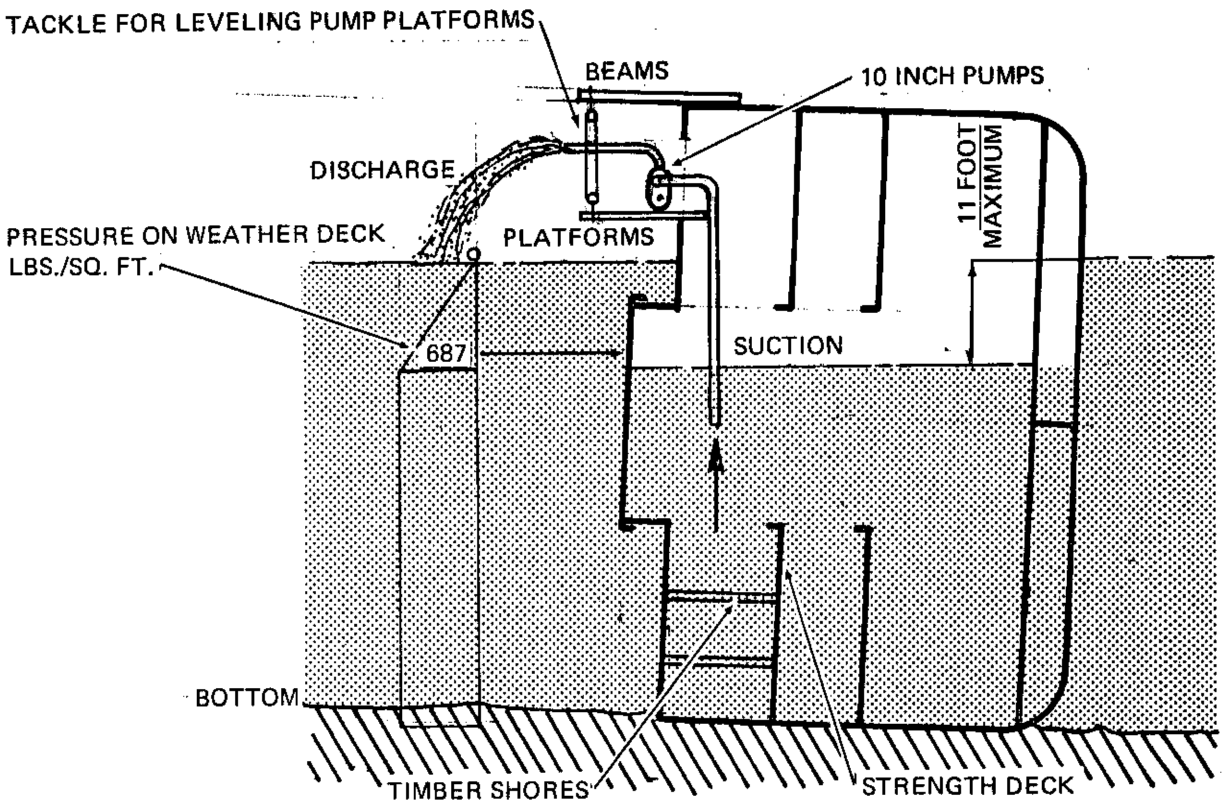
(Fig. 7, No. 9)
Dragging represented almost two weeks of constant effort. Tension was placed on one beaching gear set at a time and held, while watching for any perceptible movement.

At first, operations were conducted during daylight hours; the purchases were slacked off for the night. One night the ship suddenly slipped back into the trough from which it had been raised. When the slack was suddenly taken up, numerous wires broke; thereafter, operations were on a 24-hour basis.

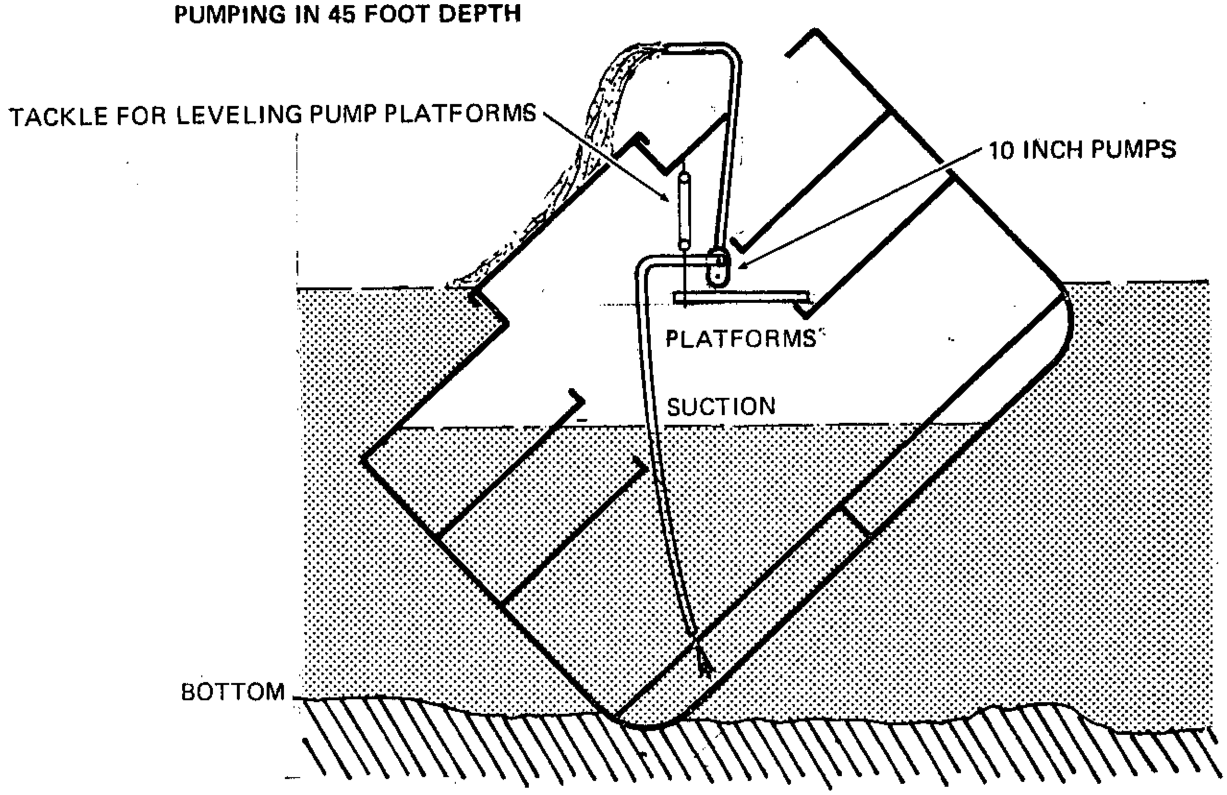
Virtually no resistance to dragging was offered in the bow section of the ship, but after a few degrees of righting, the port buttock began to resist stubbornly. To overcome this resistance the holds at the forward and after ends were alternately flooded and pumped in the hope of duck-walking the hulk over the edge of the depression. A seventh set of beaching gear was also added. A combination of these efforts succeeded in moving the vessel to shallower water.

As the list lessened, more of the ship's port side began to act as a side. The pump down limit was no longer necessary, and the forward holds were dried out. While pumping holds No. 3 and No. 5 the motor casing was also pumped out through the skylight to minimize pressure against the casing. As the after end of the ship lightened, dragging was easier and complete pumping became routine.

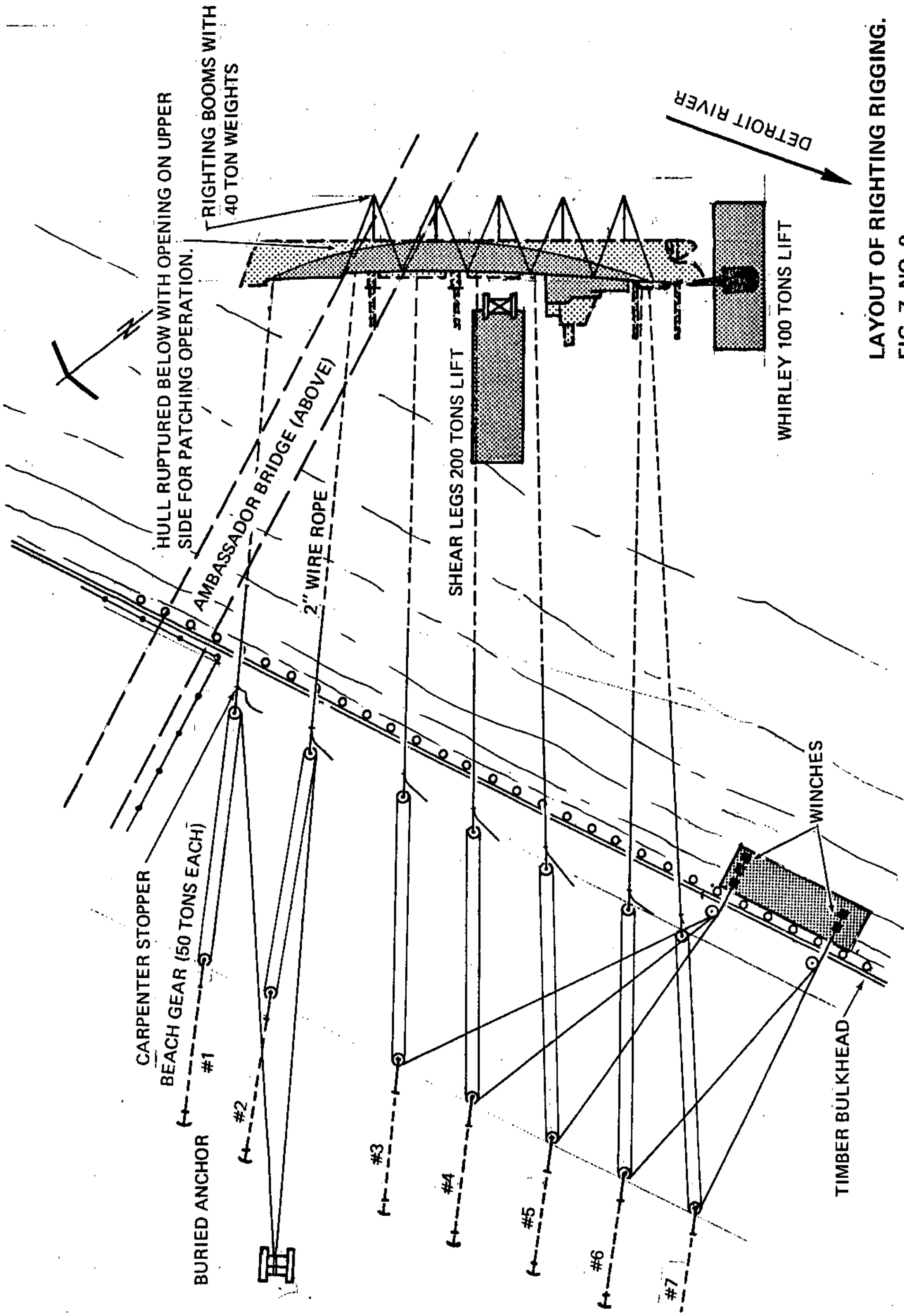
On 5 November 1962 the ship was afloat and the beaching gear was dismantled. The ten-inch pumps were taken off the ship on 7 November and the final water stripping began with pneumatic rotary sump pumps which were more suitable for small places.



PUMPING IN 45 FOOT DEPTH



RIGGING OF PUMPING PLATFORMS.
FIG. 7 NO. 8



LAYOUT OF RIGHTING RIGGING.
FIG. 7 NO. 9

7.11. FINAL WORK

After the hull was pumped out, 8,000 foot-tons of list remained from the weight of the concrete patch. In order to compensate for this, the winches and booms used during the operation were stored on the starboard side, and the port double bottom tank was pumped out. The winches were placed on the double bottom tank tops and the booms were stowed in the 'tween decks of holds No. 2 and No. 3.

Considering the magnitude of the operation, little damage occurred to the ship as a result of salvage efforts. The actual damage sustained included an access hole cut into the side and five access holes cut into the weather deck; slotting the shear strake in ten places to admit the backstay bracket webs; and removing five boom steps with a burn and grind operation. The weather deck was sprung in one area near No. 4 hatch, but this was caused by the ship's position on its side and not the dewatering operation as the deformity was in a direction opposite to the water head. There was no damage to the keel. On 12 November 1962 the *M/V MONTROSE* was turned over to her owners within two degrees of an even keel.

8. RAJAH SOLIMAN

8.1. BRIEF

During the 1964 typhoon, Winnie, in the Republic of the Philippines, the *RAJAH SOLIMAN*, ex-*USS BOWERS* (DE-637), undergoing repairs and unable to put to sea for safety, was impaled on the pier bulkheads, capsized, and came to rest bottom up at the pier. After five parbuckling attempts *RAJAH SOLIMAN* was righted, raised by lift craft and refloated by pumping.

8.2. DESCRIPTION OF THE SHIP

RAJAH SOLIMAN was originally constructed in 1944 as a destroyer escort (ex-*USS BOWERS* DE-637). The ship possessed the following dimensions:

Length	306 feet
Breadth	36 feet 11.5 inches
Draft	13 feet 6 inches
Displacement	1,400 tons

8.3. HOW THE SHIP SANK

RAJAH SOLIMAN had been transferred to the Republic of the Philippines in 1961 under MAP. On 29 June 1964 while undergoing boiler repairs at Bataan National Shipyard in R.P., she was severely battered by typhoon WINNIE. Because of boiler repairs and the loss of shore power cables the ship was helpless and unable to put to sea. The wind and wave action beat her against the sheet pile bulkhead. The concrete capping of the bulkhead was knocked off, and the ship was impaled on the jagged sheets which cut into her sides. She began to take water and the crew was forced to abandon ship. Shortly thereafter, she capsized toward the pier, shearing off most of her superstructure. (Fig. 8, No. 1).

8.4. CONDITION OF THE WRECK

The ship had settled to the bottom in 24 feet of water at an angle of 130 degrees. She was essentially upside down. Wave action and subsequent storms caused the ship to work down into the bottom an additional eight feet and increased the list to 150 degrees to starboard. About 200 feet of the bottom remained exposed at low tide, including the port bilge keel and the sonar dome.

Initial Philippine salvage operations had brought the ship up to an angle of 140 degrees from the vertical using large makeshift pontoons. Salvage operations ceased when the Philippine government realized that the cost of repairing *RAJAH SOLIMAN*, because of her turbo-electric propulsion plant,

would be prohibitive. The wreck still had to be removed as she was blocking a major portion of the most useful pier space at the shipyard. A commercial estimate of $125,000 to raise the wreck led the Philippine government to approach the US Navy with the possibility of the U.S. financing the costs of salving and rehabilitation of the ship. After a survey of the ship by U.S. Salvage Officers, the Navy recommended no funds be expended in view of the ship's age and the high cost of rehabilitation of a turbo-electric drive ship. An agreement was finally made to this effect: if and when the ship was declared "in excess" to the Philippine Navy and returned to the US Navy under the MAP agreement, the US Navy would undertake its clearance as a training operation and would sell the hulk for scrap to help defray the expenses. *RAJAH SOLIMAN* was declared "in excess" and detailed plans to salvage proceeded.

8.5. METHOD OF SALVAGE

As the wreck was upside down, a simple method of removal might have been to make the bottom watertight, as it lay exposed at low water, blow the water out with air, and drag the wreck seaward using an ARS and beach gear. Once the wreck was moved it would have been possible to dispose of it at sea thus clearing the valuable berth. This method was not adopted for two reasons.

First, the hulk had to be sold to help finance the operation; removal and sinking at sea would have prevented the sale. Second, the method was thought marginal at best, and if it had failed it might have resulted in blocking the channel at another location. On completion of successful salvage of the wreck, large amounts of mud and silt were found in the hulk indicating the great weight that had to be overcome and moved; the decision to abandon this method proved prudent.

The salvage plan adopted required righting and lifting the wreck. To assist the lifting evolution, pumping and the use of air or other buoyant material could be used. The decision was made to right the ship by rolling it to seaward through a parbuckling technique. The alternative, rotating it in its original position, was discarded for the following reasons:

1. The hull resistance and starboard bilge keel resistance in dragging toward the wharf would be excessive; and

2. Once righted in the original position, the wreck would be in a trench eight feet below normal bottom contour, making it more difficult to raise by developing buoyancy within the hull. Furthermore, this position would preclude the use of lift craft as there would be insufficient room to place the craft between the wharf and the wreck. Even if lift craft could be positioned, they would likely be ineffective because of the large initial lift required to clear the trench.

Once righted the main deck would be below the surface. Refloating by cofferdamming and pumping and/or use of air was considered impractical because of the light scantlings of the hull, probable deterioration with age and the impracticality of patching the damaged main deck. The final decision was to use lift craft to raise the wreck in stages to shallower water where the main deck would be above the waterline. The hull could then be patched and refloated by pumping.

8.6. EQUIPMENT NEEDED

Two ARS salvage ships were assigned to the operation to be used in the righting phase, and to provide manpower and equipment for the entire operation.

The key to the operation was to use lift craft. Two Pacific Fleet ARSD lift craft were in reserve and costs of activating, and manning problems, mitigated against their use. ARSDs had never been tested in this kind of operation and their capabilities for application here were seriously doubted. However, since there were spring tides with a range of over five feet in the area, the use of dumb lift craft, i.e. non self-propelled craft, was considered.

The British had two heavy lift craft in Singapore, and preliminary discussions indicated they could be contracted for. An inspection of the craft, LC-25 and LC-28, proved them to be satisfactory for the lift operation. The craft were non self-propelled, however, they did have boilers, machinery necessary for ballasting and deballasting, heavy winches and capstans, booms and living quarters. Although they were without crews and were held in reserve, they could be quickly activated and operated by USN crews. The craft were also completely outfitted with rigging, fittings, heavy lift wires and Boullivant clamps.

The lift craft arrived on the salvage site 26 January 1964.

Other craft essential to the operation were the salvage ship *USS BOLSTER* (ARS 38), the *USS GRASP* (ARS 24), two LCM pusher boats and a 100-ton floating derrick (YD).

Equipment necessary to the operation included two 600 CFM blowers, portable welding machines, 2½ inch chain for parbuckling, pumps, and steel for patching. A model of the *RAJAH SOLIMAN* was constructed to facilitate visualizing the situation and intended movements.

8.7. THE RIGHTING PHASE

Parbuckling operations began on 16 January 1964. Each salvage vessel was to pull to seaward, one at the stern and the other at the bow. The 100-ton derrick and a 60-ton shore crane were to lift on the wreck's inboard side at the bow and stern respectively. Computations showed the most crucial condition in the roll would occur when the hull was 90 degrees from upright; the available rolling forces were insufficient for the task of rolling the hull through this point. However, a large amount of air was trapped inside the hull, both in the two engineering spaces and in the fore and after sections. Hopefully the additional righting moments would be provided by the trapped air. Ultimate success depended on the location of the actual pivot points. Initially the pivot point would be at the starboard side boat deck edge, 01 level. As the wreck rolled up and against the bank the pivot point would shift up toward the crest of the trench into which the wreck had worked itself. The pivot point on the hull would then shift down the side toward the turn of the bilge. It was impossible to predict this point from inspection, but it appeared the hull would pivot above the bilge keel. Should the pivot point at 90 degrees inclination be at the bilge keel, there would be insufficient moment to right the ship.

However, as the ship rolled up above 90 degrees on the flat harbor bottom, the required moment would decrease rapidly.

From 16 to 21 January the *GRASP* crew worked to ready for the righting on 26 January, the day after *BOLSTER's* arrival. The preliminaries included off-loading, rigging, testing all portable salvage equipment, establishing two diving stations with welding equipment alongside the wreck, making a detailed survey of the hull section, and removing two propellers, three shots of 1½ inch chain, the sonar dome and forward transducers. Wires to restrain the wreck from sliding and excessive rolling were also positioned. The wires for sliding were positioned at frames 30 and 140, and rigged to deadmen ashore. The anti-rolling wire preventer was rigged at frame 71 and led shoreward through fairled blocks to a four-fold beach gear purchase at a location convenient for slacking off as the wreck approached an upright position.

During the preparatory period the locations for heavy lift wires were selected and bilge keels were notched at frames 66, 71, 84 and 104 to receive the lift wires. The starboard bilge keel was underwater. Chafing gear was welded or bolted to all notches.

At this time righting chains were also rigged. The forward righting chains at frame 23 were rigged, one part for the derrick lift and one part for *BOLSTER*. The after righting chains at frame 145 were rigged with some difficulty. A wire messenger was easily passed, but enlarging the hole under the wreck for the chains presented a problem. Air lances failed, as did a straight pullout with a small tug and two pusher boats. An attempted tunneling with a Falcon nozzle also failed. The difficulty seemed to be with shackles bending and catching on the starboard deck edge, so straps and detachable links were substituted for all shackles. The tunneling operation was hampered by the fine sand on the bottom which kept falling back into the tunnel as fast as it could be washed out. Finally an air lift supplied by a 220 CFM compressor solved the problem. The combination of tunneling with the Falcon nozzle to wash out the under-hull section, and the air lift to clear away the washings, proved successful, and two chains were pulled under the ship by an LCM.

GRASP rigged and layed two sets of beach gear to seaward, using range marks set up on the pier. Divers took bottom samples at both anchor positions and found the bottom satisfactory.

Just prior to righting operations the following work was accomplished:

a. A large inclinometer was fabricated and installed on the wreck's port bilge keel to indicate the degree of movement during the operation.

b. A tide board was constructed and hourly readings were taken for seven days to compare actual and computed data.

c. One 600 CFM 36 psi blower was rigged on the wharf for air injection into the deckhouse through a hatch at frame 60 to aid the righting forces. Air blow fittings were installed in the hulk at frame 71, 72, 84, and 106 to introduce blowing air into the spaces B1, B2, B3, and B4. A salvage manifold was rigged to dock air for distribution into the four spaces and to a hatch near the foward gun mount. Air was pumped into all sections of the wreck for testing and the wreck came up about one foot, rolled five degrees to port and became very lively.

d. Half-inch wire rope messengers were rigged over the upside down wreck from deck edge to deck edge through the bilge keel notches for use in reeving the lifting wires under the wreck's hull once the wreck rolled.

8.8. FIRST PARBUCKLING ATTEMPT

BOLSTER arrived at Mariveles Harbor at 1100, 25 January, and by 1500 had layed two sets of beach gear. Final preparations were made to right the wreck the following day. All righting calculations were double checked and indicated that there should be no major problems. That evening a salvage conference was held to go over general procedure and schedules.

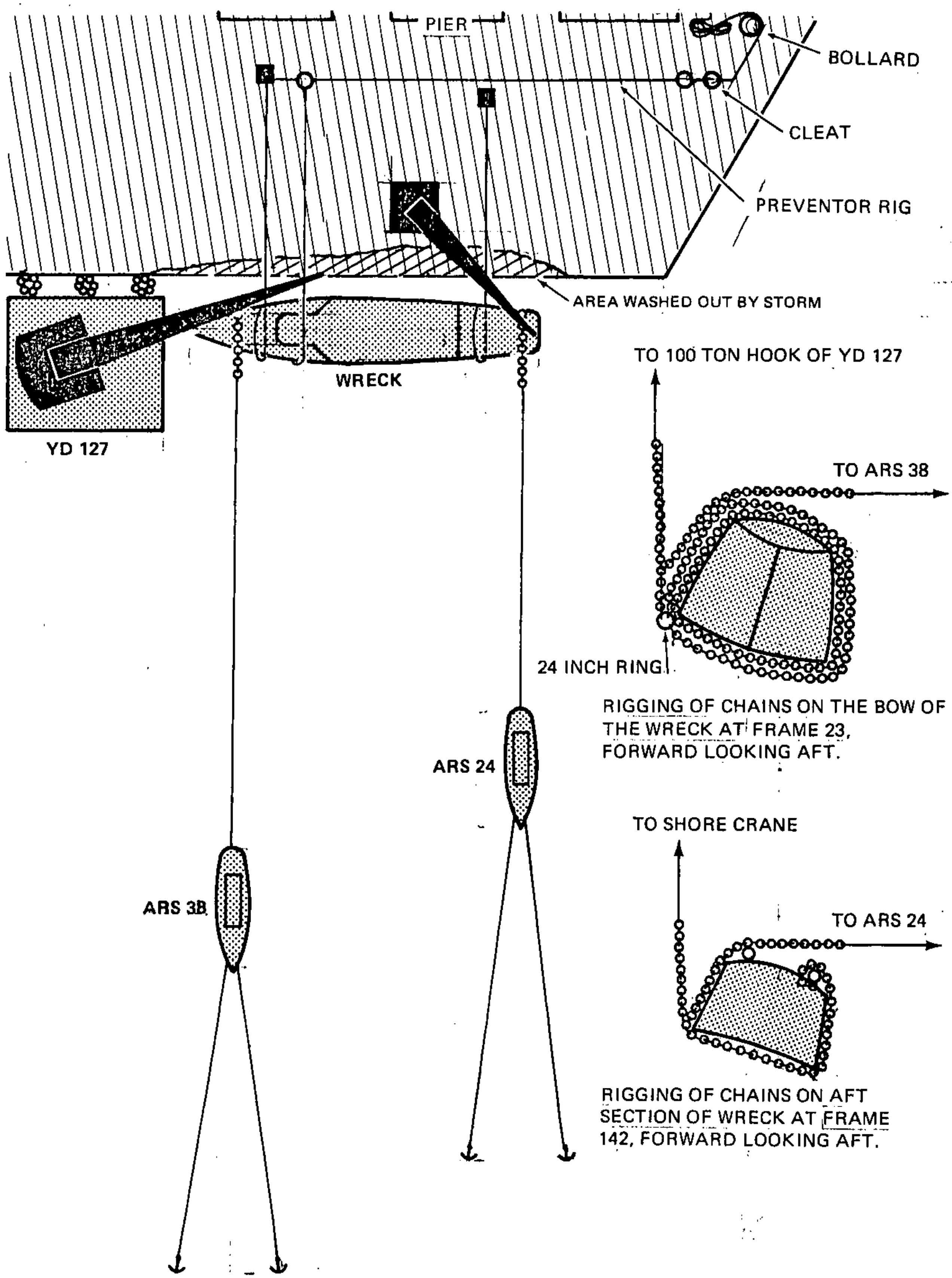
26 January at 0400, blowing of compartment B-4 commenced. At 0800 all forces were ready and positioned (Fig. 8, No. 2). All other wreck compartments commenced blowing at 0815. By 1100 the wreck had rotated five degrees and become very lively. At 1300 the first attempt at righting began. The wreck appeared to rotate slowly for the first hour, but by 1500 it was apparent the beach gear anchors of both salvage ships were not holding. The ARSs were instructed to make turns for full power with their engines and continue to haul in on the beach gear. By 1640 it was clear the first attempt had failed and the righting efforts were secured. A total rotation of 35 degrees had been achieved, but the ship had settled back to a 135 degree angle from the vertical on slacking off. The first attempt failed for two reasons: (1) the ARS anchors had not held; and (2) buoyancy inside the wreck from the air bubble was far less than expected.

While the first effort was proceeding, *USS TAKELMA* (ATF-113) arrived with the two British lift craft, LC-25 and LC-28.

NOTE:
It should be emphasized that using engines on a salvage vessel at the same time as heaving on two sets of beach gear was extremely risky because the two-inch towing hawser is not strong enough to withstand the heaving of two sets of beach gear at 50 tons each, plus the engine pull of 30 tons. In this case use of the engines was only justified because the beach gear anchors were dragging badly and the full pull of the beach gear was not realized.

8.9. SECOND PARBUCKLING ATTEMPT

Before another attempt was made an underwater inspection was conducted to ascertain the ship's new attitude with respect to the bottom. The new plan included the use of the lift craft, and provided for each salvage ship to pick up its original beach gear and re-lay two sets, with each set having two anchors in tandem. The anchors were to be either washed in or blasted in to ensure their proper setting for the second righting attempt. A review of calculations was also conducted since the wreck was now



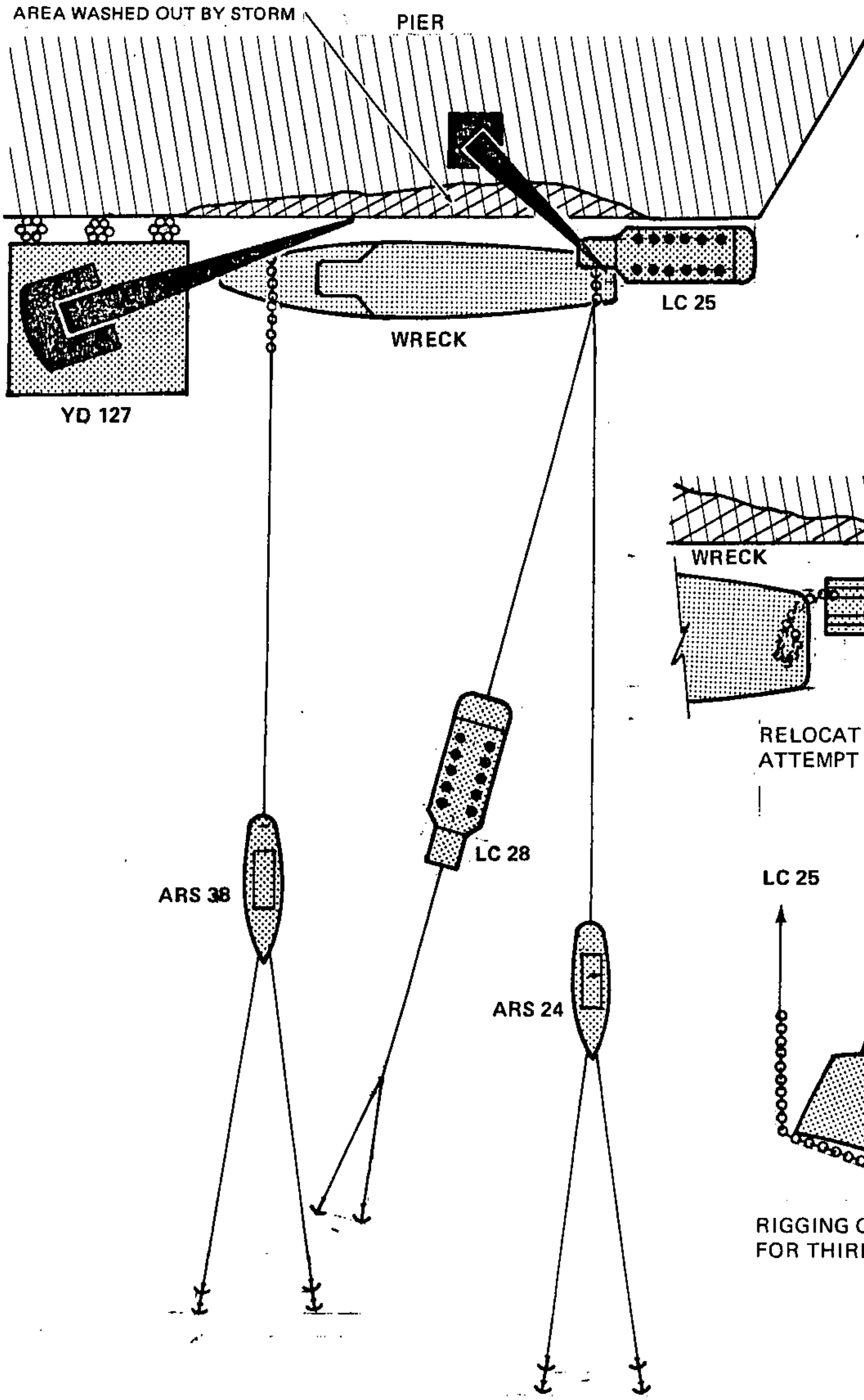
ARRANGEMENT OF FORCES FOR THE FIRST PARBUCKLING ATTEMPT.
FIG. 8 NO. 2

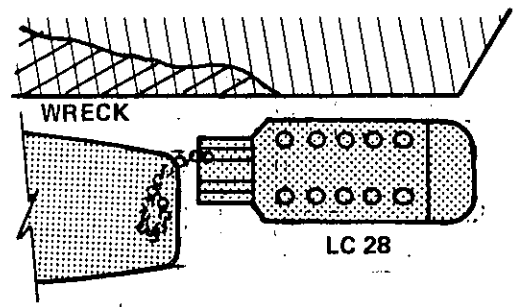
at a different attitude; the bow had been pulled seaward, and was out of the trench, and the stern was still in the original hole. The new calculations indicated the need for a rearrangement of forces as shown in Fig. 8, No. 3. With this new plan one LC would be used to lift the wreck's stern, taking the place of the 60-ton shore crane which had not been effective. The other LC was to be used as a salvage vessel, pulling on the beach gear from a position between the two ARSs. The LC was capable of a 200 ton lift or pull over the bow using two heavy deck purchases.

27 and 28 January were spent activating machinery, rigging the British lift craft for the next righting attempt, and re-laying ARS beach gear. *BOLSTER* elected to wash in her anchors and succeeded in burying them ten feet in the hard pan; *GRASP* preferred blasting holes in front of the anchors into which they would fall; the effect of blasting was not immediately known, as the anchors were out of reach of the divers. *BOLSTER* laid out a set of beach gear with two anchors for LC-28 as shown in Fig. 8, No. 3. This set consisted of 1,440 feet of six-inch circumference British wire rope, a shot of 2¼ inch chain and a heavy bull ring with two 300-foot long 1-5/8 inch wires fanning out to the two Eells anchors in parallel. During the washing in of the anchors it was noted the harbor bottom was hard pan covered with five feet of fine silt. This could have been the reason the anchors porpoised instead of digging in on the first attempt.

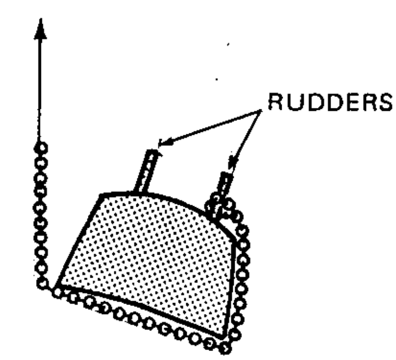
NOTE:
The method used in laying the beach gear for the LC-28 with its "parallel" anchors deserves amplification since it is unusual, perhaps even unique for the USN salvage forces. The Eells anchors were hung off on *BOLSTER's* quarter, one on each side, with the 300-foot lengths of 1-5/8 inch wire stopped off in bights over the rail. Each wire was shackled to the heavy bull ring at the stern. The 2¼ inch chain was also attached to the bull ring and led through a "U" port in the fantail bulwark where it was attached to the wire. The chain and wire were rigged for running in the normal ARS fashion with the end of the wire being appropriately stopped off with manila to insure the best possible setting of the anchors and stretching of the tackle. This arrangement proved to be much more rapid for rigging than that of using a tandem anchor rig. When letting go, one anchor dropped two or three seconds after the other because of the imprecise timing of chopping manila stoppers with axes. Use of pelican hooks with a common trip might have been a better idea. While these two anchors subsequently failed to hold under the 200 ton total pull of LC-28, this should not detract from the effectiveness of the basic arrangement since all anchors were difficult to set in the bottom of the Mariveles Harbor. The concensus among experienced salvage officers present was that relative ease of rigging the "parallel" dual anchor rig had important advantages when it was necessary to rapidly lay a two-anchor set of beach gear. The British six-inch circumference wire, 1-29/32 inches in diameter, was used because it was readily available and it would withstand the expected 100-ton pull while USN 1-5/8 inch wire would not.

A third shot of 2¼ inch chain was passed under the stern and stopped off to the port shaft. LC-25, when brought into position with port bow roller abreast the after righting chain, was connected up with two-inch wire. The bight of the two-inch wire was secured with two six-inch British Bouillivant clamps to a fairled block at the end of a six-fold moving block in the 100-ton purchase on the LC deck. The LC was initially ballasted down by the bow so as to be able to deballast and provide additional lift after the purchase had reached the limit of its winch pull.





RELOCATION OF LC 25 FOR ATTEMPT NO. 3.



RIGGING OF CHAIN ON STERN FOR THIRD MOVEMENT.

ARRANGEMENT OF FORCES FOR PARBUCKLING ATTEMPTS NUMBERS 2 & 3.
FIG. 8 NO. 3

LC-28 was moved into position bow first and a two-inch wire was shackled to the second 2¼ inch chain at the stern of the wreck. This wire was to be heaved on by the port purchase. The bitter end of the ground leg was then picked up, brought aboard over the stern, through the starboard "U" chock, and led forward where it was fairled back to the moving block of the starboard purchase. The purpose of this arrangement was to reduce the need for overhauling the heavy purchases. The intent was to heave on the starboard rig to set the anchors while holding the port set. After the anchors were set and/or the starboard rig was two-blocked, which ever came first, heaving would commence on the port rig which had less friction as it was not fairled. There was not enough time to wash in or blast in the anchors, so if the anchors held, there was sufficient fleeting distance available in one set to completely right the wreck.

The second righting attempt began on 29 January. Divers checked all anchors; they appeared to be well dug in and out of sight in the silt. Air to the wreck was cut in using a 60 psi shore air supply. At 1600 slack wire was taken in and the second effort commenced. Progress was slow and by 1730 the maximum point of roll achieved on 26 January had still to be attained. The LC-25 on the *RAJAH's* stern had not been brought into use as the wreck's edge was not clear of the bottom of the LC. At this point the decision was made to use the dock crane, which at the existing radius was estimated to be worth 30 tons of lift. All lines held what they had while divers passed a 3/4 inch four-part strap through a plate shackle at the junction of #3 part of the after righting chain, and the two inch wire to the LC-25 bow roller. The righting attempt was resumed at 1740. As the maximum point of roll which had been realized in the first effort was attained, the pendant on the 30-ton shore crane parted. Heaving without the crane continued. By 1753 the deck edge of the wreck was clear, and LC-25 commenced lifting. However, by the time LC-25 had a strain of 60 tons, the craft pulled over to plumb the load and the LC's hull was again over the deck edge of the wreck. At this point the second righting attempt was secured.

During this attempt, with her anchors slipping badly, *GRASP's* engines were used again. *BOLSTER* had developed a very heavy strain on her beach gear and her anchors appeared to hold well. The LC-25's rigging was not satisfactory and required rerigging, and the LC-28's anchors dragged and required resetting.

8.10. THIRD PARBUCKLING ATTEMPT

Preparations for the next righting attempt started that night. Divers rechecked all anchors and passed a two inch wire under the hull closer to the wreck's stern and near the port rudder stock. They also rigged a three part loop of one inch wire around the port rudder stock. This loop was shackled to the bitter end of two inch lifting wire, the other end of which was attached to the hauling purchase of the LC-25. LC-25 was ballasted down by the bow so that after developing the maximum dynamic lift with the winch and the heavy purchase, it would be possible to increase the strain by deballasting forward while holding the falls. This principle was used in all cases where the LCs were used in the bow lift. Fig. 8, No. 5, Fig. 8, No. 6, and Fig. 8, No. 7 show the LC with a heavy strain on the lift purchases; additional lift force was still available by deballasting.

By 1000 on the following day all was ready. Heaving commenced at 1045 with all forces together, and 15 minutes later the LC-25 was deballasting. At 1215 the wreck was still rotating slowly and the angle of heel was 95 degrees. The bow had been pulled out of the trench and seaward by *BOLSTER*. The anti-slide wire at the bow was taut. At 1300 the two inch bow lifting wire on the LC-25 parted where it chafed on the starboard deck edge, thereby aborting the third righting attempt. During this entire operation *GRASP* with its anchors dragging, again used full engine power in addition to the beach gear pull.

8.11. FOURTH PARBUCKLING ATTEMPT

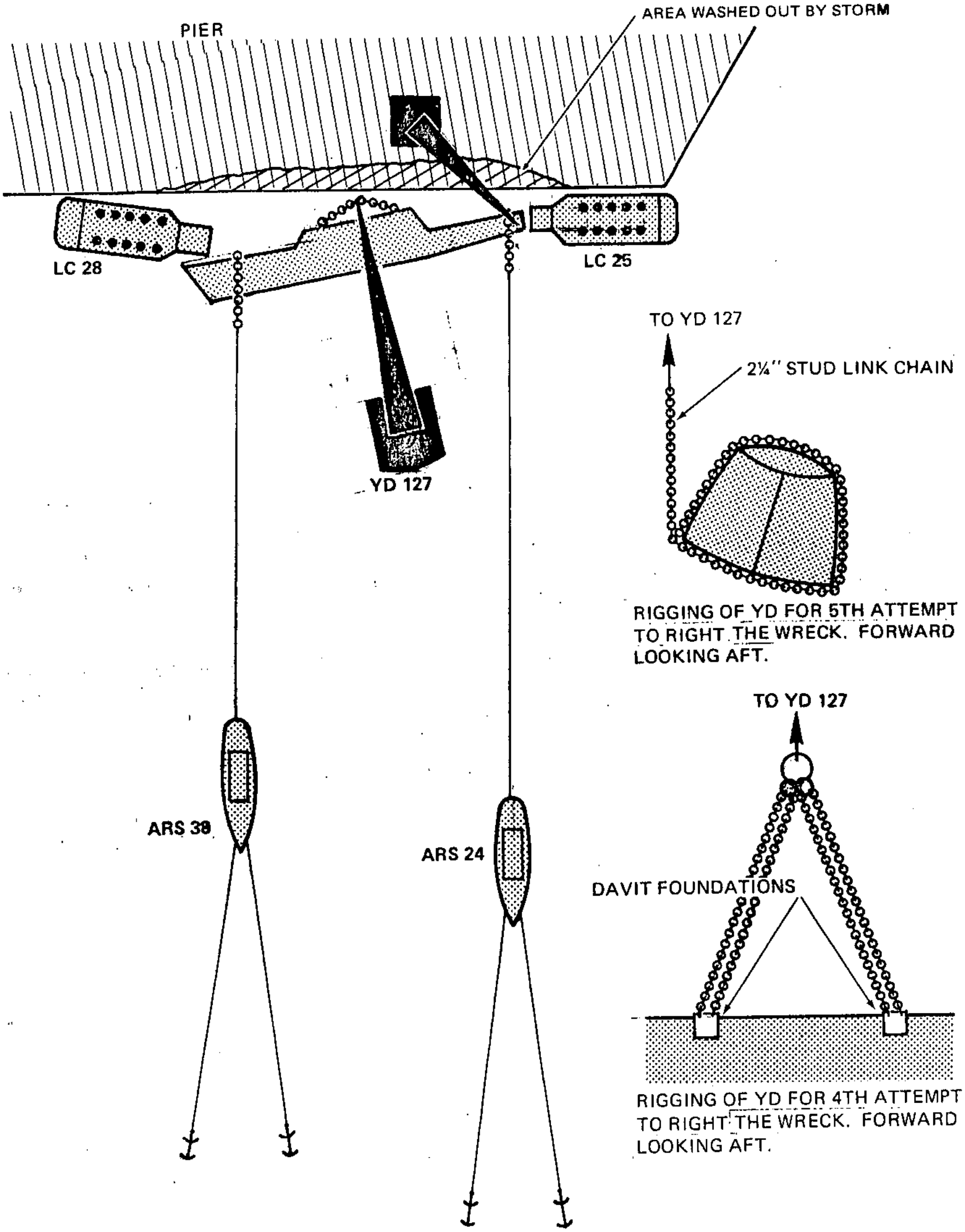
During the next salvage conference a new arrangement of forces was decided upon for the fourth attempt. This plan was directed at making full use of the positive lifting force available of the LC-28, instead of hauling against the anchors. Fig. 8, No. 8 shows the new arrangement. Underwater inspection revealed from amidships aft the wreck was resting about half way up the slope of the trench, and the bow was completely off the bottom and seaward of the trench. The YD was moored outboard of the wreck at amidships to make room for LC-28. Two doubled 2¼-inch chains were rigged around the Whelin davit base, port side of the wreck's 01 deck, for the YD's 100-ton lift, in the same manner as the LC-25 at the stern. A 2¼-inch chain was rigged through the port hawsepipe and stopped off with a three-inch diameter steel toggle bar about four feet long. From there the chain was passed around the hull to the LC to produce parbuckling action. LC-25 was rigged, passing 2¼-inch chain under the hull, stopped off at the port rudder stock.

By early evening on 31 January all was ready for the fourth righting attempt. With all forces heaving together the wreck started to roll slowly at 1945. At 2021 the strain on LC-25's lifting purchase was lost. All forces held what they had while divers inspected and engineers went to work on the generator. Inspection showed the three-inch toggle bar was bent like a hair pin and pulled through the hawsepipe. It took an hour and a half to rerun the LC-28's lifting chain through the hawsepipe, shackle it to itself, and around the hull to the LC. Heaving resumed at 2219 with both LCs pumping ballast forward. The YD's hook was loaded and stacked so as to rock the wreck. Progress was good and by 2330 the wreck was on her beam's end. With each heave by the floating crane the wreck appeared to roll an inch or two, and the ARSs held what had been gained while the derrick slacked off for the next cycle. At 2352 LC-28's 2¼-inch lifting chain parted. The tide was ebbing by this time and one of *BOLSTER's* beach gear purchases was out of commission because of a faulty block, so the salvage operations were secured. The fourth attempt to right the *RAJAH SOLIMAN* was concluded.

8.12. FIFTH PARBUCKLING ATTEMPT

On 1 February the concensus was that had LC-28's chain not parted the wreck would have rolled on the last attempt. An old crack was discovered in the link where the chain parted.

The next high tide was at 2152 so during the wait all hands turned to, to sharpen up the rigging wherever possible. Since it appeared that the YD was producing only a lifting motion and not a



ARRANGEMENT OF FORCES FOR PARBUCKLING ATTEMPTS NUMBERS 4 & 5.
FIG. 8 NO. 8

parbuckling action, the midship's chain was rerigged to one and half turns around the hull, terminating at the forward port side Whelin davit on the 01 deck. The after LC was rigged so that it would be lifting entirely with 2¼-inch chain through the port hawsepipes, stopped off on itself, and then around the hull one and a half times and finally shackled to a seven inch circumference British wire rope. Each LC was to be ballasted down forward. Then the hauling wire was pulled by winch through the six-part purchase in order to gain a strength of 70 to 80 tons. At this point the hauling wire was to be held while the forward ballast tanks were deballasted to bring the lifting forces to over 100 tons if necessary.

By 2000 all was ready and heaving commenced. Slow progress was made until 2045 when the seven inch circumference British wire rope parted at the end of the eye splice. While LC-28 was being rerigged, all others held what they had. By 2245, after 2¼-inch chain was rerigged up over the bow roller and shackled directly into the six-fold purchase on deck, LC-28 was again ready. All forces commenced heaving and the wreck again began to roll slowly. By 2300 the angle was 90 degrees and moving slowly. The floating crane was used effectively by alternating the load from 25 to 100 tons. This time the lift produced a parbuckling action. At 2400 the angle of heel was 87 degrees.

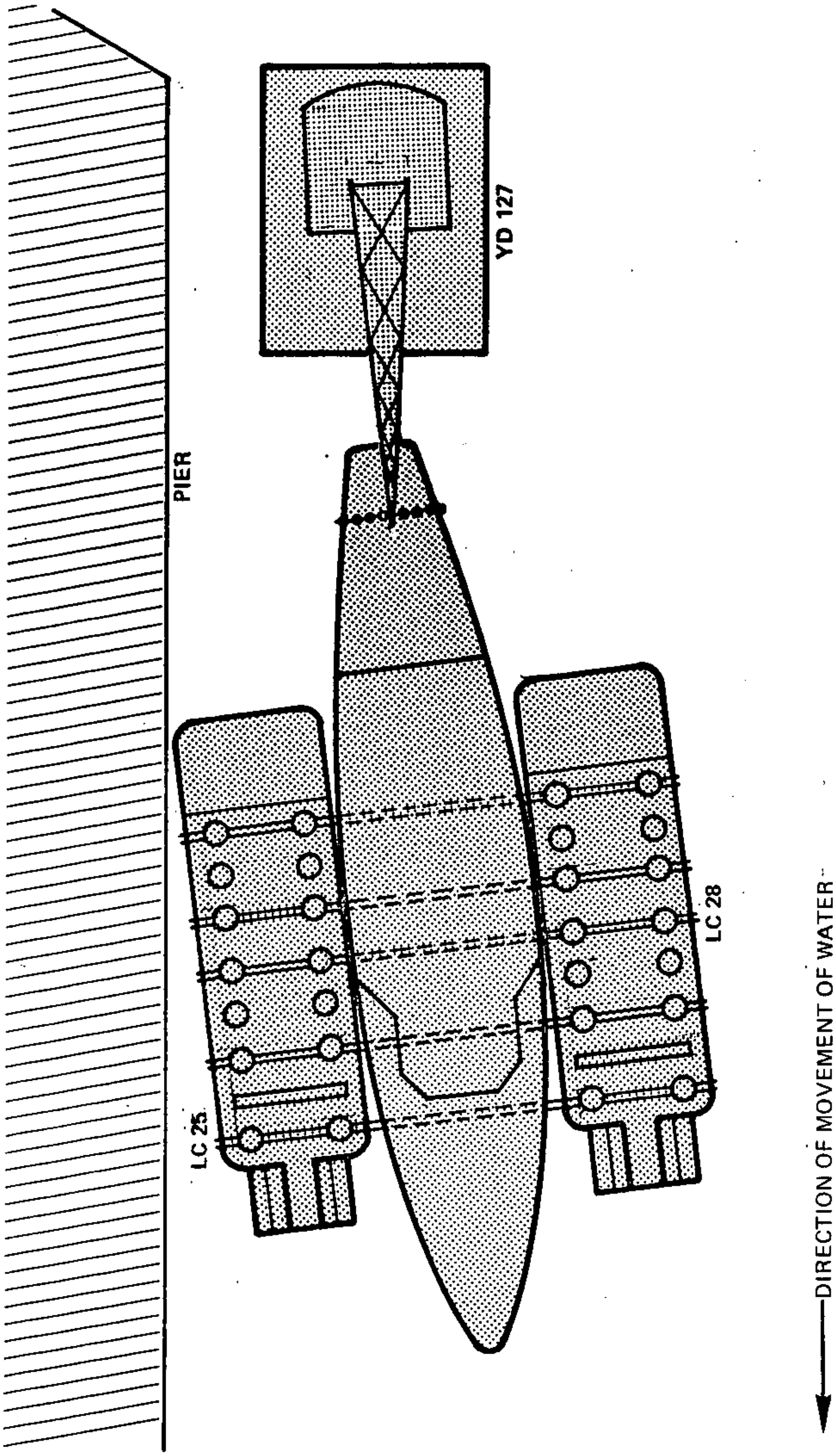
By 0105 on 2 February, *RAJAH's* port bilge keel disappeared under water and the starboard side rolled up very slowly. At 0110 the centerline of the 01 deck cleared water. At 0115 the wreck's angle of heel was 50 degrees and large quantities of oil and water gushed from the ship, as trapped air was released. At 0130 the wreck came upright with a three degree list to starboard. Hauling was then secured and the ARSs held what they had until morning, at which time a holding anchor was laid out from the wreck's port bow with a 1-5/8 inch wire rope heaved taut aboard the wreck. This anchor acted as a seaward preventer to keep the wreck from rolling back into its original position. The ARSs then slipped their beach gear and moored alongside the pier.

8.13. THE LIFTING PHASE

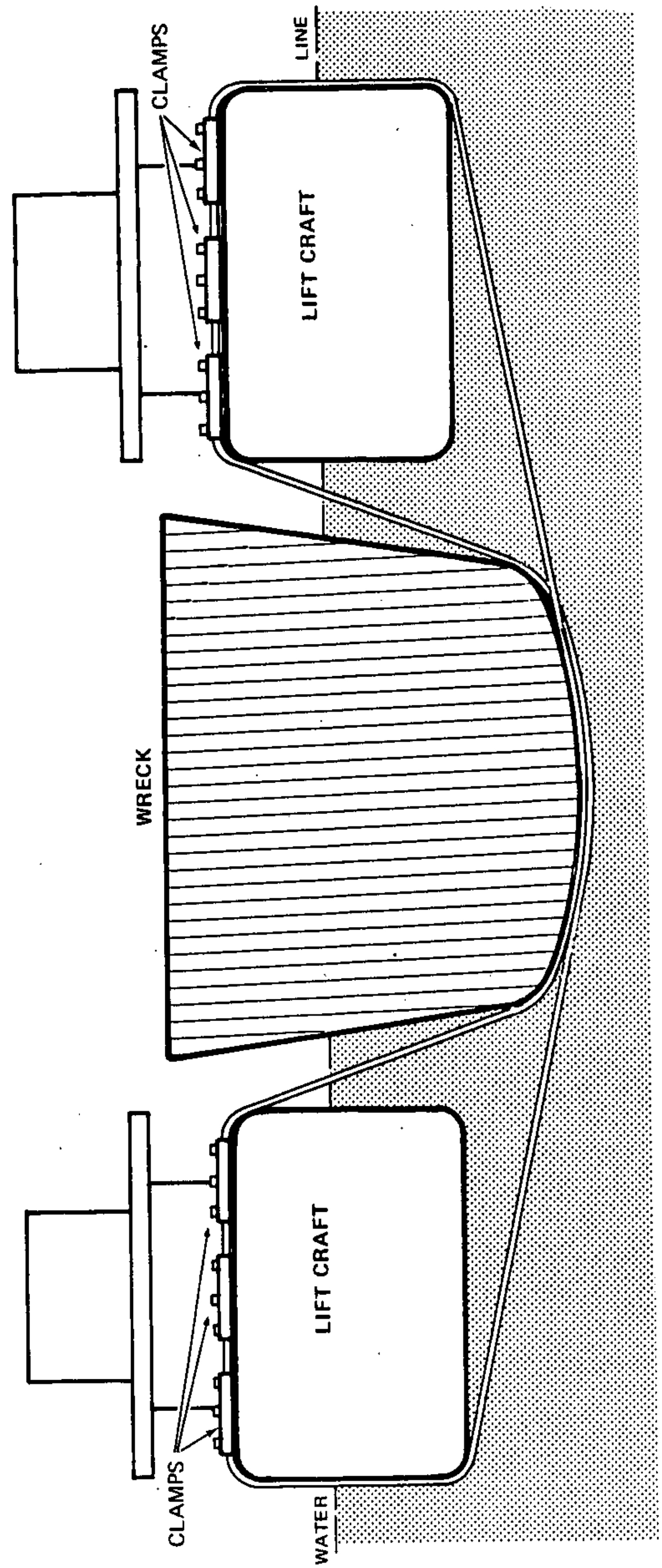
The lifting phase followed these basic steps (see Fig. 8, No. 11 and Fig. 8, No. 12):

a. Ballast down the lift craft;
b. Pass the heavy lift wires under the hull;
c. At low tide, pull nine inch diameter wires taut with messengers fairled to winches and capstans, and then pin down by tightening up on the Bouillivant clamps;
d. Take shore wire taut to winch;
e. Pump out ballast water;
f. Move the wreck toward shallower water while deballasting and/or tide rises.

The amount of lift available depended on the amount of ballast pumped off, the dead weight to be lifted, and the tons per inch immersion of the lift craft. The success of the operation depended on getting all possible slack out of the lift wires during the pinning operation, the amount of tidal rise, and the depth of the hole into which the hulk had settled.



ARRANGEMENT OF FORCES FOR LIFTING THE WRECK.
FIG. 8 NO. 11



LIFT CRAFT AND WRECK CROSS SECTION SHOWING ARRANGEMENT OF LIFT WIRES.
FIG. 8 NO. 12

SAILOR TIGHTENING A BOUILLIVANT CLAMP
DURING A PIN ON BOARD LIFT CRAFT.
FIG. 8 NO. 13

Although the wreck's forecastle was out of the water to the main deck house, there were about six feet of water over the main deck at midlength, and eight feet at the stern. Raising the ship in this position by dewatering alone was possible, but was ruled out because of the difficult stability problem. The availability of lift craft simplified this problem; the plan was to lift the ship and move it to shallower water with the lift craft so that pumping at low tide could be attempted.

Prior to righting *RAJAH SOLIMAN*, the location of her longitudinal center of gravity, LCG, had been computed, taking into account the structures and outfit known to be missing – mount 51, the stack, masts and boats. It was necessary to know the LCG in order to select the lifting stations and to notch the bilge keel to pass messengers prior to righting. Upon righting, it was found the entire 01 and 02 level deck houses were missing. This resulted in the LCG being well aft of the estimated location. Since the position of the lift craft was already fixed by the bilge keel notches and messenger wires, this could not be altered. The bilge keel should have been completely cut off as it proved to be a source of trouble through the entire operation. It was necessary to use the YD at the stern as a trimming craft to load the lift craft more evenly and to ensure that the ship's stern lifted off the bottom rather than act as an anchor during the lifting and moving.

RAJAH SOLIMAN was estimated at a dead weight of 1200 tons. Each lift craft was rated at 750 tons lift capacity and therefore it was theoretically possible for the lift craft to lift the wreck approximately 18 inches off the bottom without tidal assist. The lift required that there be no slack or stretch in the wires. Thus, with a three foot tidal assist, it would be possible to lift the ship 4.5 feet. An eight to ten foot total lift was desired to move the wreck to a position where the main deck would be above water for most tides. Soundings were made and it was decided to move the wreck down the sea wall about 400 feet where water depth was suitable for the pumping operation. Two or three lifts would be required.

On 2 February rigging was begun for the lift phase. Draft gauges were installed on the wreck fore and aft and a large inclinometer was installed on the boat deck. The lift craft were moved into position, one inboard and one outboard of *RAJAH SOLIMAN*. Anchors were set out from the outboard lift craft's bow and quarter. These anchors simplified the passing of the lift wires by enabling the lift craft to breast out. They also assisted in controlling the movement of the whole nest of ships. A chain sling was passed under the wreck's hull to the stern, just forward of the rudder posts, for use by the YD in trimming the wreck.

The next step was to pass lift wires under the wreck's hull. Five pairs of nine inch circumference wire ropes were rigged. An attempt was made to pull one inch diameter wire messengers under the hull at frames 66, 71, 84, and 116, using smaller messengers which had been rigged before righting the wreck. All but one messenger stuck in the mud while trying to pull them through. In order to solve the problem a Falcon nozzle secured to the end of the one inch wire was used to wash it through. By 1820 on 4 February all lift wires had been passed and were rigged for the first pinning operation. Meanwhile, gas safety checks had been conducted on the compartments and vents of the ship's superstructure through openings in the 01 deck with an explosivemeter and a hydrogen sulfide indicator. The results were negative. Frame numbers had also been marked, with white paint, on the forecastle and on the entire 01 deck.

Anticipating the eventual installation of dewatering pumps, holes were cut in decks and the below deck bulkhead hatches were secured. A six inch electrical submersible pump was installed at frame 33 and a six inch gasoline pump was placed at frame 7. *BOLSTER's* Power Pack generator was placed on the 01 deck forward to provide power and lights. The pumps were to be used for trimming and lightening the bow. With the YD at the stern it was possible to control fore and aft trim while lifting. Divers patched and plugged holes in the starboard side that would have interferred with pumping.

8.14. THE FIRST LIFT

At daybreak on 5 February both lift craft were flooded down and the YD was moved to a position astern of the wreck. Low tide was at 0800. Pinning down was to begin at 0700, but the LC-28 fuel pump failed and needed repair. By 1100 all systems were again ready and pinning down for the first lift began. By 1430 both lift craft were pinned down and the deballasting began at 1445. Three nine-inch Bouillivant clamps amidships on the lift craft main deck were used to marry the bitter ends of each wire pair on the lift craft. This made a total of 30 nine-inch clamps. Small stuff was laid in the clamps to protect the wire, reduce the possibility of slippage, and absorb the grease squeezed from the wire during the lift. Air impact wrenches were used to tighten down the clamp bolts while the steam winch held the wire taut. At 2400 the high tide had passed and no useful lift was accomplished. All lifting wires had stretched approximately four feet, which was more than expected, though some stretch on the first lift with new wires had been anticipated. Since the spring tides were passing, the following day would be the last three foot tide until 11 February.

NOTE:
As stated, considerable "stretch" of the nine inch circumference wires was expected on the first lift. In addition, much teamwork and practice was required to accomplish a rapid "pin" (securing the lift craft to the vessel being salved) which an experienced crew can accomplish at a rate of 45 minutes for five pairs of wires. For these reasons complete success was not expected during the first "pin" even though the tide was essentially diurnal (one high tide and one low tide per day). This long tidal period did much toward reducing the pressure of getting a rapid "pin" and there was a good possibility of making progress. There was also every intention of utilizing any headway which might be made. As it turned out, the combination of engineering failures in the lift craft, wire "stretch", and green hands was too much and no progress was made. However, it was estimated that the lift craft had taken most of the wreck's weight.

8.15. THE SECOND LIFT

An 8 foot by 8 foot access hole was cut in the 01 deck and a cofferdam consisting of two 55 gallon drums welded end to end was attached over the escape hatch leading from the ship's after fireroom, B-3. A ten inch pump was installed with its suction passing through the cofferdam in order to lighten the wreck and assist the lift craft. Divers continued to patch holes having to contend with large amounts of mud, debris and free oil.

Pin down for the second lift was at 1200, 6 February. The tides on 5 and 6 February were not strictly diurnal as can be seen from the example of tides on 5 February:

Time	0732	1356	1633	0009	(6 February)
Ht	-0.5	0.9	0.7	3.0	

By pinning down during the 0732 low tide, and "riding out" the 1356 and 1633 high and low tides, an effective tide range of 3.5 feet was available. From 7 through 10 February tides were insufficient, even using the above procedure.

The second lift was successful and by 0100 on the 7th, the wreck had been moved 46 feet down the wharf toward shallower water. A net lift of only one foot was achieved.

8.16. PREPARATIONS FOR PUMPING

The next workable tide would not occur until 11 February at 1500. The following four days were spent welding and installing cofferdams, installing and testing pumps, and patching all holes in the wreck. Calculations were again made concerning the stability of the wreck during the dewatering phase. With the engineering spaces and the three compartments on the first platform after the engineering spaces dewatered, and allowing for expected free surface, there would be a negative GM of about 10 feet.

A diver recovered the ship's damage control diagrams using information volunteered by a former member of the crew. The DC diagrams had been sealed in plastic and after 7½ months underwater had sustained no damage. They proved very useful throughout the rest of the operation. With the aid of the diagrams it was determined that *if* the wreck was held upright by the YD and the two lift craft, and *if* spaces were pumped selectively to reduce the free surface, and *if* a list of no greater than five degrees was permitted, there should be no problems.

In the time remaining before the next workable tide the following was accomplished:

- 2 by 2 foot access holes in the 01 deck were cut at frame 98, eight feet starboard of centerline for access to the escape hatch from B-4, and an oil drum cofferdam and ten inch pump were installed;
- A cofferdam of three 55 gallon drums welded end to end was installed on the hatch cover of the after cargo hold;
- Sheet metal was fastened with a stud gun around the area of the main deck that had been damaged by the righting chain, frame 165 at the starboard deck edge;
- The damaged area was filled with concrete;

- A 2 by 2 foot access was cut in the 01 deck at frame 92, starboard deck edge, for the purpose of blanking off vent pipes down to the B-3 section;
- The vent pipe was blanked off with a flat plywood patch and weights;
- Three six-inch electric submersible pumps and three six-inch gasoline pumps were installed forward on the wreck;
- An oil drum cofferdam was installed to the B-2 section for a Power-Pack ten-inch pump, and another cofferdam to B-1 for a six-inch submersible pump.

By evening 10 February all was ready to dewater B-2, B-3 and B-4 sections of the ship with ten-inch pumps, and most of the remainder of the ship with six-inch electric and gasoline pumps. (See Fig. 8, No. 14 for a drawing of the pumping arrangements.)

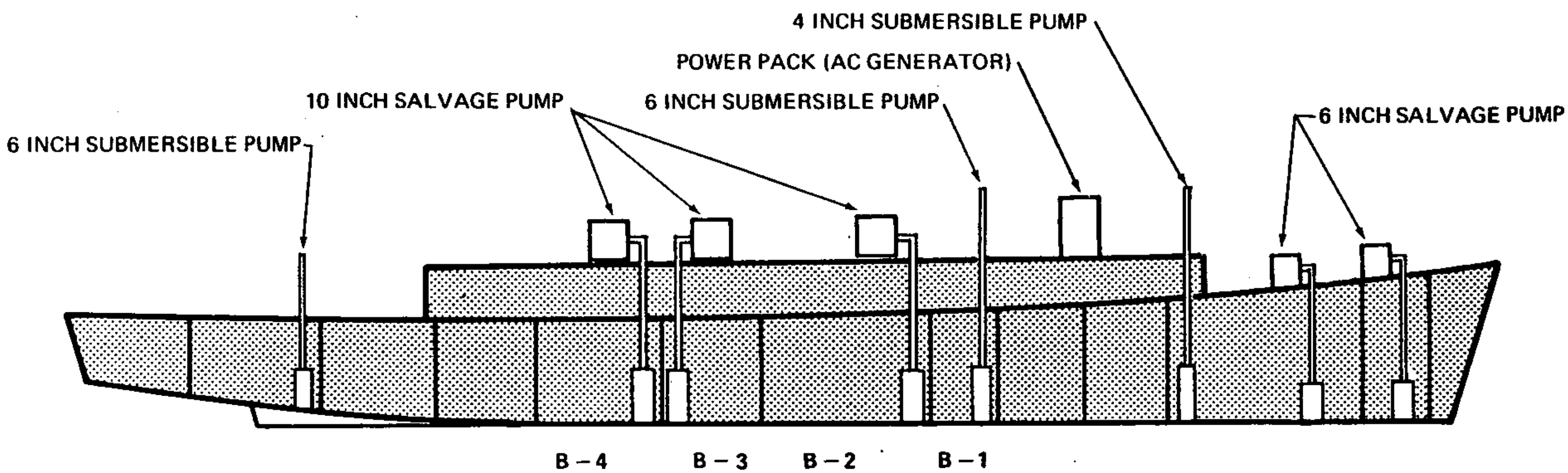
8.17. THE THIRD LIFT

Pin down for the third lift was attempted at 0100 low tide, but because of an engineering problem no steam was available until 0500. Pinning down then commenced and was completed by 0640. Deballasting began at 0700 and selective dewatering at 0915, with the YD lift at the stern. At 1103 the wreck was clear of the bottom and was slowly moved forward by wires from a winch to shore bollards. At 1300 the wreck was again beached after moving 310 feet along the wharf. The draft had decreased four feet forward and five feet aft, and the main deck was nearly awash. After this lift the port main deck edge was above the waterline aft. The remainder of the day was spent washing out sand and mud from the main deck compartments. An estimated 100 tons of mud and sand were removed at this time.

By the end of the day the wreck had a list to starboard of about 10 degrees. For the next lift the plan was to deballast the inboard lift craft first to remove the list, and then pump out the wreck while keeping the lift craft snug against her to prevent any tendency to list. With adequate breast line to hold them together the lift craft would act as pontoons to give additional stability to the wreck.

8.18. THE PUMPING PHASE

As explained before, the lift was to be reduced by selectively deballasting the lift craft and dewatering the wreck using the lift craft as pontoons. It could be accomplished prior to having the main deck above water because the pumps had been installed through cofferdams. It was possible to pump the entire first platform, much of the second platform and after hold, as well as all the engineering spaces. By pumping all possible forward and after spaces and minimizing free surface prior to pumping the engineering spaces, it was computed that the wreck would have a very slight positive GM. This was possible even with a maximum free surface in the engineering spaces. Matters were complicated because of the large amount of sand and mud, and because everything which had originally been loose



TYPES OF PUMPS USED AND THEIR LOCATION ON BOARD THE WRECK.
FIG. 8 NO. 14

SAILOR USING A FIRE HOSE FOR WASHING DOWN MUD IN THE WRECK.
FIG. 8 NO. 15

in the ship had shifted to the starboard side. Efforts were made to remove mud, sand and loose debris from the main deck house. Another 100 tons of sand, mostly from the starboard side, were removed. *GRASP* was moored alongside the outboard lift craft to supply power, fire protection, and the large amounts of water needed to wash mud and sand from the wreck.

8.19. FOURTH LIFT AND DEWATERING

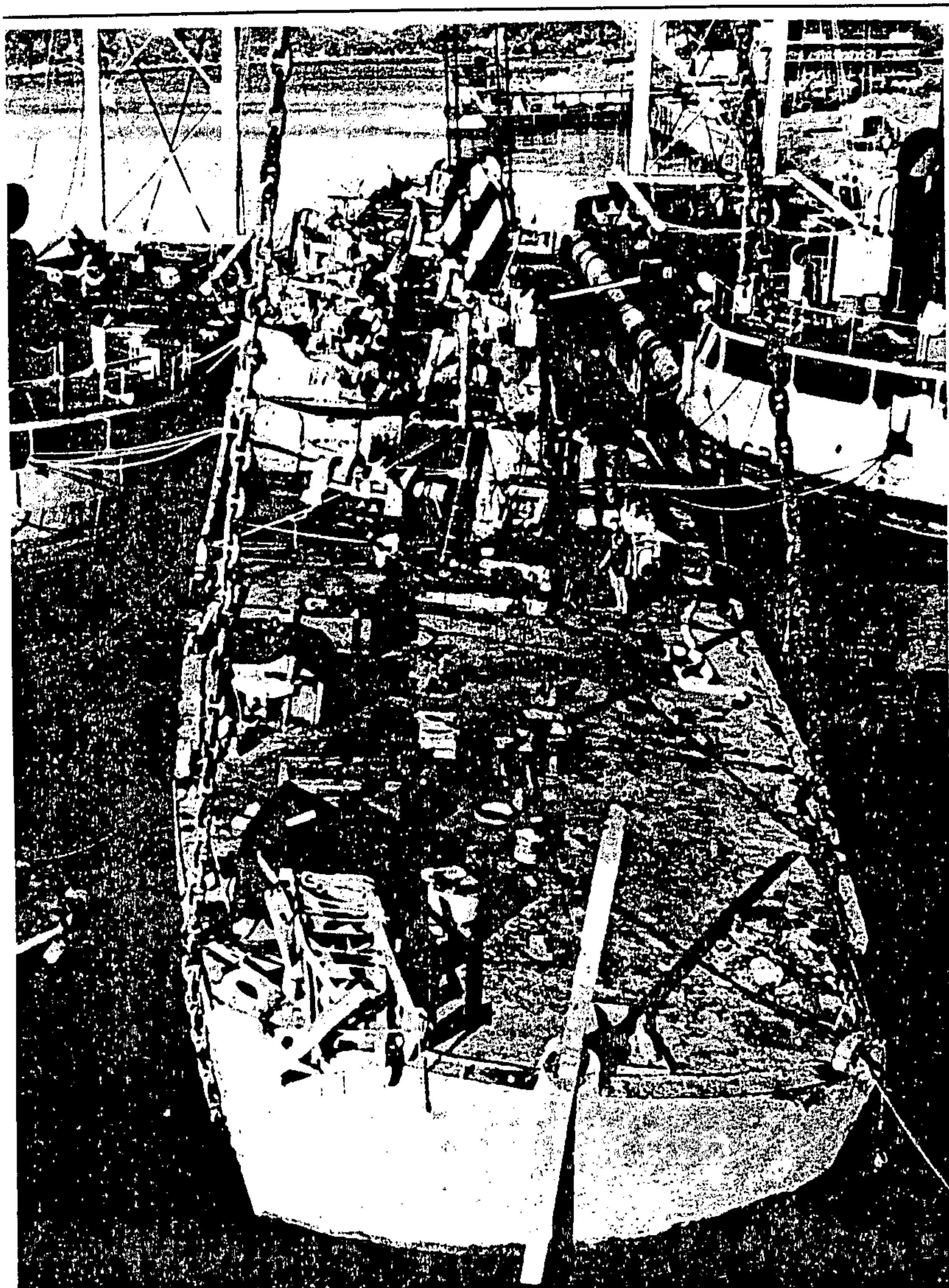
The lift craft were deballasted and pinned down on 12 February. The list on the wreck was reduced to three degrees by partially deballasting the lift craft on the low side. Pumping and stripping went on until about 2200 when the six-inch pump in C-201 broke down. There was no replacement pump available for this last compartment, so the pumps in the engineering spaces were started for the main pumping effort. Several times, while pumping the engineering spaces, the wreck rolled to starboard in the cradle formed by the lift wires. By 2300 the wreck had listed 9.6 degrees to starboard and was very lively, indicating that she was off the bottom. About 2400 the wreck rolled again, listing about 12 degrees, but by this time she had floated free of the lift craft.

The early hours of 13 February were spent consolidating gains made during the night. The work of stripping water from the wreck went on well and by 1000 the next day the list had been reduced somewhat. At 1100 it was decided to move the wreck, derrick, lift craft, and *GRASP* as a nest, back down to the end of the pier to get her under the shore crane in deeper water. The move was completed at 1130. During the afternoon, shipyard laborers removed loose gear from the ship, while the salvage gangs put six-inch submersible pumps in each of the four main engineering spaces. These pumps could be easily started and stopped, and worked well for stripping water on the low side of the spaces.

By 14 February all the six-inch submersible pumps had been rigged and the water stripped from the engineering spaces. Pumping and removal of mud and loose gear reduced the list of the wreck to nine degrees. A ten-inch pump was then set up to pump the mud out of C-202L. This pump ran until its suction was hampered by loose gear in the wreck. It was then decided to secure the pumping effort and shovel out as much debris as possible from this and the other first platform compartments. By 15 February the salvage work was essentially complete.

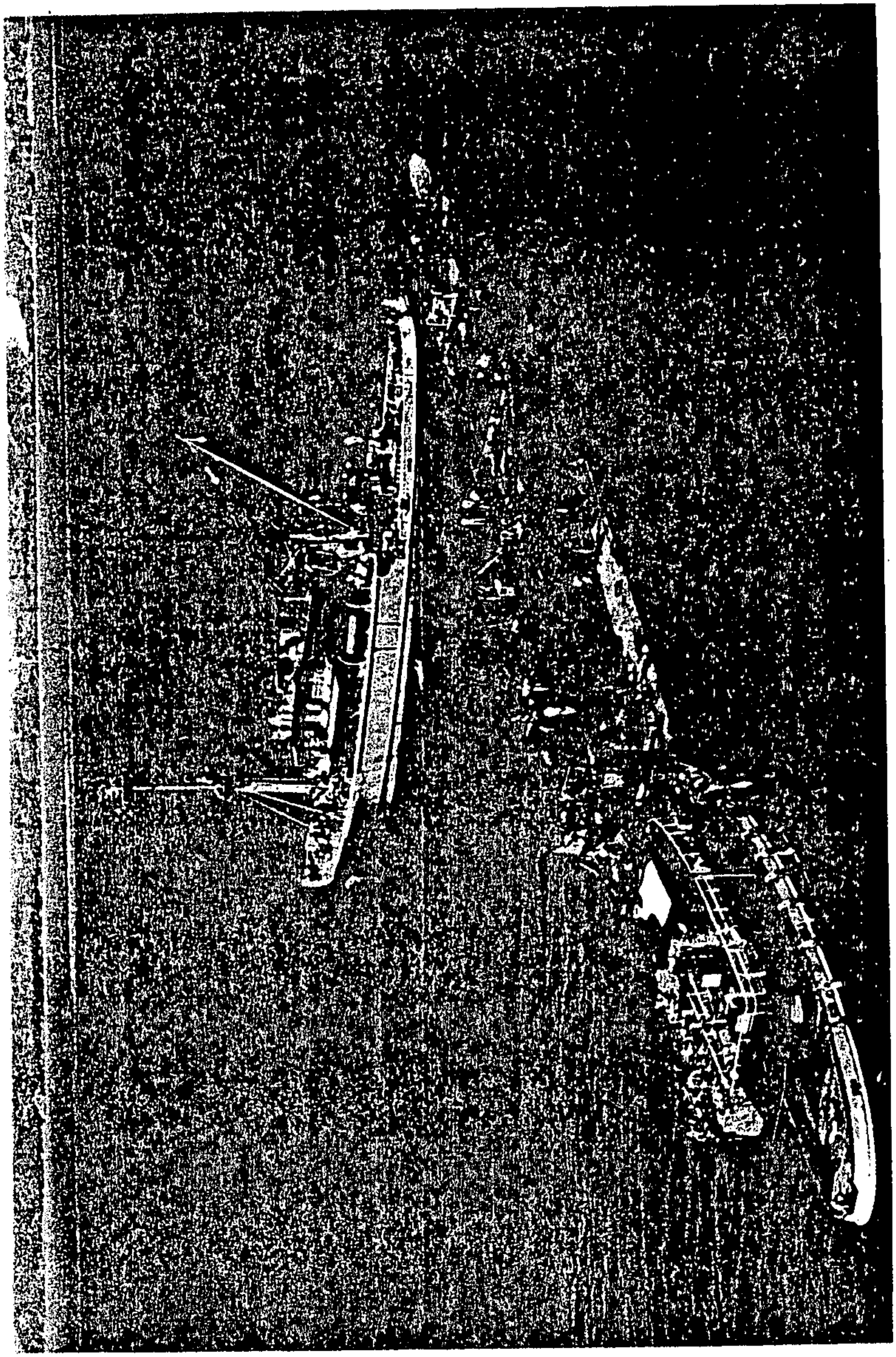
On 15 February the *RAJAH SOLIMAN* was prepared for tow to Subic Bay. The wreck was removed from between the lift craft and moored alongside the pier to facilitate patching and the removal of water soaked ammunition. Work details from the salvage ships spent the day mucking out the first platform. This increased the stability a great deal. The wreck was sallied and a seven second period of roll was recorded. The metacentric height (GM) was 5.1 feet; this large GM was attributable to the large amounts of mud still in the lowest parts of the engineering spaces and the absence of almost all topside structures. The large amount of mud and sand also accounted for the greater than expected difficulty of righting the wreck.

During righting operations the chains used on the wreck had cut many holes in the deck edges and several additional holes had been cut in the forecastle to allow pump suctions to be lowered into the wreck. Before towing, all these holes were closed.



THE WRECK BUOYED UP BY TWO LIFT CRAFT ALONGSIDE AND THE FLOATING CRANE HOLDING THE STERN FOR ADDED STABILITY.
FIG. 8 NO. 16

FLOATING CRANE YD-120 WITH LIFTING CHAIN IN POSITION UNDER THE STERN.
FIG. 8 NO. 17



YARD TUG TAKING THE "RAJAH SOLIMAN" FROM "USS BOLSTER" (ARS 38) ON ARRIVAL IN SUBIC BAY.
FIG. 8 NO. 18

By the evening of 16 February all 40 mm ammunition was off the wreck and off-loading of five inch ammunition commenced. The list was reduced from 9.5 to 5 degrees by pumping out starboard tanks, possible only because of the high GM.

In preparing the ship for tow, good use was made of "Waterplug" concrete to reduce the leakage. Each leak was stopped either by using concrete, wooden bolted patches, or plates and gaskets attached by stud drivers. In no instance were only wedges or wooden plugs relied upon.

The following portable machinery was taken aboard the wreck for the tow to Subic Bay:

220 volt AC Power-Pack generator
220 CFM Power-Pack compressor
Two 6-inch submersible electric salvage pumps
Four 3-inch salvage pumps
Two 2½-inch AC electric damage control submersible pumps
Several 1½-inch pneumatic submersible pumps.

Original plans called for the use of one six-inch submersible pump in each engineering space, however, failure of two of them precluded this plan. A 2½-inch electric submersible damage control pump was put into B-3 while another 2½-inch pump was placed in B-4. The wreck was taken in tow by *BOLSTER* at 0730, 18 February and delivered to Subic Bay at about 1300. *RAJAH SOLIMAN* was immediately drydocked. The remaining list was removed by the use of cement blocks on the main deck.

9. USNS CARD

9.1. BRIEF

USNS CARD, while moored in Saigon, Viet Nam on 1 May 1964, was sabotaged by two explosives set against her hull. Serious damage to the hull structure near the engineroom caused her to flood. The resulting successful salvage operation is believed to be the largest patching and pumping operation by the U.S. Navy since World War II. It is significant that the ship was dewatered nine days after the casualty, and only six days after the arrival of the first salvage ship.

9.2. DESCRIPTION OF THE SHIP

The *USNS CARD* (T-AKV 40; ex-CVE 11) was an escort carrier converted from a C3-S-A1 merchant hull. The ship's principal dimensions were:

Length	495 feet 11 inches
Breadth (Max.)	100 feet 7½ inches
Draft (full load)	24 feet 6 inches
Displacement (full load)	14,760 tons

9.3. HOW THE SHIP SANK

On 1 May 1964, *USNS CARD* arrived in Saigon, Viet Nam with a load of helicopters and supplies, and berthed starboard side to the wharf at berth K-13 in the commercial port district of Kanh Hoi, Saigon. Early on 2 May, all cargo had been off-loaded and 13 helicopters were loaded on the hangar deck for return to the United States. At 0500 one or more explosions were set off against the starboard side just aft of the quarterdeck; the ship immediately began to take water and all power was lost.

9.4. PACIFIC FLEET ASSISTANCE

Support arrived on 3 May when COMNAVPHIL Salvage Officer, Lt. W. H. Smith and four divers arrived in Saigon. On 4 May CFT 73s Salvage Officer LCDR J. H. Boyd arrived and was designated Salvage Officer-in-Charge.

USS RECLAIMER (ARS 42) enroute to Subic Bay, arrived on 5 May and moored starboard side to *CARD;* followed by *USS TAWAKONI* (AFT 114), arriving on 6 May, and mooring outboard of *RECLAIMER.* On 9 May RADM R. Kefaver, USN, CFT 73, arrived and personally took charge of the overall operation and preparation for safe removal of *CARD* from Viet Nam.

9.5. CONDITION OF THE WRECK

Immediate damage control efforts were hampered by the lack of power and lights. The first evident sign of damage was flooding. The emergency diesel generator room, located at frames 87-102 port, flooded shortly after the explosion and water rose rapidly to the waterline. The engineroom, frames 102-122, flooded slowly. The remote-operated watertight sliding door in the after bulkhead of the engineroom was inadvertently opened, permitting the shaft alley to flood. The door could not be completely reclosed and flooding continued to the waterline. The source of this flooding was not discovered until later. The after magazines on the second platform, frames 122-136, flooded as water came through the access from the escape trunk at the after end of the shaft alley. Secondary flooding attributable to plumbing, deck drains and leaky wireways occurred in many compartments aft of the engineroom. By midmorning *CARD'S* drafts had steadied at approximately 27 feet forward, and 41 feet aft. She was erroneously reported to be resting on the bottom at this time.

9.6. STABILITY CALCULATIONS

Preliminary stability condition reports revealed *CARD* had a zero GM, and she was unstable. Consequently an order was issued prohibiting all pumping other than was necessary to control progressive flooding, until an accurate report of stability was determined. The stability report was immediately undertaken and initial findings confirmed that in its present condition *CARD* was stable. The majority of the floodwater acted as extra weight, lowering the center of gravity of the ship, improving the initial stability. Compartments at frames 87-136 were flooded to the waterline. Floodwater from frames 95 to 136 was pressed up to the second deck. An exception was in the machinery trunk, frames 111-122, but because of its relatively small width its actual effect on stability was negligible. Some unsymmetrical flooding undoubtedly existed, yet there was only a 1-1/2 degree starboard list.

As the water was pumped out of *CARD* the added low weight would be removed thereby reducing the stability. There remained a need for a calculation of the free surface effect. No Inclining Experiment data was available for *CARD* at the time, but her "Trim and Stability Booklet" was located. It provided information on VCG, capacities of all tanks, and the KG of light ship based on a 1958 Inclining Experiment.

All tanks could probably be either filled to capacity or completely emptied. When the weight and VCG of the floodwater of the various compartments was estimated, it was found that the initial GM was 8.7 feet even with a maximum free surface correction of 4.2 feet in the main flooded area, and another 0.8 feet in minor flooded areas. This gave a virtual GM of 3.7 feet shortly after the pumping was started. The proposed loading of tanks showed the existence of a 7.1 GM with all floodwater pumped out. From these figures it was determined the ship would still have a GM of 2.1 feet with a minimum added weight of floodwater and a maximum free surface. The after peak tank was emptied and the remaining tanks were filled to reduce *CARD'S* trim.

9.7. IMMEDIATE DAMAGE CONTROL MEASURES

Damage control assistance was received from U.S. Military Headquarters Support Activity, Saigon (HSAS), MAAG personnel, the Saigon Fire Department, and the Viet Namese Navy. There was no firemain pressure and the portable gasoline driven pumping equipment from *CARD* could not be located, so the Viet Namese Navy *LST DA MANG* was called to assist *CARD* with power, equipment and personnel. The LST provided 2½ inch electric submersible pumps, P-250 pumps and water pressure for eductors. A diesel electric locomotive was obtained to provide additional DC power for the operation of the submersible pumps. By using this power source, the after elevator which had been stuck in the mid-position was again made operable.

Flooding through bulkhead 87 was stopped by plugging leaky stuffing tubes. The second deck non-watertight hatches at frames 89 and 130, and the door from the shaft alley into the steering machinery room were shored. Aft of frame 136 some progressive floodwater was pumped out, and further major flooding was arrested by plugging the stuffing tubes and deck drains.

9.8. EARLY SALVAGE OPERATIONS

The initial hull damage inspection was extremely difficult. Damage inspection from the inside of the hull was impossible because access to the damaged area was obstructed by dislodged stowage bins and shelves. External inspection was hampered because diving conditions were very poor. The water was polluted and maximum visibility below the surface was only four feet. A continuous three to four knot current in the area that only slackened for a short period twice a day, impeded diving operations.

The first divers, from the Viet Namese Navy, reported that a three foot wide rupture extended some 30 feet along the hull. The Viet Namese Shipyard at Saigon made preparations to fabricate a cofferdam to these dimensions. Upon arrival of five Navy divers on 3 May, it was redetermined that the actual ruptured area extended for only about 12 feet with a maximum opening of three feet. The area surrounding the rupture was badly deformed and it appeared that the lips of the rupture extended outward in some places. The dimensions of the cofferdam were modified to 18 feet long, 6 feet wide and approximately 30 inches deep, to allow for the projecting portions of the shell. The Viet Namese Navy Shipyard proceeded to fabricate the cofferdam to these new dimensions.

Since no ruptures could be found in the hull area of the engineroom, it was assumed this space had flooded from damage to its forward bulkhead at frame 102; this coincided with the after extremity of the known shell rupture area. Patching this rupture should have facilitated the dewatering of the entire ship.

The cofferdam was completed and installed on 4 May. At this point a large dish in the shell extending several feet below the cofferdam was found. It was determined that the depth of the cofferdam should be increased to 12 feet. The cofferdam was removed to the Viet Namese Shipyard for necessary modifications. In order to facilitate the speedy completion of the rest of the salvage operation, equipment and auxiliary piping, hose, fittings, and spare parts were airlifted from the Emergency Ship

Salvage Material Pool (ESSM) and the COMSERVPAC Ship Salvage Material Base at Subic Bay. The equipment included:

4 each 10-inch gasoline driven salvage pumps
4 each 6-inch gasoline driven salvage pumps
2 each 6-inch electric submersible salvage pumps
4 each 3-inch gasoline driven salvage pumps
1 each high pressure compressor for charging SCUBA

The last of this equipment was received 6 May.

9.9. THE PUMPING PLAN AND PRELIMINARY PUMPING EFFORTS

The cofferdam was expected to close the only known leak in the hull, and a maximum free surface could be expected. The pumping plan was simply to dewater the ship as quickly as possible.

ENGINEROOM

Two ten-inch pumps were lowered to the second deck at frame 90 starboard side, with suction pipes extending through the ladder well into the hold. These would pump the water from the engineroom, frame 87-102, giving the necessary differential pressure to seal the cofferdam firmly.

A six-inch gasoline driven pump was placed on the second deck, frame 90, port side, for eventual use in dewatering the emergency diesel generator room. This space was separated from the starboard side below the second platform by centerline water tanks and aviation lube oil tanks.

A soft patch in the main (hangar) deck at frame 111 was removed and two ten-inch pump suctions were extended as far as possible down into the engineroom. This was a difficult operation as there was interference from piping and vent ducting. These pumps would only be effective in lowering the water level to the operating level of the engineroom, so a six-inch electric submersible pump was introduced to the lower level deck plates through the escape trunk in the forward port corner of the engineroom. If needed, more six-inch submersible pumps were available for engineroom use.

SHAFT ALLEY

The plan to dewater the shaft alley called for two six-inch submersible pumps lowered down the escape trunk at frame 182 on the fantail. The area between frames 122-136 would be dewatered by four six-inch gasoline driven pumps; two each located at hatches on each side of the second deck at frame 134. These pumps could not be rigged until water pressure was released from the two hatches. A trial pumping of the shaft alley was undertaken with the submersible pumps on 6 May. The trial lowered the water in this area by four feet, permitting the hatches at frame 134 to be opened, and the gasoline pump sections were rigged. Operating at full capacity the four pumps could not lower the water level more than six feet in this area, and it was necessary to use these pumps continually to prevent flooding above the second deck hatches at frame 134.

All pumps were in place and tested by 7 May. Two ten-inch pumps, five six-inch gasoline driven pumps, and one six-inch submersible pump were ready for standby use.

9.10. THE MAIN PUMPING EFFORT

The enlarged cofferdam was reinstalled on 7 May. During installation a large dent was discovered that extended approximately 18 inches beyond the side of the cofferdam and had a gap 12 inches in width along its top at mid-length. Mattresses failed to seal the gap, so a ten pound "L" shaped plate was fabricated. One side of the plate would be attached to the shell, covering the lower dent, and the other side would be attached to the side of the cofferdam. An NUD-38 underwater stud driver was used to fasten the plate, but it failed when the studs would not penetrate the armor plated hull of the ship. Large wedges were finally used to effect a partial closure. With this partial closure the two ten-inch pumps were able to lower the water level by three feet.

On 8 May it was decided to pump out the ship in sections working from aft to forward, isolating and patching leaks as they were found. A scuttle was reported somewhere near the forward end of the shaft alley. Divers located the scuttle and found it open. The scuttle was closed and rapid progress was made for a short time in frames 122-136, using the two six-inch pumps. Progress slowed again when pump troubles developed and the scuttle started to leak. A dangerous dive was made down through the engineroom and the door from the engineroom to the shaft alley was found open about three inches. After it was closed pumping continued in the area aft of frame 122.

In the engineroom the two ten-inch pumps lowered the water level some ten feet until equilibrium was reached between leakage and water removal. Divers searched the starboard side of the forward bulkhead, frame 102, but could not find any bulkhead leaks. It was concluded that if there were any leaks in the bulkhead, they were minor. No holes had been found previously in the side of the ship near the engineroom, so major leakage in the engineroom was probably coming from broken or leaking engineroom salt water piping.

By evening 8 May the area aft the engineroom was nearly dewatered. The engineroom flooding was under control, and bulkhead 102 was thought to be essentially intact. During the day maximum free surface had been developed, allowing whatever off-center weight that existed to increase the ship's list from 1.5 to 2.5 degrees starboard. Efforts continued on the cofferdam without success, and more pump problems developed. The two ten-inch pump engines continually failed because of gasoline vapor lock caused by high temperatures in the below deck spaces where the pumps were operating. Efforts were made to cool the engines with portable blowers and fans. Even when both pumps were operating, the water level could only be lowered three feet. It was obvious there were additional leaks. Searches were made during every slack tide for the next two days, but no leaks were located.

During the night of 8-9 May pumping aft of frame 102 continued. The water level in this area held steady, but progress was made aft of frame 122. Trying to reduce the water level as fast as possible, the night personnel overlooked large pockets of residual water that should have been pumped out. This increased free surface, and with progressive lightening, the ship listed to seven degrees starboard.

On 9 May these pockets were discovered and stripped, and the list decreased to four degrees. It was felt that there must still be some unreported off-center weight, most likely liquid in nature. During the morning slack tide on 9 May divers located two leaking auxiliary circulating sea chests and approximately 50 leaky rivets on the starboard side of the engineroom. These were plugged and the water level in the engineroom quickly dropped to the operating limit of the ten-inch pump suctions. Dewatering continued with the six-inch submersible pump on the port side of the engineroom. One of the ten-inch pumps was removed to make room for a second six-inch submersible pump, and two smaller pumps were put into service. The water level lowered again. It was suspected at this time that there had been a second explosion in the area of the engineroom.

Little headway was gained in the area of frames 87-102, where one ten-inch pump block cracked from overheating. Most of the day was spent rigging a pump replacement. The unsuccessful search for additional leaks continued.

On the evening of 9 May the drafts were 27 feet forward, and 32 feet aft; a nine foot rise at the stern and a mean rise of approximately five feet. List remained four to five feet to starboard. Three additional six-inch submersible pumps were requested from COMSERVPAC as another of the pumps on board had broken down, and one was failing.

On 10 May a third ten-inch pump was lowered into frames 87-102 by cutting suction pipe accesses through the second deck and second platform. With this third large pump operating, two additional feet of progress were gained. The engineroom water slowly decreased with 13 feet of water remaining. Removal of water from the hold, frames 122-136, was very slow because of the high lift or discharge head required. Oil was discovered in the compartment and it was impossible to use the electric submersible pumps which would have been better for the high lift job.

On 11 May the pumps were rearranged and the side of the engineroom and the cofferdam were addressed with maximum effort. More leaky rivets and a vertical crack were found in the area of the engineroom. After these were plugged, pumping continued to progress. The storeroom near the upper extremity of the shell rupture, starboard side, frames 94-102, had been cleared, and it was decided to attach a large "J" bolt and strong back to hold the cofferdam. An access point was burned in the second platform deck at frame 99½ to permit placing the strongback across the hole. The hole was crescent-shaped with the upper portion of the rupture in the shell straddling the second platform deck, and two tears trailing off and downward. Divers improved the position of the wedges and the packing around the cofferdam, and once the patch was made watertight, a boot strap type operation followed; the pumps made a little headway, the increased differential head forced the cofferdam a little tighter against the hull, and the pumps again increased headway. The use of the "J" bolt was the key to this operation since prior to that the cofferdam was held vertically by only three chain falls, and horizontally by two 7/8-inch wire hogging lines. The "J" bolt held the cofferdam firmly enough so when wedges were driven in, they didn't simply lift the cofferdam away from the hull.

Suspicions were confirmed, on 11 May, of a second explosion occurring near the engineroom. Fortunately the explosion had been placed against the armor plate which extended a foot or so below the waterline. This protected the engineroom from a bad shell rupture, but even so about ten frames were pushed in approximately 18 inches below the armor plate. The armor plate and shell around the armor plate was deformed inward about one foot, and the armor plate had a vertical crack, ¼ inch wide, from its lower extremity up five feet. The engineroom leakage was caused by the shearing off of an eight-inch circulating water inlet line. It flooded the area and allowed the eight-inch discharge to flood back through the condenser and into the engineroom.

The ruptured inlet line was plugged and on the evening of 11 May the *CARD* was afloat with drafts of 25 feet 6 inches forward and 26 feet 0 inches aft. Off-center flooding in the cofferdam on the starboard side of the aviation gasoline tanks was found and dewatered. No appreciable list could be detected. Only minor water remained, and this was being removed by small pumps. Leakage in frames 87-102 area was about 500 GPM, and the water level was easily held down; leakage in the engineroom through sheared and loose rivets was about 1000 GPM, easily controllable with a six-inch submersible pump.

9.11. TEMPORARY REPAIRS

Repair crews initially planned to build an internal cofferdam in each damaged area. A more practical plan, agreed to, was to box in the damaged area, frames 95-102, from the inside. The lower level of the engineroom would be strengthened laterally by a large fore-and-aft beam suitably shored by internal strength members.

In the frames 95-102 area, the tears which terminated in cracks were safe-ended and covered with plate on the inside. The major opening near the second platform deck was closed by building a cofferdam from shell to second platform deck, above and below, as shown in Fig. 10, No. 1. Beams were added to compensate for the damaged beams. Three of the original beams were knocked off completely and had to be replaced.

The numerous rivet holes were closed with steel plugs, working from top to bottom so the cofferdam was kept dry. Two access holes were cut in the top of the cofferdam which was above the waterline, and the shell was closed from the outside using small pieces of ten pound plate. This left a space into which nine cubic yards of concrete were poured. All damage in this area was temporarily repaired by 19 May.

In order to make repairs to the engineroom area a heavy ten-inch "H" beam was located. It was cut into three pieces and lowered into the engineroom. The pieces were placed eight feet above the tank top running from frame 102 aft to frame 116, forward side of the starboard fuel oil settling tank in the lower level of the engineroom. The three pieces were then welded into one, and each frame was connected to the beam by transverse and diagonal two-inch by four-inch channels. The last step was to brace the beam transversely at each end and at its mid-length. This work was also completed by 19 May.

RECLAIMER and *TAWAKONI* personnel were set to work eliminating inside leakage in the engineroom. By listing the ship to port the entire crack was exposed. The vertical crack under the armor plate, and the crack in the shell extending six inches below the plate, were welded. A ten-pound doubler was welded to the plating over this crack. Every rivet that could possibly be leaking was plugged with hardwood plugs, welded over with underwater welding gear, or patched with rubber gasket material under small plates which were attached with the underwater stud driver.

9.12. PREPARATIONS FOR THE TOW

Leakage after repairs was estimated at 10 GPM in the engineroom and 50 GPM in the frame 95-102 area. This leakage was attributable to loose rivets at the tank top or around the concrete ballast and it was considered impractical to stop them.

The tow down the Saigon River required that the ship be lightened to a 24 foot draft. This was done by pumping out 750 tons of locked-in ballast water from the former *AVGAS* tanks, off-loading 260 tons of oil from the after deep tank, and off-loading one ballasted forward deep tank. The combined processes brought the ship's draft to 23 feet forward and 24 feet aft.

Pumps were installed for emergency use during the tow to Subic Bay. Extra pumps for the frame 87-102 area included one ten-inch gasoline driven pump, one six-inch electric submersible pump, and several smaller pumps. In the engineroom two six-inch electric submersible pumps and the ship's installed reciprocating bilge pump, rigged to be driven by compressed air, were on standby for emergency use. A ten-inch gasoline driven pump remained in place in case of heavy flooding in the engineroom, but could not pump water from below the operating level of the engineroom because of suction lift limitations. One six-inch gasoline driven pump and several smaller pumps were retained to use aft of frame 122. Several 2½ inch electric submersible damage control pumps and 1½ inch air driven sump pumps were also readily available.

DC power for the ship's steering gear, anchor windlass, 2½ inch submersible pumps and emergency lighting was supplied by a 60 KW diesel generator and a 75 KW Power Pack diesel. A 210 CFM gasoline driven compressor was supplied and a 100 KW 220/440 volt AC diesel generator provided power for the six-inch submersible electric pumps.

The riding crew consisted of the Salvage Officer-in-Charge, and divers, shipfitters, enginemen, damage controlmen, boatswain mates and an electrician from *TAWAKONI* and *RECLAIMER*. Sixteen *CARD* crewmen were also on board.

The diesel oil and fresh water in *CARD'S* tanks were still usable and pneumatic submersible pumps transferred fuel and water from the tanks. Drums of gasoline were loaded on the fantail for use during the tow.

9.13. TOW TO SUBIC BAY

The towing plans called for *TAWAKONI* to tow *CARD*, while the *RECLAIMER* acted as a "brake" during the transit down river. The 48 mile transit of the river included many sharp turns and shallow areas. The tow was attempted on 20 May with only one serious incident. As she was towed around a sharp bend, *CARD* grounded on a mud bank. The tide was rising at the time and *CARD* was freed easily in 1-3/4 hours.

A virtual GM of 3.5 could be obtained by *CARD* in her present condition which gave her adequate stability to withstand the complete flooding of any two of her compartments. This made it possible for the *CARD* to reballast after passing the shallow areas of the river, improving her stability.

When *CARD* reached the open sea, wave action caused the engineroom side to work. This working resulted in new rivet leaks and greatly increased the rate of flooding. The leaks were reduced to 200 GPM in the engineroom by the use of internally driven wedges, but leakage in the frame 95-102 damage area increased to 100 GPM as waves drove water through loose rivets above the normal waterline.

CARD reached Subic Bay on the morning of 25 May and was turned over to her Master.

10. SCAPA FLOW

10.1. BRIEF

Following World War I the entire German war fleet, under an armistice agreement at Scapa Flow, was scuttled and sank. In a salvage operation that lasted seven years, 32 of the scuttled ships including six ships of 20,000 tons or more, were successfully salved. The task was carried out by a team of civilians, inexperienced in salvage techniques, who in the course of the operations invented many methods which are still in use today.

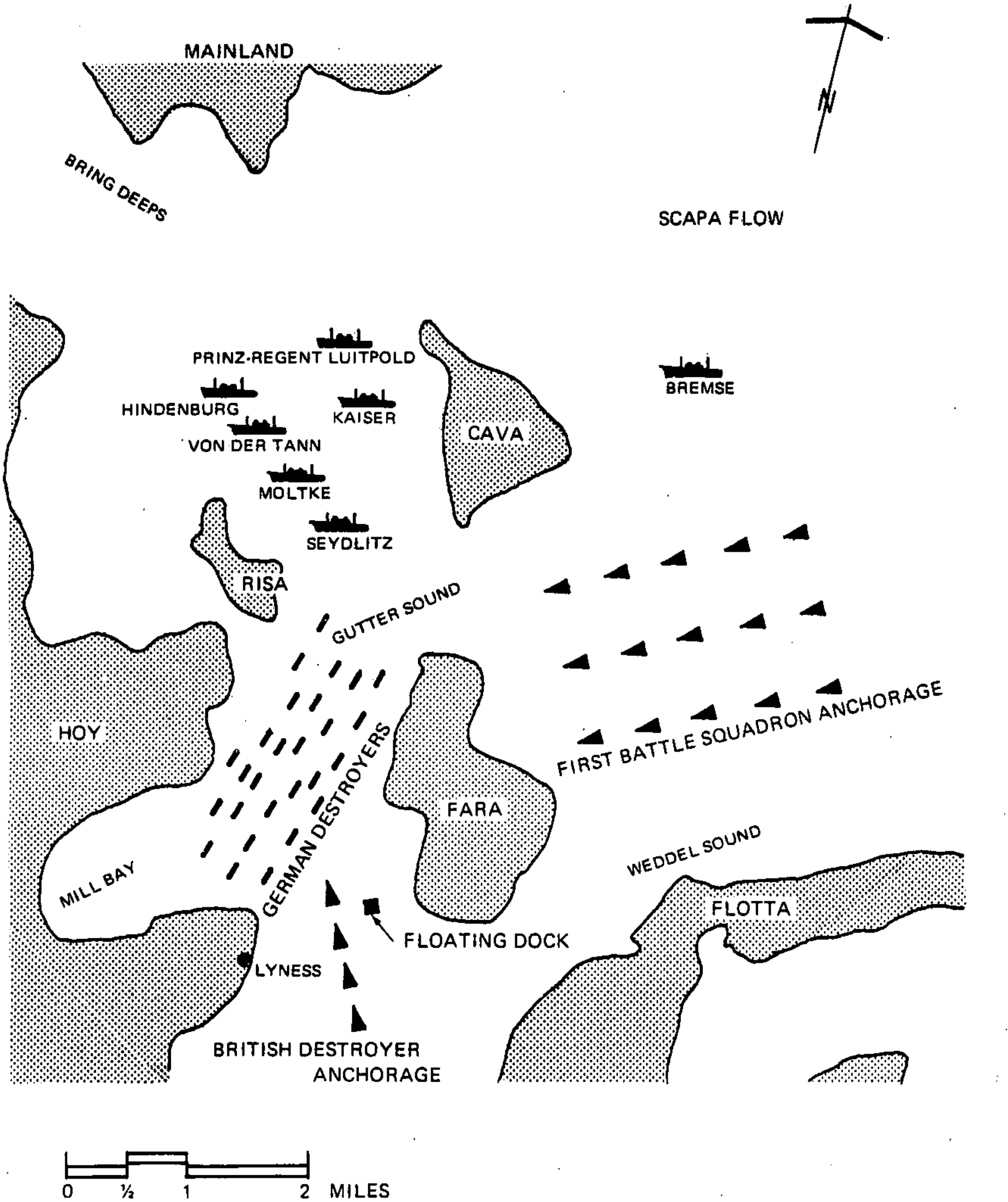
10.2. BACKGROUND

As World War I drew to a close the German war fleet was surrendered to the British under the armistice and proposed treaty. For safe keeping and surveillance they were temporarily taken to Scapa Flow, Orkney, Scotland where they remained under the command of German Admiral von Reuter, and the British Navy. They were manned by skeleton maintenance crews of German sailors and kept under constant guard. The ships had been relieved of all weapons and munitions, and as the months passed it became known that the British would probably acquire the German fleet as part of the terms of reparation. Admiral von Reuter did not want the fleet surrendered on any terms and so he organized a conspiracy among his officers, without the knowledge of the German authorities, to scuttle the fleet should surrender look imminent.

On 21 June 1919 the fleet of 78 ships was sabotaged and in a very short time went to the bottom of Scapa Flow despite British efforts to save the ships. Military engineers upon surveying the scene shortly thereafter, concluded the fleet was unsalvable except for a few of the smaller ships. The expense of raising the ships, as compared to their value for scrap, did not warrant salving these smaller ships. As the sunken fleet did not constitute a threat to any major navigable waterway, they were left as they lay. (See Fig. 10, No. 1).

Instead of the German fleet the British accepted several large German floating docks in reparation. The docks were later to figure extensively in the salvage of the fleet at Scapa Flow.

In 1921 Ernest Frank Cox, then in the scrap metal business, discovered the German docks were not in use by the British. Each dock supported a huge pressure cylinder which had been used to test German U-boats after launching. The cylinder would be pressurized to equal the pressure at the depths in which the U-boats would be operating; the boats were tested in the cylinder before they went to sea. Knowing the value of the steel and metals in the docks, Cox purchased one for scrap. He was approached by a customer of his however, who recognized the value of the dock as a salvage tool to raise the smaller ships at Scapa Flow which could in turn be sold for scrap. After salving as many of these ships as he could, the dock could then be scrapped itself.



THE GERMAN WAR FLEET AT SCAPA FLOW IN JUNE 1919.
FIG. 10 NO. 1

Convinced that the plan would work from an economic as well as engineering standpoint, Cox decided to try it. The dock was 400 feet long, 40 feet in diameter and had a lift capacity of 3000 tons. None of the destroyers at Scapa Flow weighed much over 1000 tons each. The dock had been outfitted with pumps and compressors housed in its walls when it was used as a drydock. There was enough storage space in the dock for all the special salvage equipment needed. It was "U" shaped and was constructed so that when the submarine tube was removed it could sink to a level where a ship could be moved within its walls to be pressurized and tested.

Cox quickly developed a more definite plan. Raising and scrapping the smaller destroyers would provide enough capital to raise the battleship *HINDENBURG*, which could then be used as a giant pontoon to raise the rest of the large ships. After having surveyed the scene at Scapa Flow, Cox purchased 26 destroyers and two battleships from the British Admiralty for about 24,000 pounds.

10.3. EQUIPMENT AND OPERATIONS

Along with the dock, the other equipment Cox took with him to Scapa Flow included railway track, cars and other related equipment; two 7½ ton cranes; equipment for an engineer's workshop; a complete oxygen plant; and chain. He was able to store it all on the dock which itself contained a whole system of work shops, electric generators, air compressors, and carpentry and joinery units. Cox also bought two ocean-going tugs to begin the salvage work, the *FERRODANKS* and the *SIDONIAN*. In addition, there were several smaller craft left at Scapa Flow which he got permission to use while there.

In the way of personnel, Cox hired engineers, fitters, riggers, electricians, divers, shipwrights, laborers, clerics and a complete catering staff which he transported to Scapa Flow. Although these men were each experts in their own field, none of them, including Cox, had any practical salvage experience.

When they arrived at Scapa Flow, Cox and his team took over the abandoned Navy and Air Station facilities, a deep water quay and slipway, and a steam pinnace. He had to set up and stock sleeping quarters, a mess hall, gear storage and administrative facilities, before any practical work could get under way.

The first task after setting up the operation was to complete cutting the dock apart to make it functional in Cox's plan. As it was to be used only on sunken ships, Cox had the front wall cut off and the aft wall sealed. So lift could be provided on both sides of the dock, he decided to cut the dock in half athwartships and take the weight of the ships to be raised between the two halves of the dock; the two halves would each be "L" shaped and 200 feet long. Each section was equipped with boiler rooms, engines, dynamos, and air compressors. The flat deck of each was fitted with 12 pulleys running on a shaft supported by 12-ton pulley blocks especially designed for use on the dock. Twelve triple-geared hand winches were connected to twelve 100-ton tackles bolted to the wall by massive plates. At the end of each tackle chains were passed over grooved pulleys and ran down over the deck edge of the dock into the water. The hand winches required two teams of two men at each winch handle. The block was shackled to a length of nine inch circumference steel cable which had been passed over the pulley on a six-inch shaft and led down to the sunken ship and up again to an opposite pair of winding gear on the other dock section. (See Fig. 10, No. 2).

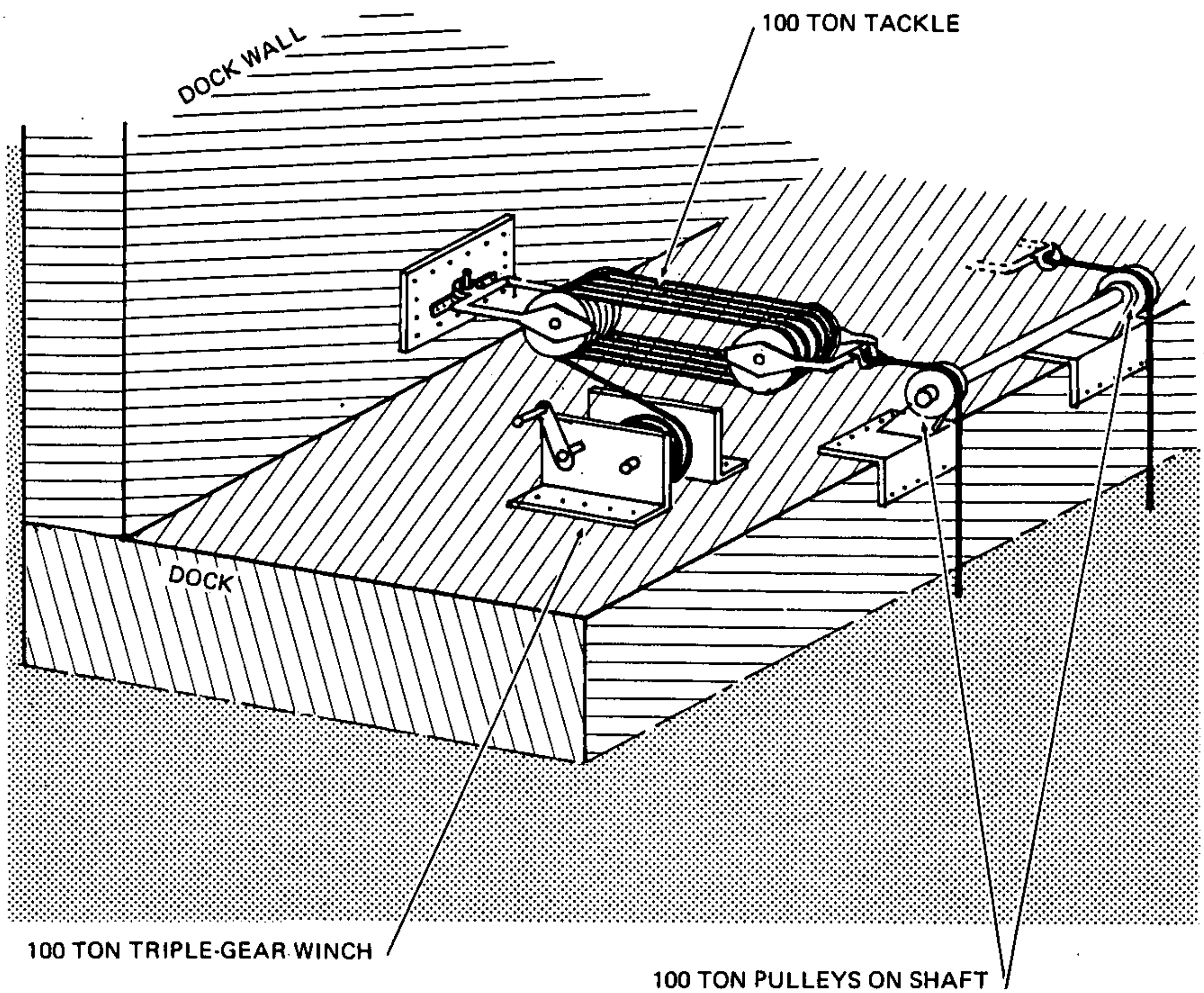
10.4. THE FIRST SUCCESS

The first ship Cox and his men tackled was the *V.70*, a torpedo boat destroyer. She was an 800 ton ship laying upright in 60 feet of water two miles from shore. The weather conditions were good with the water temperature at 35-40 degrees. The two separate halves of the dock were positioned over the wreck at low tide. Divers placed a length of chain connected to the winches of both docks under the propeller shaft bosses of the *V. 70* stern. Winchmen wound the chain taut and as the tide rose the docks rose, and with them, the stern of the ship. While the stern was lifted the divers got a second chain under the stern section using an 18-foot long metal lance, shackled to the chain ends and pushed under the ship where a pair of divers on the other side pulled it through. It was fastened to the deck chains of the opposite dock and hauled up to be fastened to winches at the dock's far end. The chains were then wound in, and in doing this, the chain would move forward from the stern toward the bow section. Successive tides were used to get ten more chains under the ship so that a chain cradle was formed for the ship. The first lift attempt failed because the chains would not support the weight of the ship; nine-inch wire cables with flattened centers were substituted. The same procedure was used for getting them under the ship. Divers in pairs on each side of the ship worked the lance through, but this time a two-inch messenger was attached to the end of the lance. The messenger was shackled to the end of a winch line and pulled up to the opposite dock where the main nine-inch circumference 250-ton cable was attached. The messenger and cable were then pulled back under the ship by the first deck winch. Where the lance could not be pushed under the ship a pressure hose was used with the pressure supplied by a hydraulic pump. The lance would then be pushed through the tunnel made by the pressure hose.

As the ship was laying on its side, several wires were hooked under the stern "A" bracket and the stern section was lifted. Successive wires were then worked under the side and seesawed forward. They would be tightened to lift the ship higher, and the process was repeated until all wires were in place. Twelve wires were usually used to insure stability of the cradle and ship.

On 31 July 1924 the cables on the *V. 70* were positioned and connected to the 24 winches manned by 96 men. With the combined tidal and winch lift, 20 turns to the 1½ inch, the *V. 70* was raised. By the time high water was reached the bridge and top hamper were exposed; the deck moorings were cut loose, and the dock, cradle and ship were towed by the two tugs toward the shore. The tugs would tow the group until they grounded in shallower water. The cable wire would be hauled in again until taut as the tide went down, and when it rose the ship would again be lifted. She was towed in this position until she grounded and the procedure was repeated until the ship was beached. Four lifts by dock and tide were necessary to beach the ship. In the meantime, pumps were installed to start the dewatering of the wreck.

WINDING GEAR ON DOCKS



PURCHASE GEAR AND WINCH ON THE DOCK.
FIG. 10 NO. 2

10.5. ROUTINE SALVAGE AND SOME SPECIAL CASES

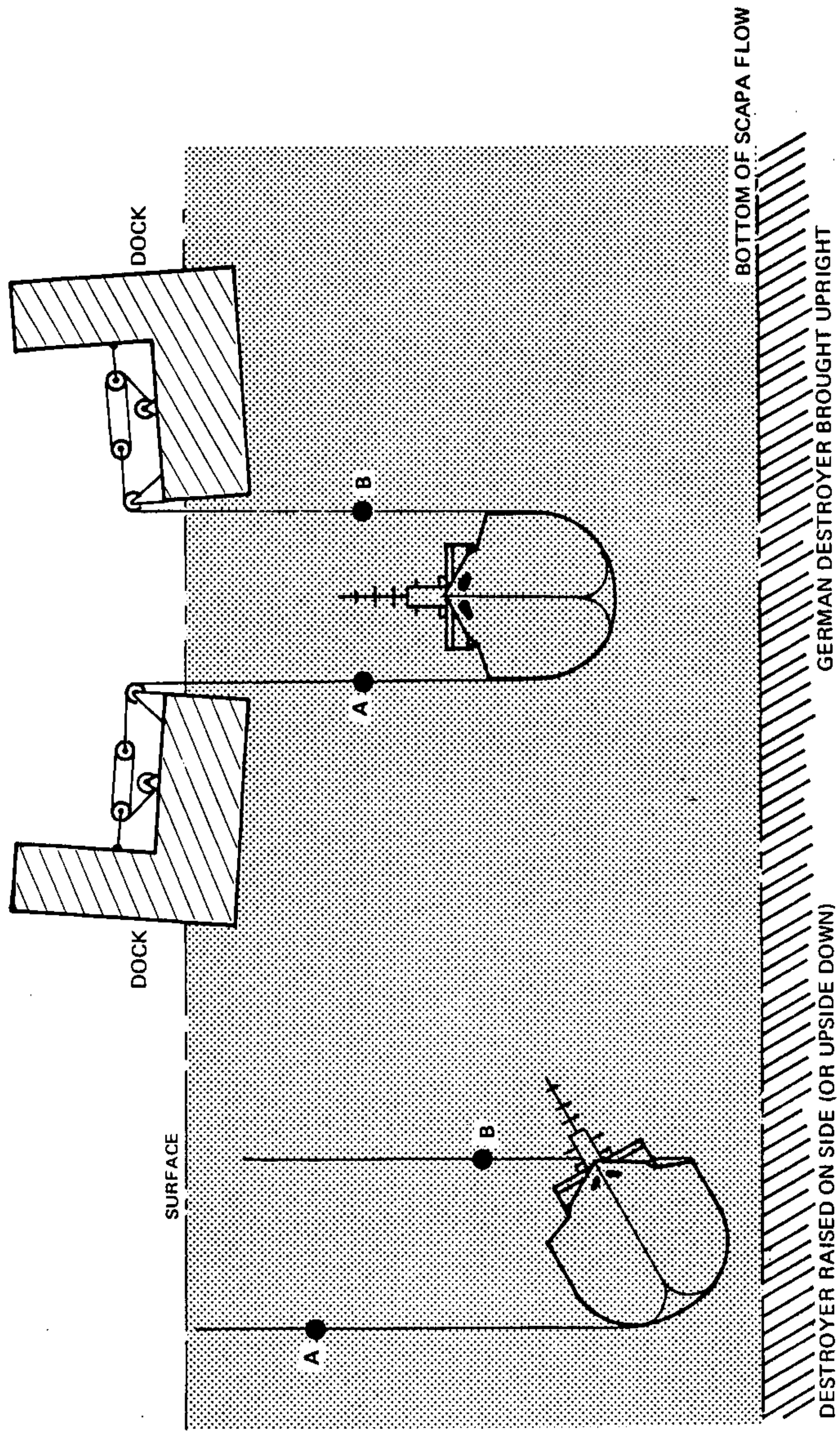
With this same basic procedure Cox raised the *S. 53* eleven days later, and work from then on progressed rapidly. On 29 August he raised *S. 55*, 12 September, *G. 91*, 29 September, *G. 38*, and 13 October, *S. 52*. After that he stopped for the rest of the year to get his workshops going, cut up the beached destroyers which were badly damaged, and ship the scrap to the buyers. The ships that had been raised in fairly good condition were patched and towed to the yards where they would be scrapped.

The most skillful and intricate work accomplished was untangling groups of several destroyers which had been moored together and had sunk in a huge pile along with their buoys. Because the ships had been moored in a tight pattern this situation occurred frequently. The ships had to be cut apart underwater with explosive charges detonated from a distance by remote control so that the underwater shocks would not injure the divers. Each ship as it came free from the tangle would then be raised.

By 1925 salvage operations had become more or less routine for Cox and his men. A big tug, *LYNESS*, was used as a diving station to locate the next ship to be salved, using shot rope and distance lines. Wires were then attached to the sunken hull fore and aft to mark her exact location so that the docks could move in at precisely the correct position for the lift. The cables were passed under the hull and the routine established was re-enacted with little modification for each ship.

One of the most interesting techniques invented by Cox at Scapa Flow was the process of righting a capsized hull. The hulls had to be righted in order to facilitate the positioning of the ship between the two dock halves for the tow to the beach. Righting, or parbuckling, was faster and cheaper than trying to cut away the superstructure of the ship which could foul on the bottom or catch on the docks. After the ships had been raised off the bottom in the wire cradles, they were towed out to deeper water. The cables on the dock were played out on one side a short distance, and the opposite ends of the cable on the other dock half were hauled in by the same amount. As one side was played out the effect was to roll the hull over and sink it slightly deeper. The sinking movement however, was cancelled by the winding in of the cable on the other side of the ship, and as a result the rolling movement increased and the ship would slowly right underwater. An operation of parbuckling would take about an hour. (See Fig. 10, No. 3).

In the first year of work Cox's inexperienced team raised 18 ships averaging 750 tons each. Because of this success half of his capital outlay was recovered so he decided to move on to the larger ships of 1200-1500 tons. For this task he purchased another German dock, intending to use it as a submersible pontoon which, when sunk to the sea floor, would form a cradle to raise the larger ships in one move. In theory the "L" docks with wire cradles would lift the ships into the sunken "U" dock which would then be deballasted to bring the ship up inside the dock. The problem in realizing this plan was that the ship could not be lifted high enough to clear the walls of the "U" dock. Cox thought that by removing one of the walls and then lashing the ship in place against the other wall the same type of lift could be accomplished. However, the weight of the ship and the unbalanced condition of the sunken dock only served to capsize the dock and spill the ship out, damaging the ship and the dock. Though



PARBUCKLING A DESTROYER USING LIFT ROTATION.
FIG. 10 NO. 3

Cox later retrieved the sunken dock, he used it only for one other salvage job. Abandoning the plan, he outfitted the "L" shaped docks with an extra pair of winches, and in this way was able to raise the 1200-1500 ton ships by the same procedure he had used before. On 1 May 1926 he had raised the last of the large destroyers and his total tonnage raised reached the 23,000 ton mark.

10.6. THE MOLTKE

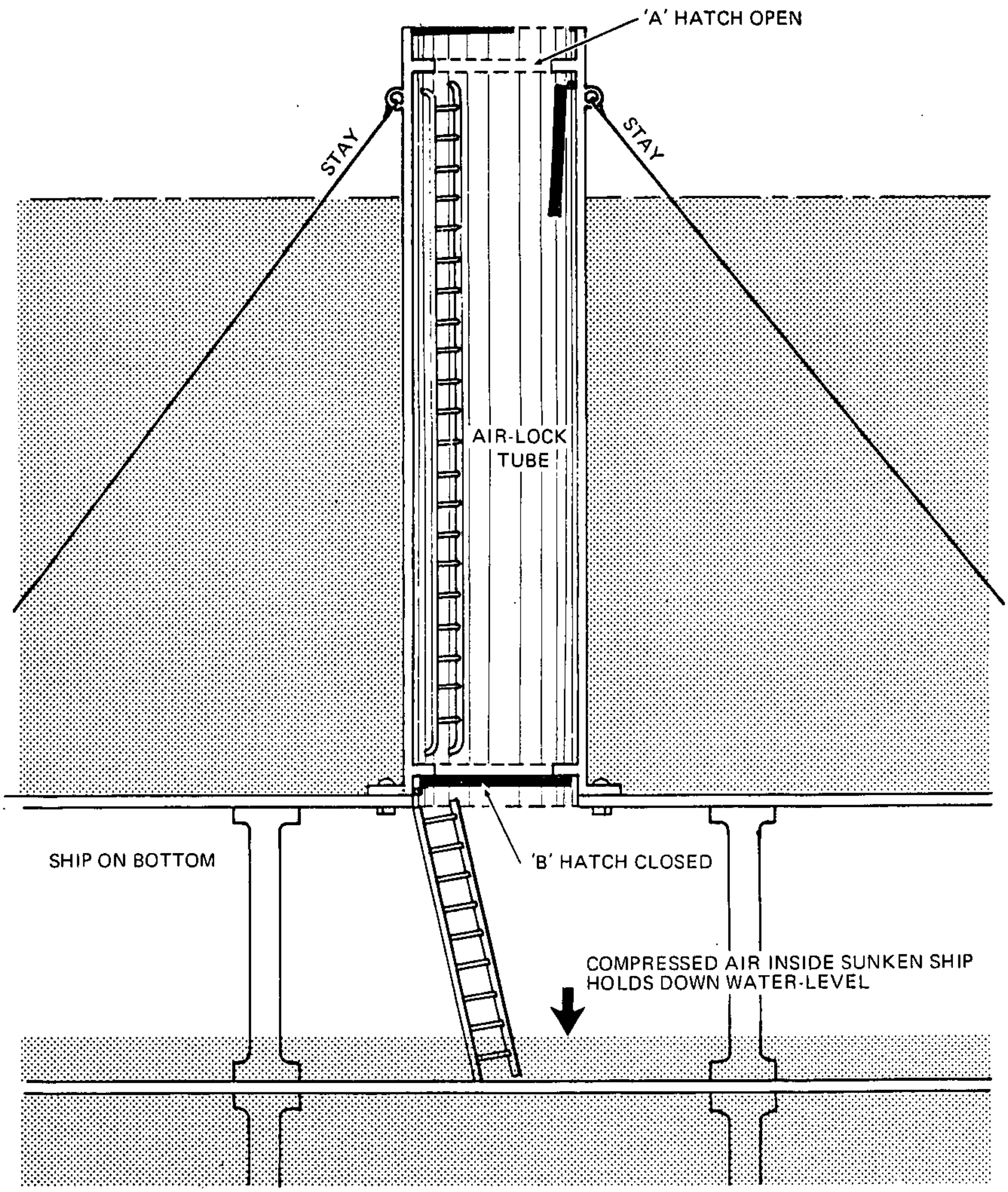
Cox next attempted to raise the *HINDENBURG*, a battleship. He brought in heavier equipment, but experienced repeated failures in trying to raise her because she tended to capsize when she reached the surface. He abandoned the *HINDENBURG* temporarily and focused his attention on the *MOLTKE*, another large battleship. In salving the *MOLTKE*, Cox again displayed his engineering genius. The *MOLTKE* had turned turtle before capsizing and lay upside down on the bottom. To parbuckle her would have been a tremendous task if it could be accomplished at all with the equipment Cox had, so he decided to lift her as she lay with the use of compressed air. She was patched with concrete so that she was completely air and watertight; then she was compartmented to facilitate pumping the air into various selected spaces to keep her stable. The compartments or bulkheads were built by the divers working in the pressurized air spaces pumped into the hull. Any protruding superstructure or especially heavy equipment was cut off the hulk using torches and gelatinite explosive charges, to balance her more evenly and remove obstructions which might foul during the beaching or tow. In order to gain access into the hull while it was under water, to build the bulkheads and patch, air locks were built. (See Fig. 10, No. 4). They were long tubes fastened over hull holes extending from above the surface to the wreck. At each end hatches were placed with pressure valves which could pressurize the tube so that the divers could enter the hull and the compressed air atmosphere with no danger. In this manner the men could climb in or out of the hull from surface boats to work. These air locks were built on all of the larger ships which were raised using the compressed air method. They were of different lengths depending on the depth and position of the ship, some extending down 100 feet.

Another technique used by Cox when raising heavier ships by compressed air was to use large destroyer hulls filled with compressed air as huge pontoons.

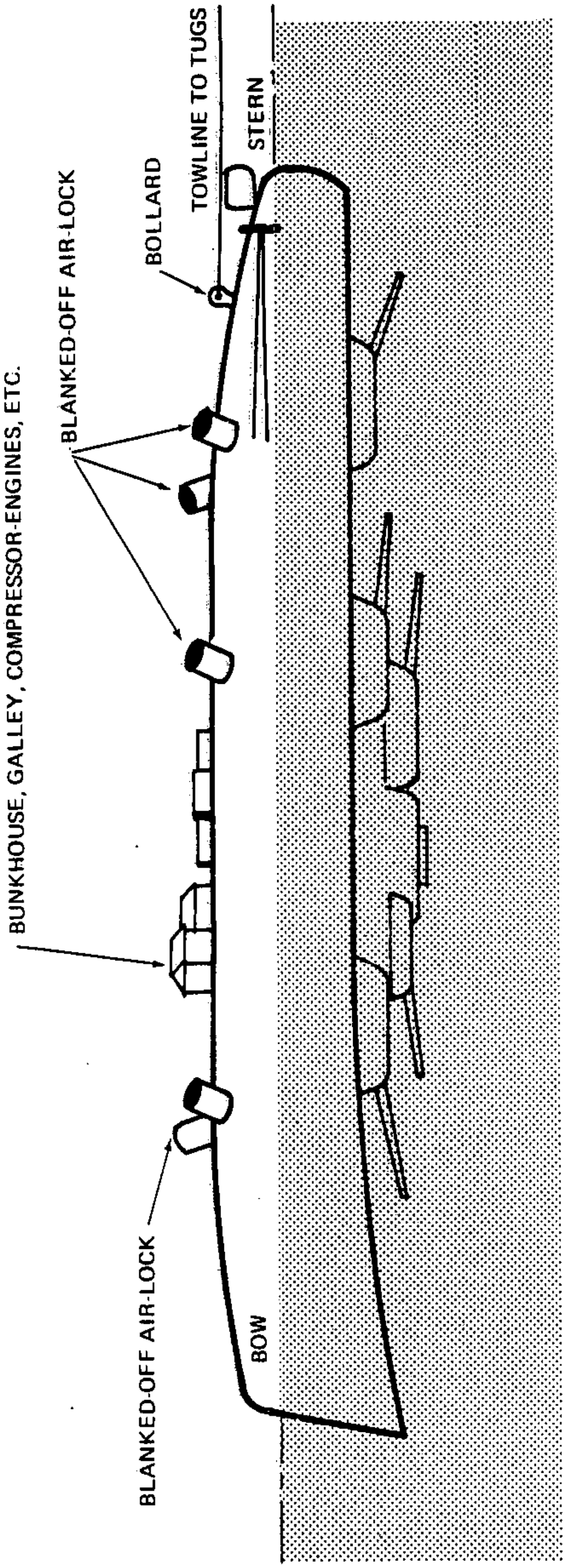
Once the ship had been raised it was strengthened to withstand the exposure of the open seas. Deck houses were built on the bottom of the hull, which became analogous to the top deck, housing air compressors, generators, and the small crew responsible for keeping the ship filled with air during the tow. (See Fig. 10, No. 5). Finally the ship was taken in tow, in its upside down position, and towed to the shipyards where it was drydocked, also upside down, stripped, and scrapped. All of the large battleships, except the *HINDENBURG*, were raised this way, varying the procedure only slightly for individual circumstances.

10.7. THE HINDENBURG

The *HINDENBURG* was Cox's largest single job. She was a battleship of the following dimensions:



AIR-LOCK IN POSITION ON A SUNKEN SHIP.
FIG. 10 NO. 4



BATTLESHIP FLOATING ON AN AIR BUBBLE READY FOR TOW TO SCRAPPING YARD.
FIG. 10 NO. 5

Waterline	700 feet
Beam	96 feet
Draft	27 feet

She lay upright in about 70 feet of water, pointing north. Her funnels, masts and gun turrets were above water.

The first attempt at raising the *HINDENBURG* failed because of the tremendous amount of water trapped inside the ship. If she had even the slightest list as she came up, water would rush to the angle of inclination (free surface) and this force would roll the ship until she capsized. There was no way to keep her upright because she was balanced on the sea floor on only three feet of keel.

In earlier attempts at raising, the ship had listed to port; to counter that motion Cox had a giant concrete wedge prepared to go under her stern on the port side. To make the wedge, a slice of a salved destroyer engineroom section was cut out, the strongest section of the ship. This section was towed out and sunk into position, then filled with 'Ciment Fondu', a special concrete mix, transported in jute-sacks down slings to the divers. The divers placed the sacks in position to fill the wedge. It took 600 tons of concrete to attain the level needed to imbed the propeller and shaft housing on the port side, a vertical distance of only 10 or 12 feet.

In order to make *HINDENBURG* watertight, the bottom openings had to be patched. A total of 800 patches were used. The patches varied in size and type from 18 inches square, to enormous patches used to cover the opening of the engineroom ventilator and the after funnel. The after funnel patch itself was 40 feet by 21 feet. It was built in two layers of three-inch timber and reinforced with six-inch "H"-section steel beams. It weighed about 11 tons.

All the patches were made by Cox's crew at Scapa Flow, and most were copied from templates made by the divers underwater. In order to fit tightly to the hull, each patch was secured with a 'pudding joint'. This was made by packing a canvas strip with oakum, and nailing it around the edges of the patch so that it was about three inches thick all around. When the patch was bolted on, the jointing was compressed to about half an inch, and the edges sealed with tallow. This made the patch watertight and gave it some resistance to pressure. During the patching it was discovered that some of the local fish had developed a taste for the tallow, so cement had to be mixed in with the tallow to make the mixture hard enough to keep the fish from nibbling it.

For the *HINDENBURG* attempt Cox brought one new dock section, repaired the second section which had sunk, and these two along with his two originals were moored at points around the *HINDENBURG.* He strung suspension bridges from dock to dock, and dock to ship so that the entire assembly became a unit and each piece was easily accessable from any other. He also anchored two water-filled destroyer hulls outside the *HINDENBURG* to act as protection for the ship and divers from swells and weather. When the weather got really bad, they had to be towed away as they dragged anchor and threatened the operation.

Cox also constructed rudimentary cofferdams for this job made of old boiler shells, seven feet wide and 20 feet high, flanged at the bottom so that they could be bolted over the main hatches, two port and two starboard. Pumps and men were lowered into the ship through these cofferdams which extended well above the water. There were six main pumping stations controlled electrically from the bridge. Six, 6-inch pumps each capable of delivering 300 tons per hour were installed; four 12-inch pumps were added later. It was not practical to raise the ship's fore and aft sections together as there was no means of controlling the stability of the hull this way. Therefore the bow section was raised first so that the trapped water would flow down to the stabilized stern where it was later pumped out. The gun turrets, and all other superstructure except the bridge, were removed.

Two hours after pumping began, the bow had risen out of the water ten feet, and the ship held steady. When she had come up 16 feet, a list of half a degree was noticed to starboard which increased gradually until the ship had to be submerged again. As should have been expected, when the ship began to rise the water shifted to the unsupported side of the ship, and she listed to starboard.

In order to check this list another 'Ciment Fondu' wedge had to be constructed for the starboard stern side. The jute-sacks filled with cement were placed in a semi-circle and built up, tapering each layer until the wedge was up around the starboard propeller-shaft housing. It took a week for the wedge to set up sufficiently for work to resume.

When pumping finally began for the last attempt, the bow lifted as before. As it became buoyant the pumps were shifted down into lower levels where the water was concentrating, by crane lines operating through the cofferdams. Part way through the pumping all work was stopped because it was feared that the ship's back was in danger of breaking. Diver inspection showed an area of weakened and sagging deck plate, bent inward. The danger from this was not that the ship might break in two, but that new leaks might be caused in the weakened area. However, Cox decided that it was safe enough to resume pumping, and no problems ever developed as a result of this strain.

When sufficient water was pumped out of the bow section, the stern section was tackled. It had been continually pumped by the smaller pumps during the operation, but at a much reduced rate, so that it did not interfere with the plans for the bow lift. The pumping in the stern gained headway and the stern began to rise by inches, but to the dismay of all, the list reappeared and slowly increased with the rise of the ship. The list went from half a degree to six and a half degrees before it steadied and began to fall. After the ship leveled again, she remained stable for the rest of the pumping and surfaced dead level. She was towed to shallower water where she was lightened even more for her upside down compressed air tow to the scrap yards.

10.8. TOTAL SHIPS RAISED

The list of ships raised by Cox and his men in the seven years of work at Scapa Flow is impressive. It is a feat which has never been equalled in salvage history. Starting with no practical experience, the salvage teams relied on their intelligence, imaginative resources, skill and luck, and in doing so, set precedents for salvors which are still exemplary today.

The list of ships salved by Cox follows:

1 August 1924	V. 70 destroyer	750 tons
13 August 1924	S. 53 destroyer	750 tons
29 August 1924	S. 55 destroyer	750 tons
12 September	G. 91 destroyer	750 tons
27 September	G. 38 destroyer	750 tons
13 October	S. 52 destroyer	750 tons
14 March 1925	H. 145 destroyer	750 tons
3 April	S. 136 destroyer	750 tons
18 April	S. 36 destroyer	750 tons
1 May	S. 138 destroyer	750 tons
16 May	S. 65 destroyer	750 tons
5 June	S. 56 destroyer	750 tons
19 June	S. 32 destroyer	750 tons
3 July	G. 39 destroyer	750 tons
14 July	G. 86 destroyer	750 tons
29 July	G. 40 destroyer	750 tons
11 August	V. 129 destroyer	750 tons
7 September	V. 78 destroyer	750 tons
30 September	G. 103 destroyer	1,300 tons
11 December	B. 110 destroyer	1,300 tons
1 February 1926	B. 112 destroyer	1,300 tons
8 March	B. 111 destroyer	1,300 tons
27 March	B. 109 destroyer	1,300 tons
13 April	G. 101 destroyer	1,300 tons
30 April	G. 104 destroyer	1,300 tons
10 June 1927	MOLTKE Battlecruiser	23,000 tons
2 November 1928	SEYDLITZ Battlecruiser	25,000 tons
20 March 1929	KAISER Battleship	24,000 tons
27 November 1929	BREMSE Light Cruiser	4,000 tons
22 July 1930	HINDENBURG Battlecruiser	28,000 tons
7 December 1930	VON DER TANN Battlecruiser	20,000 tons
9 July 1931	PRINZ REGENT LUITPOLD Battleship	25,000 tons

Total Ships Raised: 32 Total Tonnage Raised: 172,000 tons

11. WORLD WAR II HARBOR CLEARANCE OPERATIONS

11.1 BRIEF

The harbor clearance operations during World War II were the first large scale salvage operations ever undertaken by the U.S. Navy. It was during this period that the Navy salvage forces grew from a small nucleus of trained salvors, to a large, viable, working force capable of meeting the demands necessary to logistically support the Allied war effort. The following is a brief of the inception of the salvage force, its operation, and several of the major harbor clearance operations undertaken during the war.

NOTE: Much information included in this brief on World War II Harbor Clearance Operations was derived from excellent notes and personal presentations by Rear Admiral W. A. Sullivan, USN, (Retired). Admiral Sullivan was personally involved, and directed, much of the harbor clearance work during, and after, the war.

11.2. HISTORICAL BACKGROUND

Prior to World War I the U.S. Navy had never been called upon to execute large scale harbor clearance operations. In fact, before World War I the Navy had virtually no salvage capability at all. The principal operation involving a Naval ship prior to that time had been the raising of the battleship *MAINE* in Havana Harbor, Cuba. This task was undertaken by the U.S. Army Corps of Engineers, and was accomplished through the application of civil engineering techniques; i.e. the construction of a heavy steel cofferdam around the ship, pumping the cofferdam dry, and removing the ship, piece-by-piece.

When U.S. involvement in World War I seemed a distinct possibility, the salvage needs of the Navy were assessed and it was considered prudent to establish a salvage service. This was done in 1917, utilizing personnel from the embryonic diving school at Newport, Rhode Island, and the facilities and personnel of three commercial ship salvage firms along the east coast. This salvage organization compiled a good record on those jobs that were undertaken, saving hundreds of millions of dollars in hulls and cargos. However, its total activities were too restricted in both quantity and area to provide a foundation for any permanent Naval Salvage Service.

During the period between the wars, the Navy routinely performed minor underwater repairs to damaged ships and also raised several sunken submarines; otherwise, there was no salvage organization on the eve of World War II. The American marine salvage industry had also declined steadily between the wars. One of the three firms that had constituted the Navy Salvage Service during World War I went into bankruptcy as soon as it was demobilized and the other two combined. By the mid-30's the lone commercial salvage firm operating on the west coast had terminated activities there.

Thus in 1940 with the international tensions growing, the Navy found itself with no real salvage capability, with few officers and men conversant with salvage techniques, and with a less than adequate industrial base.

The Navy assigned LCDR William A. Sullivan (now RADM., Ret.) to the task of building up a salvage force. He went to England to survey how the Admirality was coping with its enormous salvage needs and assessed the main problems faced by the British to be a shortage of salvage gear, salvage ships, and trained men.

After Sullivan reported his findings and recommendations, a three pronged effort was undertaken to improve the U.S. ship salvage capability. First, an inshore salvage service for the Western Hemisphere was established, based on district organizations that were made responsible for salvage in Navy Yards and of Naval vessels in inland waters. This work was seldom time-critical, and with adequate direction such work could be accomplished by nonprofessionals. Supplementing the Navy District oriented operation was the Navy Rescue Salvage Service which was employed only for rescue towing of disabled ships.

Second, for the more demanding offshore salvage tasks, the Secretary of the Navy executed a contract with the remaining commercial salvage firm Merritt-Chapman & Scott Corporation. Under the terms of this agreement, the Navy took over the concern's Marine Salvage Department and its personnel, and augmented it with additional equipment and ships. This was the genesis of the Navy Salvage Service.

During the war the Navy Salvage Service answered over 600 calls for assistance, of which over 65 per cent were major salvage operations. This effort resulted in the reclamation of ships and cargos valued at almost $600 million, more than 35 times what it cost the Government to operate the Service. It was amply demonstrated that it was much cheaper and quicker to salve a ship and put her back in service than to build a new one.

Third and undoubtedly most important, were the salvage needs of the fleet. To resolve such needs, the Bureau of Ships authorized construction of 31 salvage vessels, outfitted four major shore-based Harbor Clearance Units, and equipped 13 salvage bases at strategic points throughout the world.

More difficult than the provision of the necessary ships and hardware was the problem of providing trained salvors. A major ship disaster ironically presented the ideal salvage training site. After the *USS LAFAYETTE*, formerly the French passenger liner *NORMANDIE*, took fire, capsized and sank next to Pier 88, New York Harbor, a salvage school was set up, at the pier to train both divers and salvage officers. During the war the Navy Salvage School trained 2500 salvage officers and enlisted salvage divers. Graduates of the school were involved in every major invasion in Europe and the Pacific. The equipment and ships salved or reclaimed by these people had a value of more than $2 billion, and their tactical contribution through rapid clearance of sunken or stranded ships from harbors and other areas of attack or supply was beyond estimation in terms of dollars.

11.3. BASIC METHODS OF HARBOR CLEARANCE

Harbor clearance work assumed considerable importance and magnitude during World War II. Major harbor clearance efforts were required for the restoration of harbor facilities so that ships could unload supplies for the support of military forces operating in the area. Most of the ports were captured from the land side, and fighting often continued after the initial occupation of the port; therefore, it was essential to open up the port for transportation, especially to reduce trucking of supplies from some central port or beach in the rear. Combined salvage forces were involved in the clearance operations of a dozen major ports and three dozen minor ones.

It is important to note that World War II harbor clearance was substantially different from what we know harbor clearance to be today. The clearance work consisted largely of removing sunken ships and wreckage of dock cranes, floating cranes, barges, lock gates or other heavy equipment dumped or blown into the harbor by retreating enemy demobilization teams or Allied bombardment. In most cases little effort was expended in the actual salving of ships. The clearance was time critical and therefore it was more important to drag ships out of the way and shift debris around until the harbor entrance and facilities were operational. Because of the urgency of the clearance work many salvage tasks were carried out using makeshift, risky methods, which under normal circumstances would not be undertaken. Very often however, because of the necessity to act quickly and innovate procedures, the salvors devised new effective methods of salvage which have been incorporated into modern salvage practices.

The salvage operations varied from port to port and ship to ship as special conditions existed in each area. Salvage personnel were rarely able to anticipate what type of work they would be engaged in, nor the conditions under which they would be required to work. Consequently they had to bring in enough equipment and supplies to tackle any type of job, yet they had to remain highly mobile and almost 100 per cent self-sufficient.

The first lesson learned by the group was to begin work as soon as possible when they entered a port. This enabled them to save ships which were in the process of sinking, and cut down their work load later. It also enabled them to open temporary supply lines for themselves and the Army.

After several experiences in harbor clearance, the Navy salvors adopted a plan for entering and surveying a harbor to be rehabilitated, and this plan became their routine for all operations with few variations. A small salvage party of less than 150 men entered the port from the land side with the combat forces when the port was won. This team would immediately institute damage control measures, such as fire fighting or saving a sinking ship, find available billeting, survey the area for damage, and then coordinate their findings with the Army Engineers to plan the total rehabilitation effort required. The harbor entrance was usually cleared first so that the supplies and the remaining salvage forces could enter. As soon as the harbor entrance was cleared the Base Salvage Vessel was brought in and this ship was used as a base of operations for messing and equipment until a local labor force could be recruited for the messing, and the supplies and equipment could be unloaded in a suitable area. This usually took a week to ten days. The Base Salvage Vessel was then sent back to the main salvage base for more supplies. As a main salvage base was maintained in each theater, there were reserve personnel and equipment to draw from for a job.

One of the most basic factors to the success of a clearance operation was the cooperation and combination of efforts between the Army Engineers and the Navy salvage teams. Though the Army was in charge of land clearance, and the Navy, harbor clearance, there was only a fine line of distinction between the two operations. Full and complete cooperation and coordination was required between the two forces as their efforts were combined toward a common goal – the rehabilitation of a port. The two were interdependent not only for equipment and supplies, but also during the actual clearance operations. It would contribute little to the war effort if the Navy cleared water access to a berth for ship docking, while the access roads were unusable. Conversely, it was of no value for the Army to rebuild a pier that was unusable because of ship wreckage blocking its access. The best method for the effective clearance of a port without risk of duplication of effort was the development of a joint priority list. This list was based on the Army and Navy surveys of damage and rehabilitation effort required, and was finalized with the Army's eventual use of the port in mind. By giving the parties in command of operations sufficient leeway, flexibility, and license, the priority list method proved itself effective in almost every instance.

To offer a better understanding of how World War II harbor clearance operations were performed the following briefs of work performed are presented. Summaries of operations, and technical problems encountered, are stated. These briefs of operations in major ports in Europe and in the Western Pacific offer a good guideline of methods and lessons learned.

11.4. CASABLANCA, MOROCCO

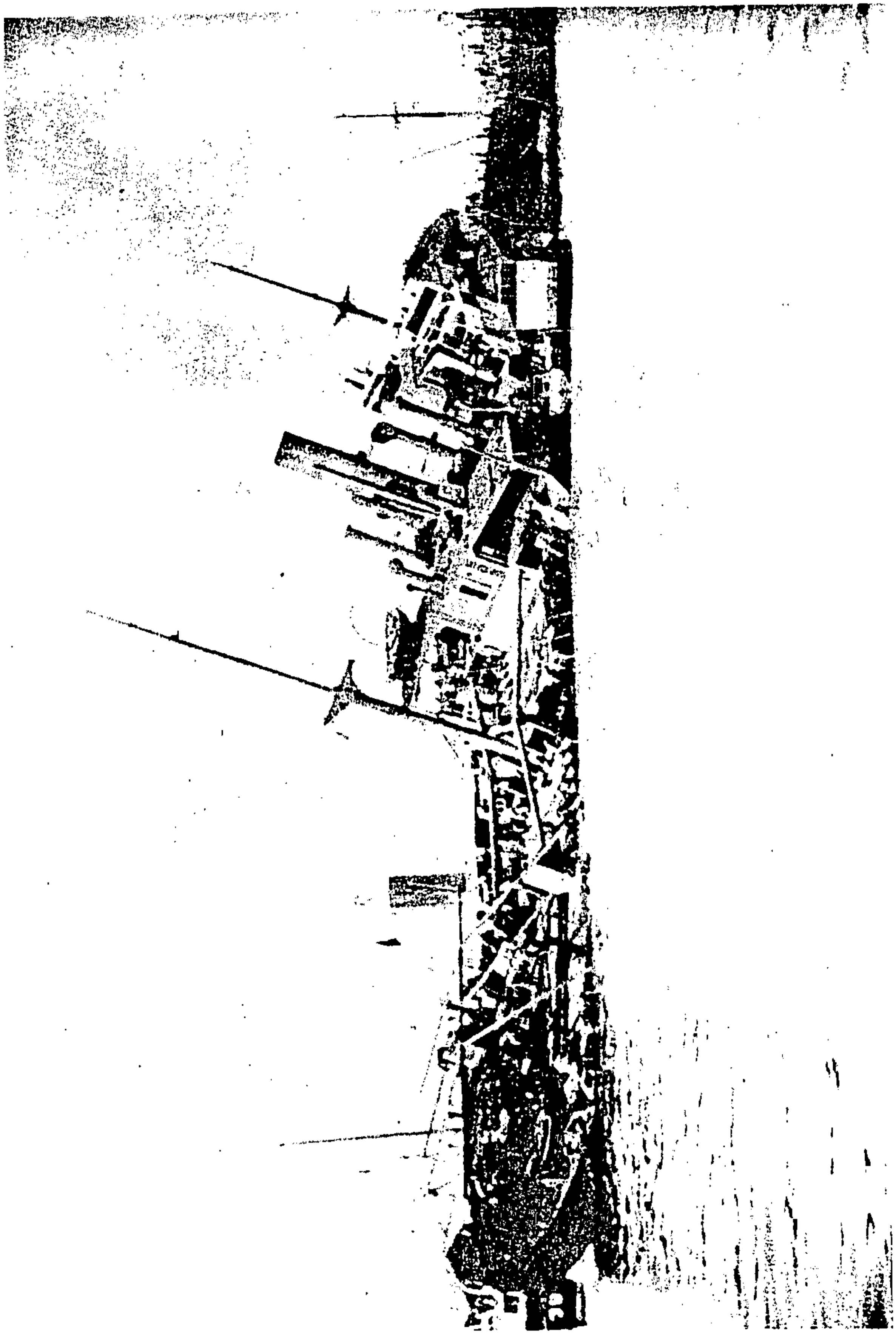
Damage to shipping in the port of Casablanca was caused by the 8-inch and 16-inch armor piercing shells from allied cruisers and battleships offshore, firing at the French battleship *JEAN BART* in the harbor. The shells passed through the sides of the merchant ships in the harbor and exploded after they had penetrated eight or ten inches into the rock bottom of the harbor or into the sides of the stone quays. The exploding shells hurled numerous rock fragments which pierced ship hulls in the vicinity.

The largest ship sunk in Casablanca was the *SS SAVOIA*, 18,000 tons. Salvage required a patching and pumping operation which was attempted many times before success could be had. Because of the deteriorated condition of the bulkheads, it could not be test pumped more than six inches down in any of the compartments, and as soon as this level was reached and the pressure held, the compartment was considered satisfactory. All compartments were tested and an attempt was made to float the ship off the bottom; however, when enough buoyancy was generated, the ship would fill again and immediately sink. Investigation revealed holes in the bottom not previously discovered. The bottom configuration of the harbor was rock, covered with about four feet of fine mud. Mud had leaked into the small holes in the ship's bottom and formed clay patches, impervious, except when a pressure of eight to ten feet head of water was gained; then the clay patches would blow out. About 1600 holes were patched on the *SAVOIA*, some of which could only be reached by tunneling out portions of rock bottom under the ship.

A sunken drydock in Casablanca also presented an interesting problem. To float the drydock the side wall compartments had to be pumped out. If the pumps were placed on the top of the side walls, requiring a suction lift of 35 feet, the pumps would not work. Therefore, the suction pumps were

SALVORS RIGGING A PUMP ON BOARD A SUNK ITALIAN FREIGHTER IN CASABLANCA.

FIG. 11 NO. 1



ITALIAN FREIGHTER SUNK OFF CASABLANCA.
FIG. 11 NO. 2

placed on floats alongside the dock and divers tapped the suction pipes through the sides of the dock near the bottom of the tanks. The drydock was then pumped out in one operation.

One job done at Casablanca was interesting technically, though not of importance to clearance operations. It was a sunken lifting crane used for lifting sunken submarines. The crane had not been successful and was moored out of the way of the harbor and left for some years unattended; the plating had become paper thin. The structure looked like a drydock and was believed to be one, so the team was asked to raise it so that it could be used to increase the docking facilities of the harbor. If the dock was raised by pumping, the water pressure would crush the deteriorated sides. The amount of timber needed to shore the sides from the inside would have been prohibitive. Therefore the team embarked upon experimentation; the compartments would be pumped, but as the water level was reduced the air pressure would be built up to offset the water pressure outside the hull. The operation was attempted with one pound of air pressure per three feet of water pumped out and it worked. In order to prepare for the operation many holes in the top side had to be plugged and the suction to the pipe plugs had to be welded to the deck plating. Good sight vents, to relieve the air pressure as the structure lifted, also had to be provided. When the structure was finally raised it was found to be useless.

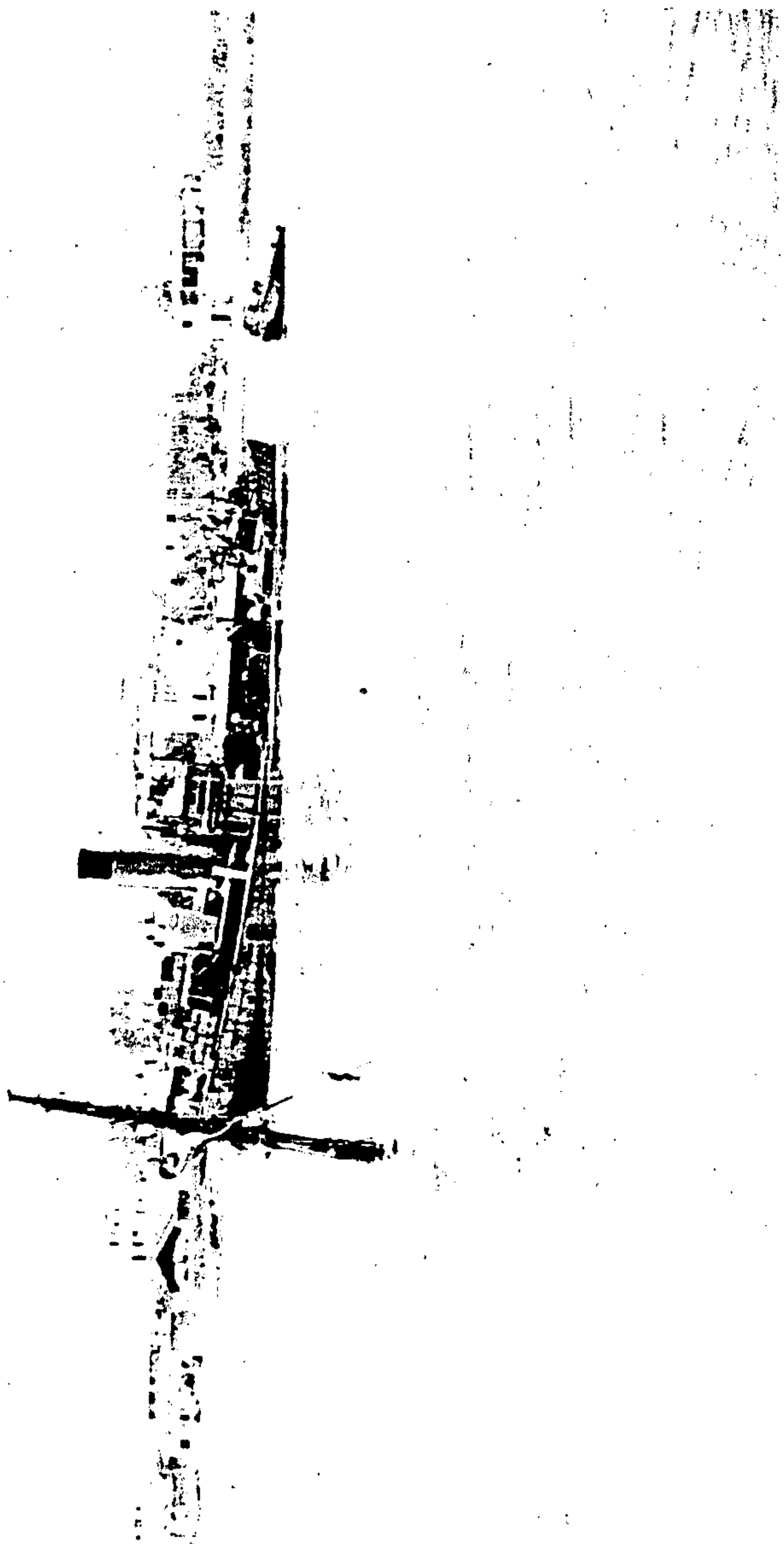
11.5. PORT LYAUTEY (KENITRA)

Seventeen ships were sunk in the river at Port Lyautey, 12 of which were small four-hatch, two-hold coasters. The holes in the bilges of the ships were not difficult to patch but this type of ship was difficult to keep from capsizing when pumping operations were in process. No large cranes or lift ships were available to help keep them upright. A few had sunk near the bank in shallow water and were floated without difficulty as they had to be pumped almost dry in order to obtain enough buoyancy for flotation. Those in the center of the channel presented a problem. It was solved by dragging them with heavy anchors and cable to shallower water. The ships were pumped enough to lighten them, but not enough to permit them to float until they reached the safety of the shallow water.

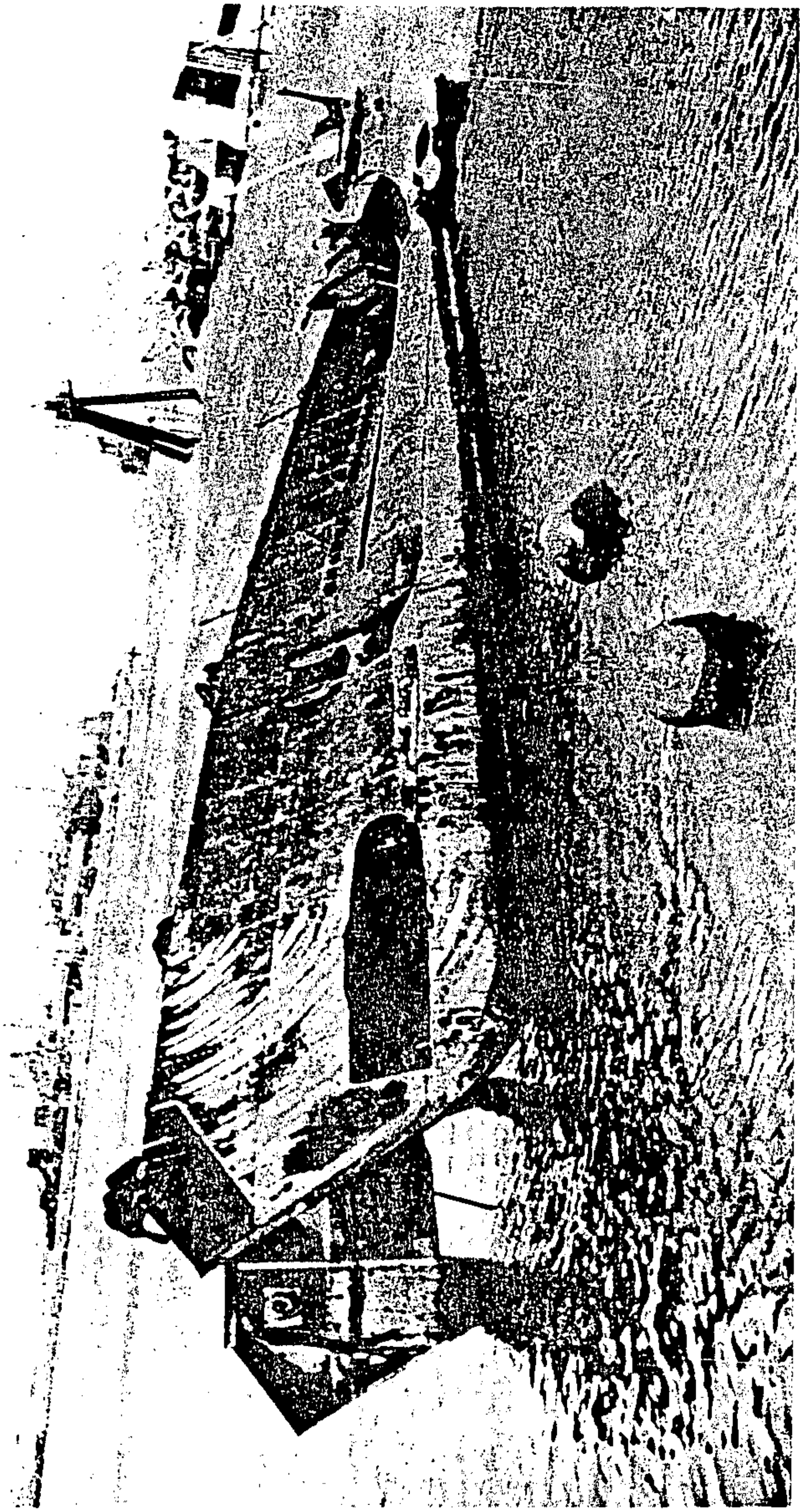
11.6 BIZERTE CHANNEL, TUNISIA

The clearing of Bizerte Channel was one of the most important operations conducted. The Germans were expected to block the channel before leaving Bizerte and the channel controlled the entrance of traffic into Lac de Bizerte. Plans for the invasion of Sicily were complete except for setting a date. The Lac de Bizerte was to be used for staging the landing craft and supply ships for the operation and no date could be agreed upon until it was known whether the channel had been effectively blocked, and if it could be cleared.

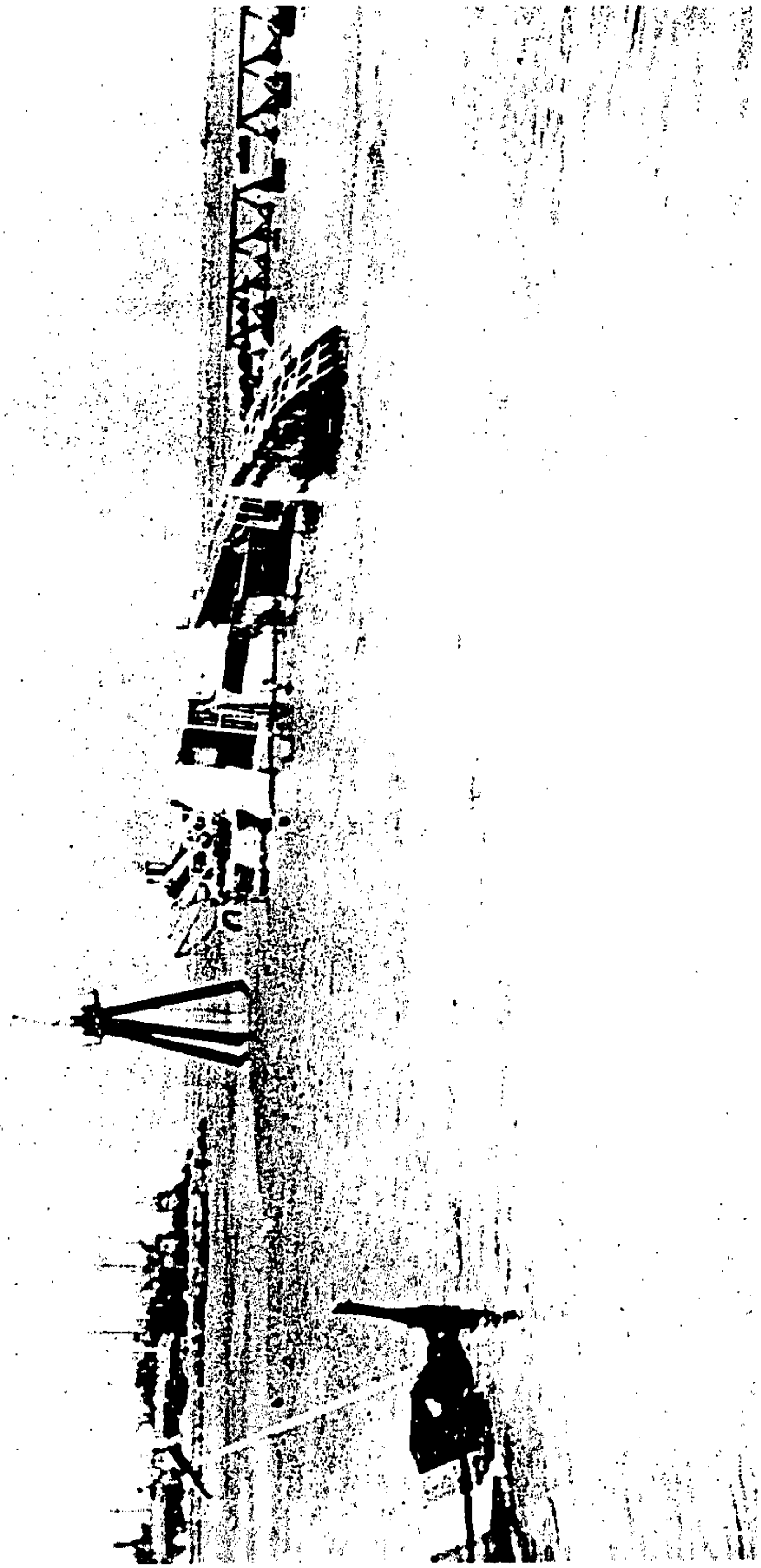
Considerable information had been gathered about the area, and a similar circumstance had been dealt with a year before at the Cape Cod Canal, and the plan had been to explode the ships into the bottom of the channel. It was hoped that the same method could be used in this instance. The Germans would undoubtedly block the channel to the best of their ability; the big question was whether they might,



WRECKS BLOCKING THE CHANNEL AT BIZERTE, TUNISIA.
FIG. 11 NO. 3



WRECKED SUBMARINE BLOCKING THE CHANNEL AT BIZERTE, TUNISIA.
FIG. 11 NO. 4



SUNKEN SHIP BLOCKING THE CHANNEL AT BIZERTE, TUNISIA.
FIG. 11 NO. 5

before sinking the block ships, fill them with sand bags with a sand and cement mixture which would harden underwater and make salvage very difficult. When Bizerte fell to Allied control, the salvage team entered with the military forces. The Germans had sunk 28 ships in the channel but fortunately all were empty. The current had destroyed the formation the Germans had laid the ships out in for sinking, and they were all piled together, some three ships deep. To blow the channel through, 180 tons of explosives were used. Salvors had to delay operations to let Liberty ships pass as soon as they had blown a passage wide enough to allow a ship through. The invasion of Sicily was slightly delayed, however, the clearance and the invasion were successful.

11.7. FERRYVILLE, TUNISIA

Ferryville was the French Naval Base at Bizerte. It was a modern facility and the drydocks there were in great demand for the repair of Naval and supply ships in the Mediterranean. Before leaving, the Germans blew the caissons of each of the six docks, however, they were easily repaired and put to use again.

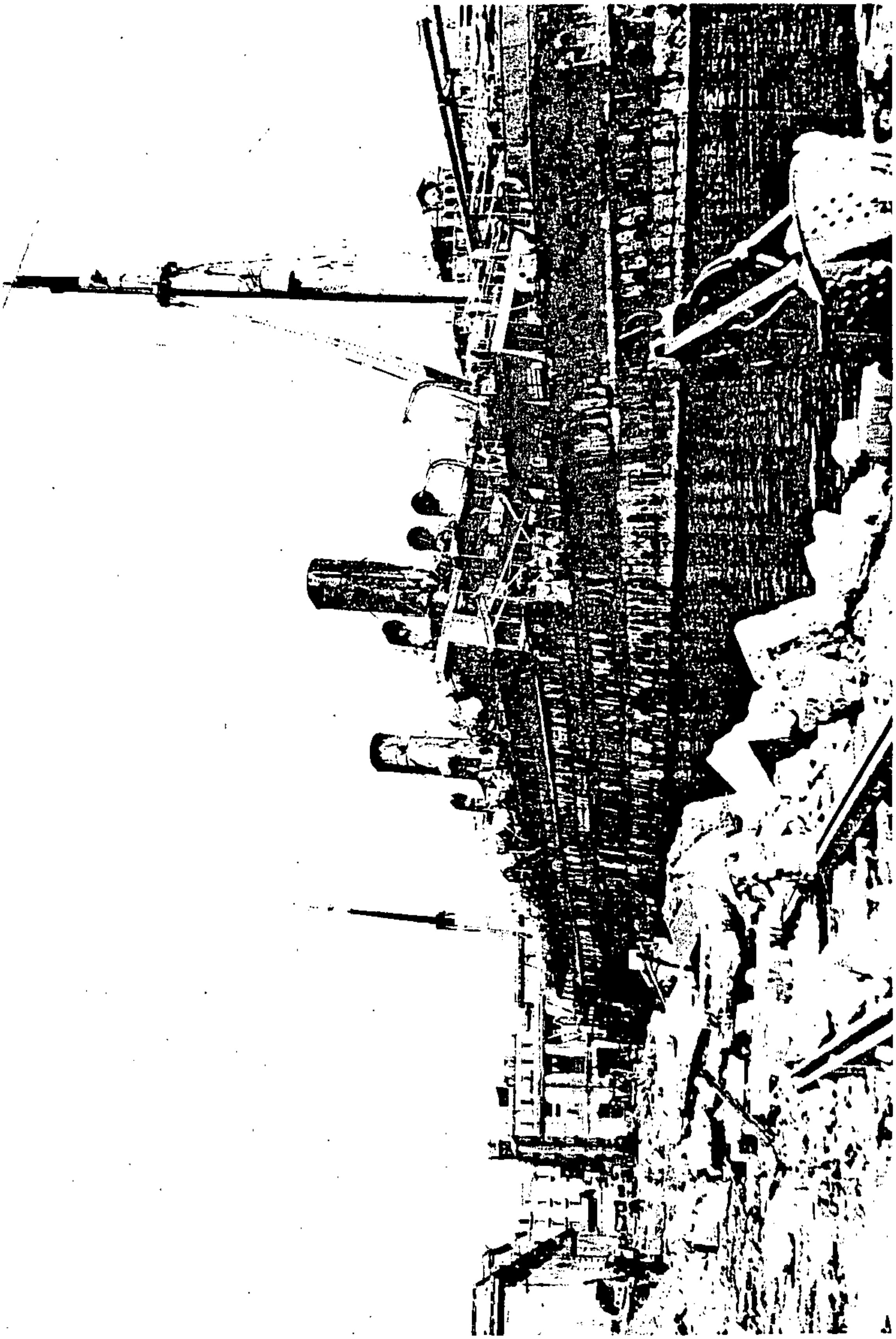
The most difficult job at Ferryville was the clearance of an old Italian ammunition ship which had been hit by one of the Allied bombs and blew up. The ammunition had been stored in the three holds forward of the machinery space, and the entire ship's structure in this area was demolished. The stern portion was intact however. It had been blown across the harbor about two-thirds of a mile and lay in front of the drydock area on shore, blocking the access to three docks. A considerable amount of work was necessary for the divers to patch the holes in the bulkheads and shell plating of the ship, but the holes in the stern section were patched and the ship was pumped out and removed.

11.8. PALERMO, SICILY

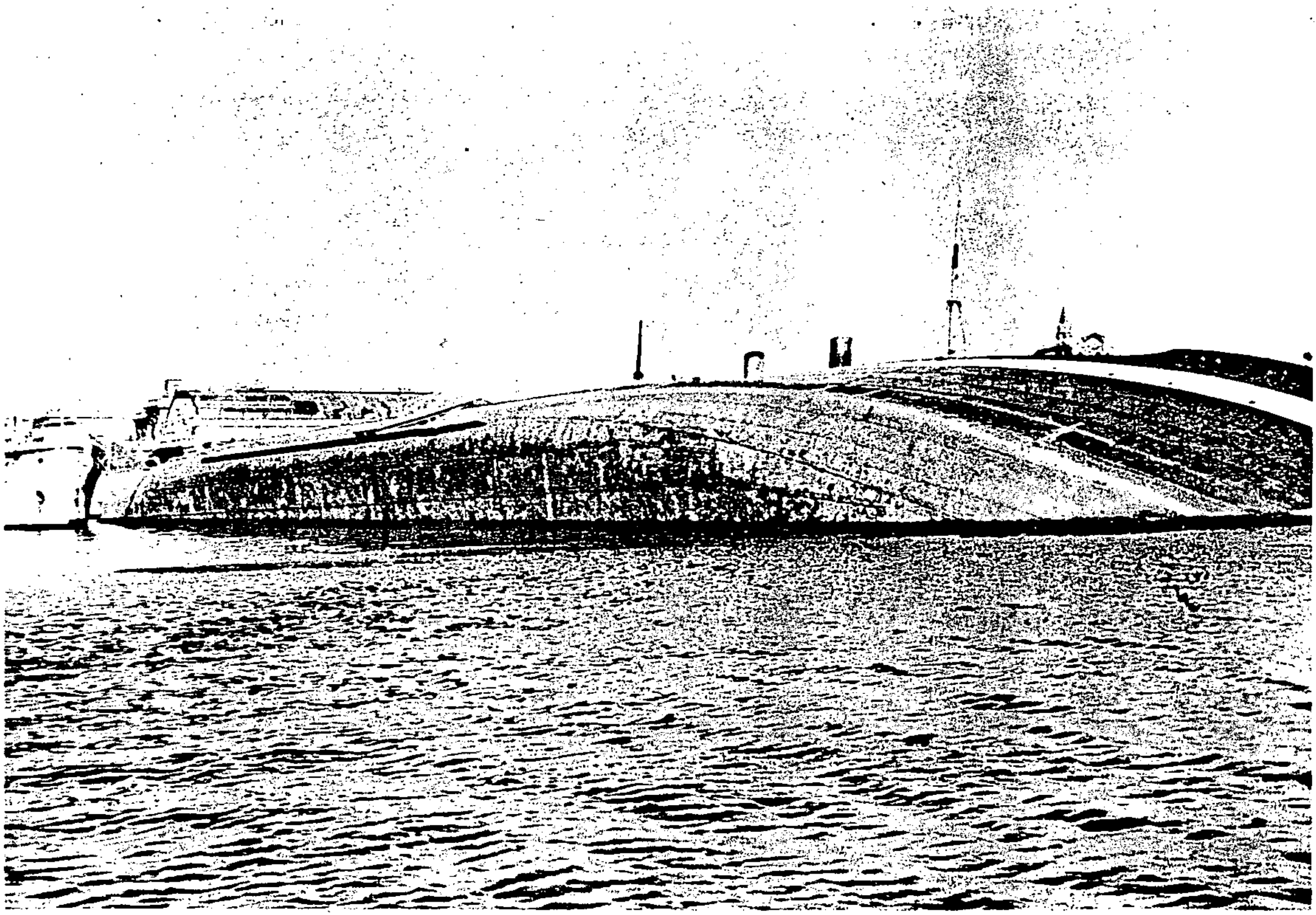
The ships sunk in Palermo were sunk as a result of Allied bombing. Many of them were alongside piers and as they were badly damaged the work required to remove them would have taken much longer than would be required to trim off their topside superstructure and extend the decks of the piers with timber shoring out over the wrecks. The second alternative was chosen.

A job of technical interest in Palermo was that of the caisson to a graving dock which was hit by a large bomb and broken in two. In the dock at the time was a large Italian destroyer and a spare caisson. The rush of water when the bomb hit knocked the spare caisson at the head of the dock over on its side, lifted the destroyer up, and capsized it on top of the caisson. The magazines of the destroyer were full of ammunition so the ship could not be cut up with either torches or explosives. The method chosen was to cut out the keel blocks from under the caisson and drag it from under the destroyer.

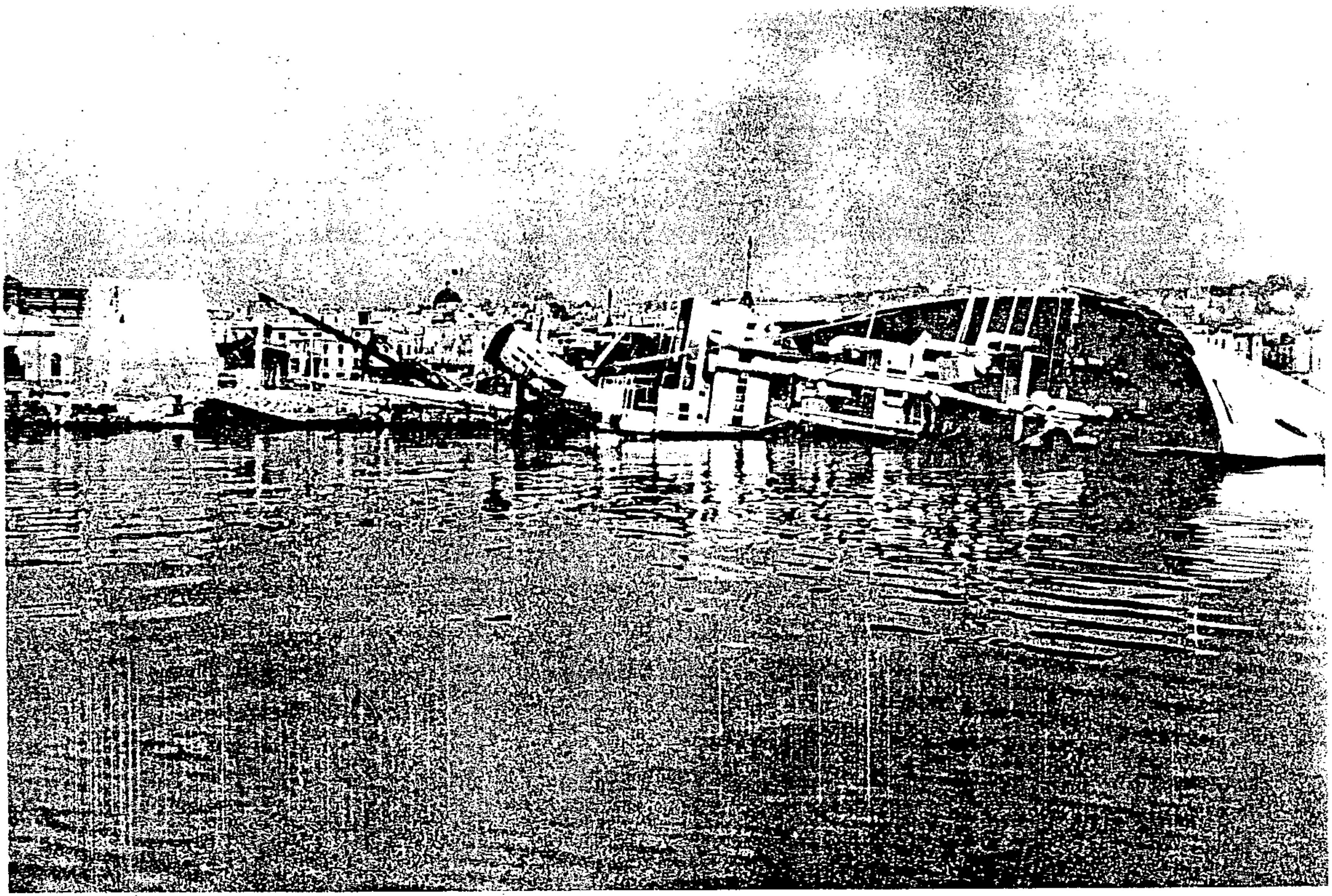
After this was done, the spare caisson was placed in position at the sill and the dock was pumped out. The destroyer was then patched and pumped.



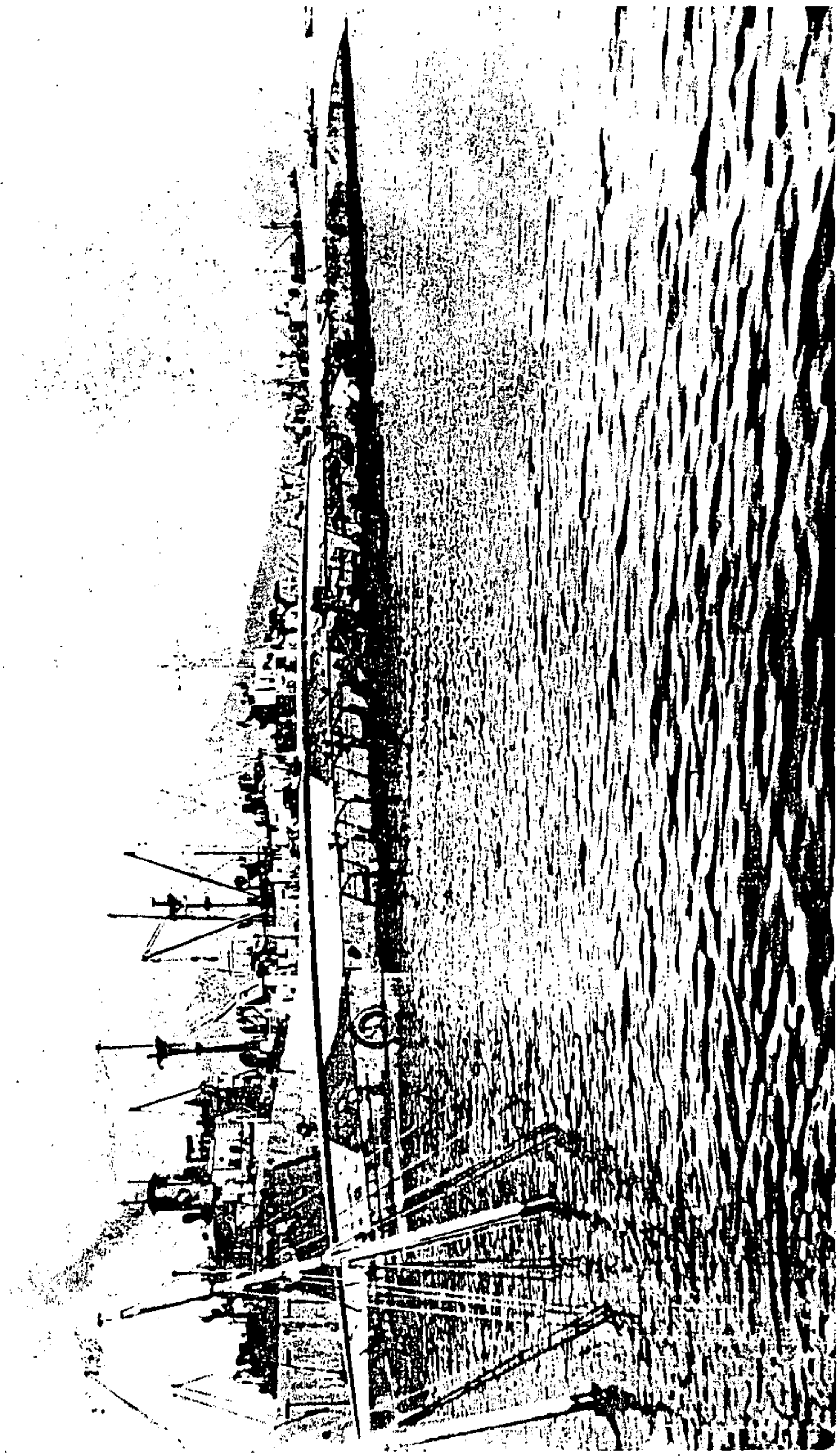
DAMAGED MOLE AND RAIL LINE. THE SHIP "RESOLUTE", DAMAGED, CAN BE SEEN IN THE BACKGROUND.
FIG. 11 NO. 6.



CAPSIZED HOSPITAL SHIP IN NAPLES HARBOR.
FIG. 11 NO. 7

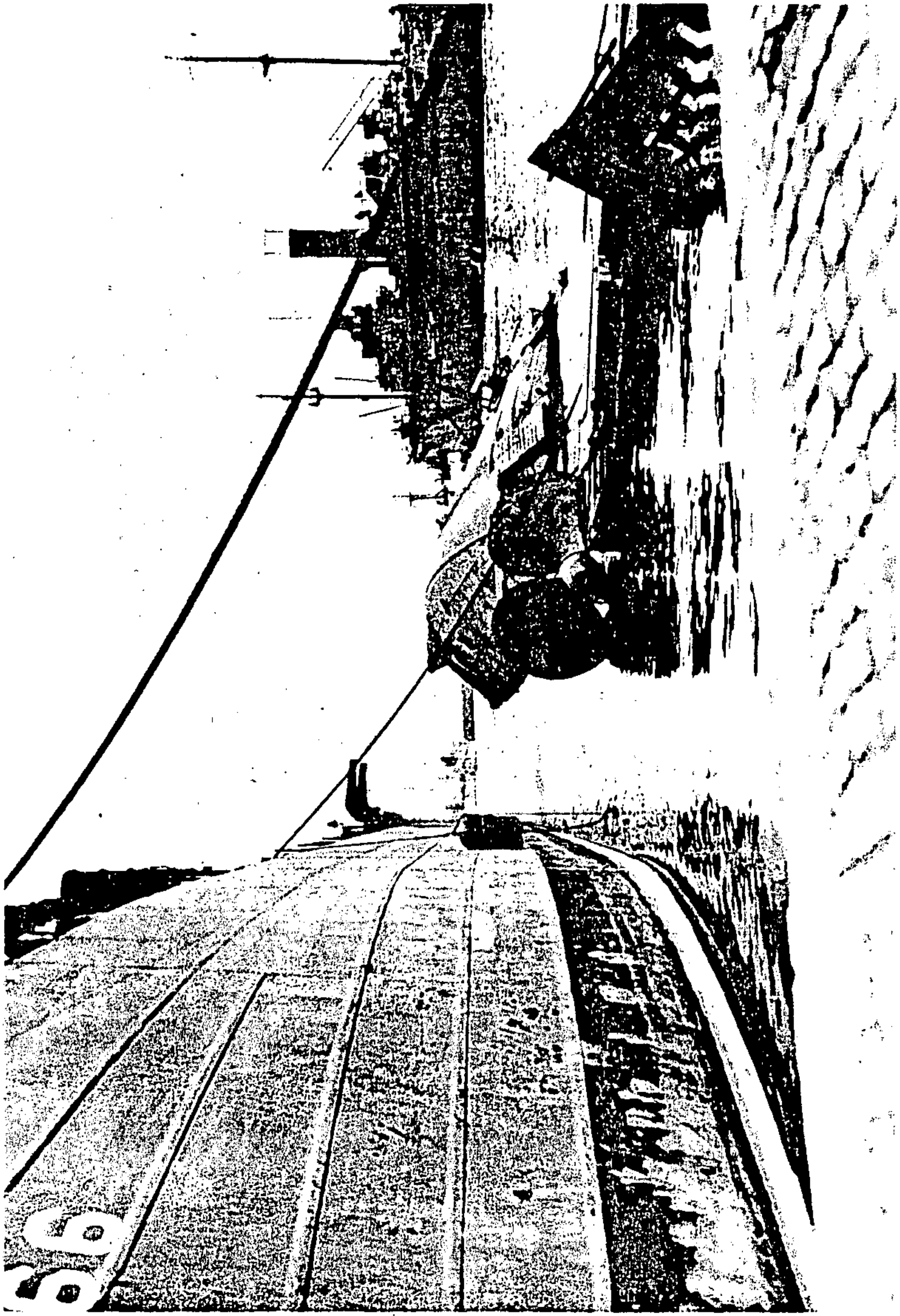


CAPSIZED SHIP IN THE HARBOR AT NAPLES.
FIG. 11 NO. 8



A CAPSIZED ITALIAN CRUISER OFF MOLE "B". MAST OF A SMALL BOAT YET TO BE REMOVED CAN BE SEEN. LST IN THE BACKGROUND IS USED TO UNLOAD VECHILES FROM TRANSPORTS.

FIG. 11 NO. 9



ITALIAN CRUISER SUNK AT MOLE "B".
FIG. 11 NO. 10

A problem that was encountered at Palermo, which afforded a valuable lesson to the salvage forces, was live ammunition at the bottom of the harbor that was part of cargos of undetonated ammunition of sunken ships. The worst of this ammunition were the land mines which had nearly neutral buoyancy and were washed along the bottom by tidal currents. Gradually the currents gathered the mines together and built up a bank which was dangerous to any underwater demolition or dredging. While using explosive charges to cut up a small steel schooner sunk in the harbor, a tremendous explosion took place that rocked the port. A section of nearby quay caved in for about 290 feet to a depth of 80 feet, and all ships at the docks broke loose from their moorings. It was later discovered that the build up of land mines on the banks had caused the explosion.

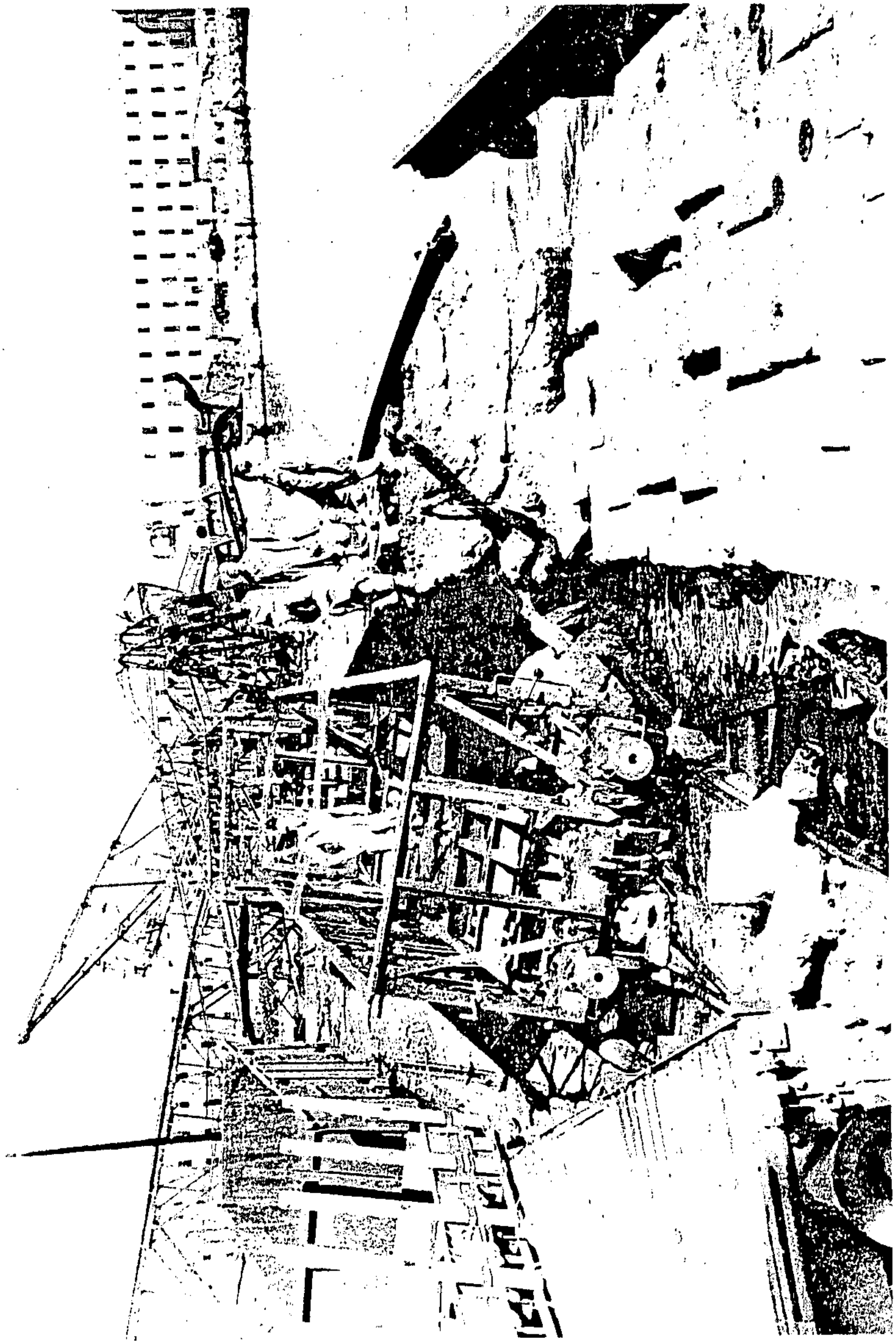
11.9. NAPLES, ITALY

The harbor clearance operation in Naples was the largest encountered up until that time. The task there was complicated by the number of ships involved and the urgency of the operation rather than the nature of the salvage task at hand. The clearance force at Naples was a joint British and American effort, and the forces amassed there constituted the largest unit used at any place in Europe. The British were in charge of the clearance of two large ships on the northern part of Naples Harbor. For their work they had the use of two British lift craft. In two weeks time they removed the wrecks of 84 fishing vessels of three or four masts each, two destroyers, two large tugs, and two tank barges. Twenty groups of divers were kept busy fitting slings under the wrecks, and the lift craft worked around the clock dragging the wrecks outside the harbor. One of the lift craft was a newly constructed ship with a capacity over the bow of 250 tons. The other was an older ship whose machinery was mostly inoperative. Both craft possessed large capacity air compressors which were valuable in securing extra lift by passing air hoses through all of the openings in the wrecks too heavy to lift with lifting gear alone. For the two destroyers, the two tugs and the two tank barges, the weight was largely carried by air.

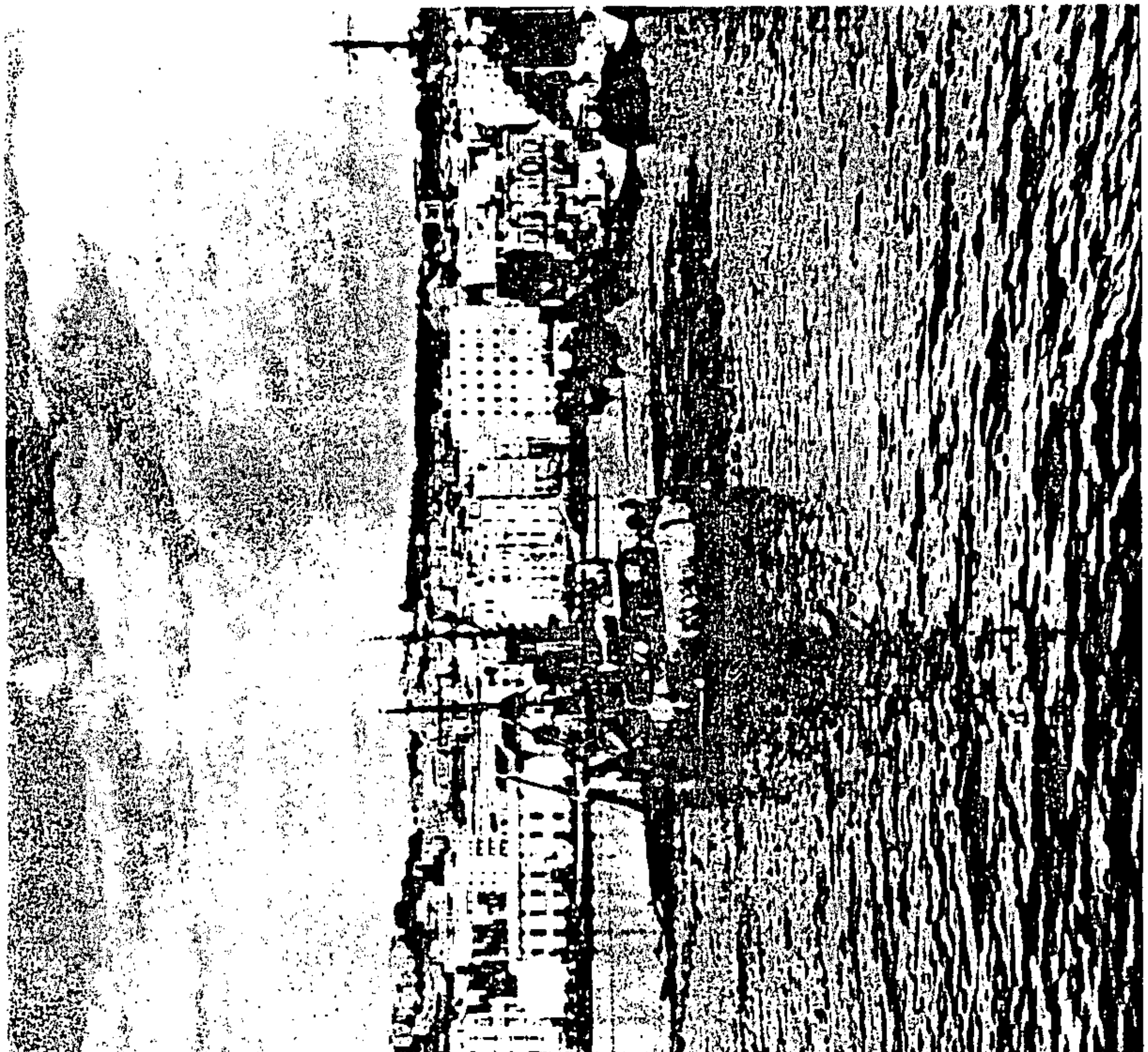
During the first two weeks American forces began clearing the wreckage of an Italian destroyer and a pontoon that formerly supported a 150-ton crane. Work was abandoned on both of these jobs because they seemed to offer too many difficulties. Before work was stopped on the destroyer, the salvage team had pumped air into it for almost a day. A few weeks later, after a storm, the bow and bridge sections of the destroyer appeared. Apparently the air had worked forward and the ship had righted itself during the storm. By pumping in a little more air, the lift craft were able to remove the hulk from the harbor that day. The pontoon had been so well sabotaged by the Germans that it took nearly a month of continuous underwater patching in order to raise it.

Another of the salvage operations encountered was the removal of structural debris resulting from German demolition of the dock cranes, girders that supported the roofs of various waterfront structures, and a number of vehicles, freight cars and locomotives run off the end of the docks. Using Army floating cranes and British derrick ships some 4,000 tons of debris were removed in a few weeks.

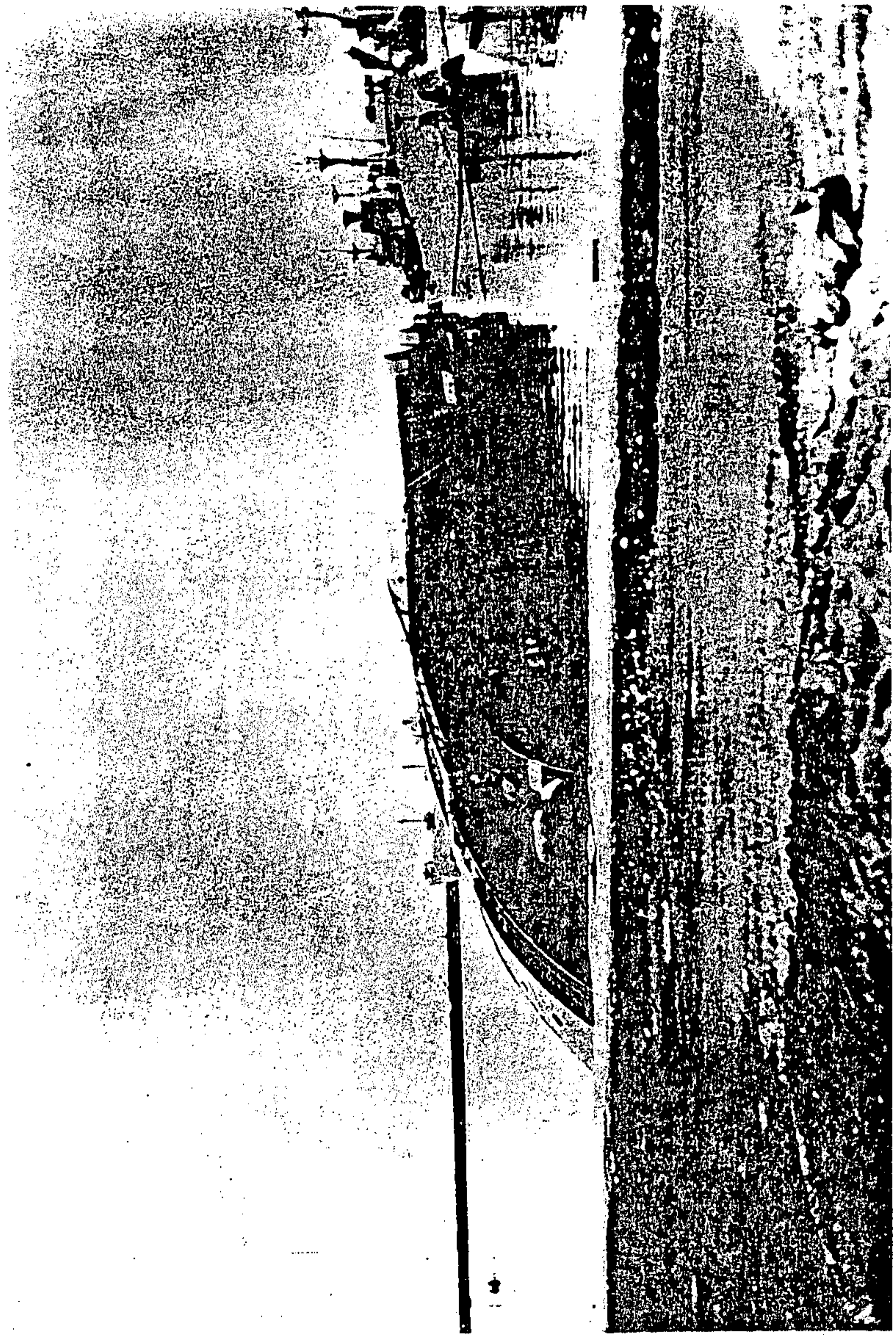
In no port previously cleared was the lack of efficiency of the German's sabotage more apparent than in Naples. For more than a week prior to Allied occupation in the harbor, the Germans had blown up



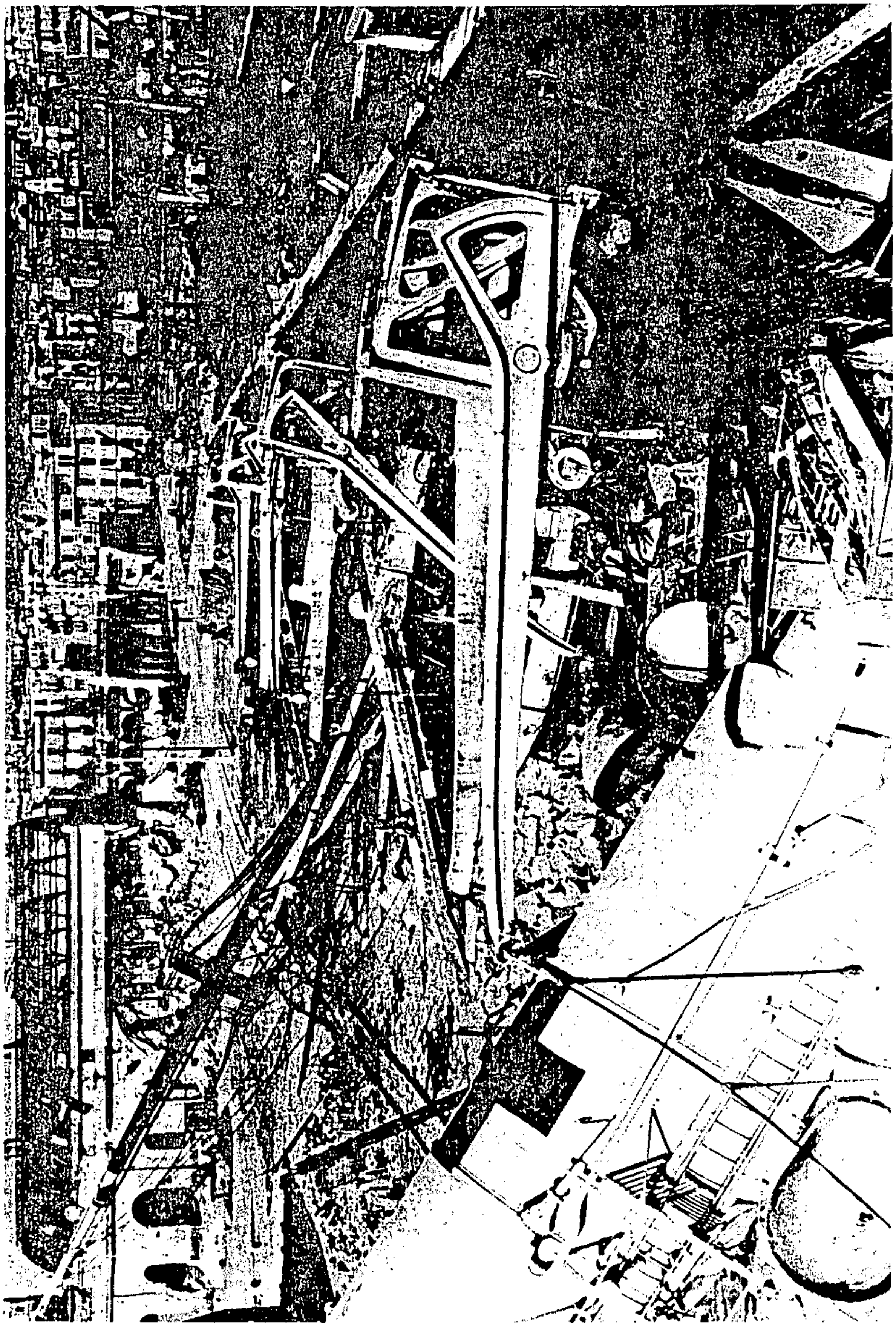
DOCKSIDE WRECKAGE IN NAPLES.
FIG. 11 NO. 11



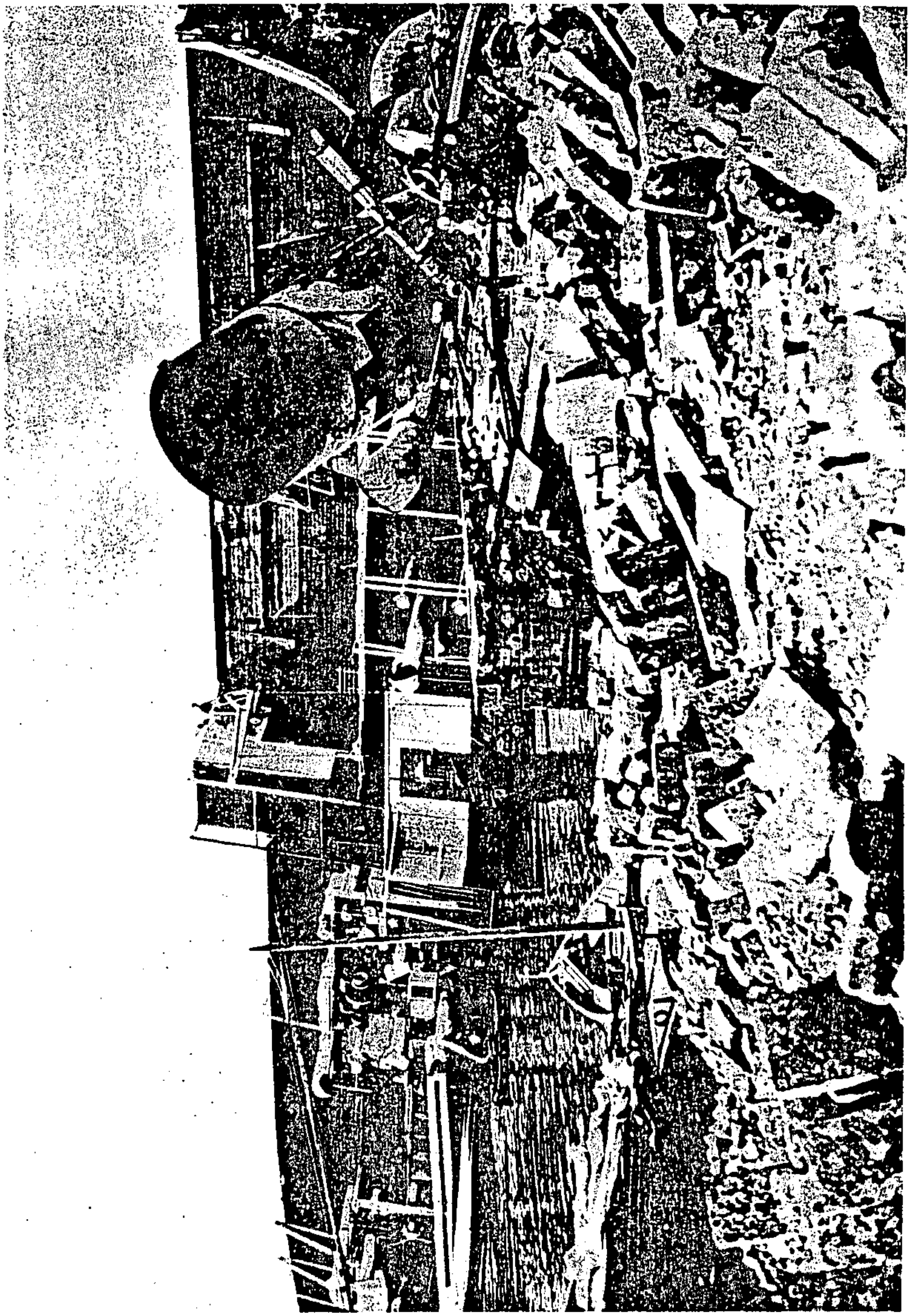
BRITISH LIFT SHIP WORKING IN NAPLES HARBOR.
FIG. 11 NO. 12



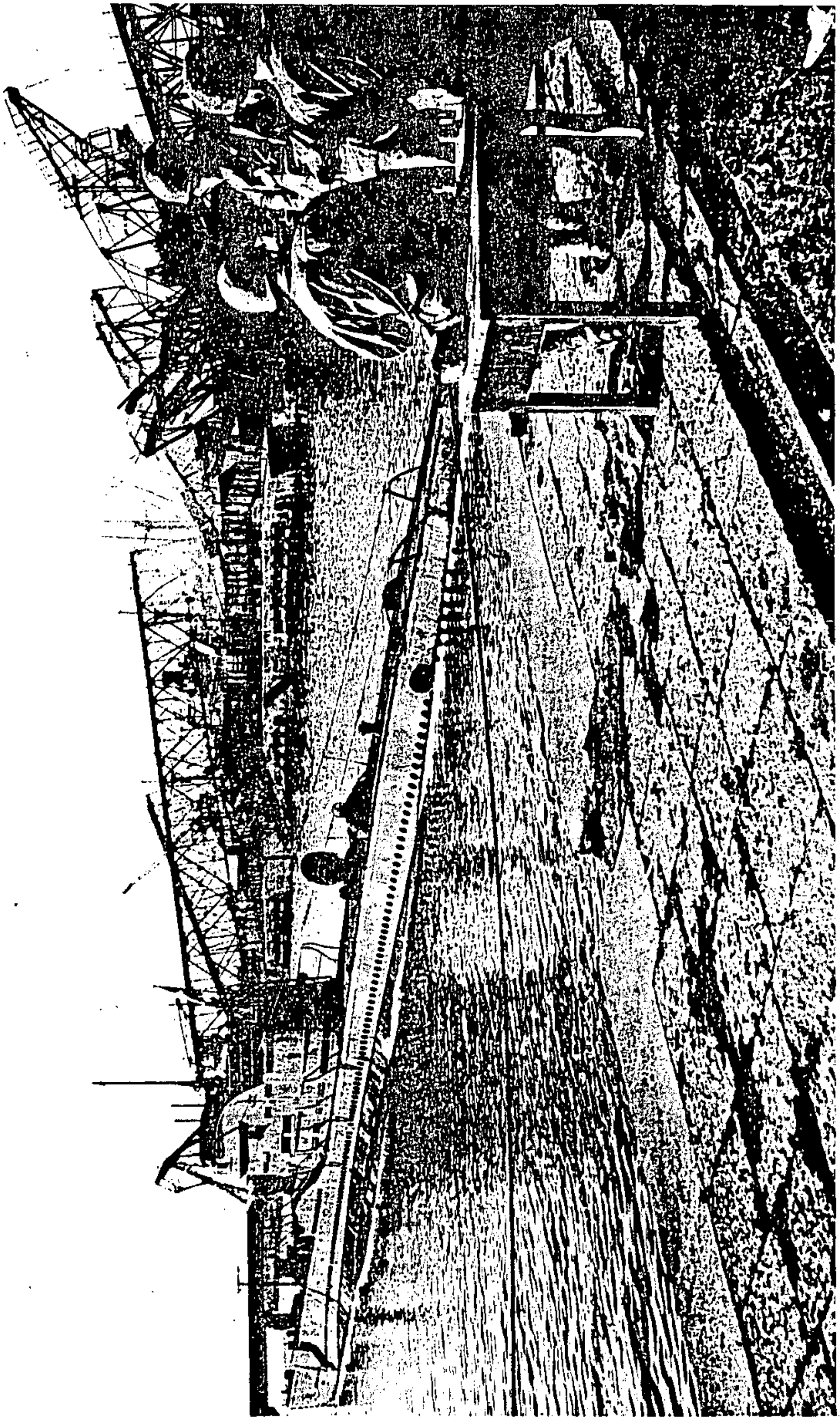
CAPSIZED GERMAN TANKER IN THE HARBOR AT NAPLES.
FIG. 11 NO. 13



SUNK HOSPITAL SHIP ALONGSIDE PIER "C".
FIG. 11 NO. 14



WRECKED HOSPITAL SHIP.
FIG. 11 NO. 15



U.S. ARMY SOLDIERS SURVEY DAMAGE IN NAPLES HARBOR.
FIG. 11 NO. 16

and burned waterfront installations and buildings. Although they accomplished an enormous amount of damage, they aided the Allied effort in several ways. A large slum area had cut off the access road north and south of Naples, and would have presented great difficulty to troop and support movement had the Germans not set fire to it. As it was, Allied forces soon bulldozed off the wreckage and built suitable access roads to the docks. By destroying the buildings on the piers, the Germans made the piers more suitable for the removal of cargo.

One last example of the inefficiency of the German demolition can be found in connection with the two graving docks which the Allies had hoped to use for berthing space. On a survey of the port they discovered the smaller of the two drydocks flooded, with an Italian destroyer sunk at an angle of 40 degrees and resting against one of the side walls. The caisson appeared to be nearly broken in two. Consideration was given to rehabilitate it, but as it seemed so much like the situation encountered at Palermo, the salvage team felt there was little chance of salving the dock. However, a while later they discovered the spare caisson for the dock moored alongside a pier, undamaged. Returning to the drydock they found that the caisson which had been blown up was occupying the inner sill, so the spare caisson was moved into the outer sill; with ten-inch salvage pumps they pumped the dock dry. The demolition of the first caisson had not been particularly successful and had merely blown out the diaphragm, not damaging the ballast tanks.

The larger graving dock was also flooded; four holes had been blown in two of the ballast tanks, but the holes were small and a team of divers patched them in only a few days. The dock was pumped dry as before with ten-inch salvage pumps. The dock contained two large coasters and a spare caisson. The ships and caissons had been damaged also, but were quickly patched, and the docks were used as unloading berths for two Liberties. Timber platforms were built over the alters along one side of the dock on a level with the railway for cargo removal.

11.10. CHERBOURG, FRANCE

The salvage operations at Cherbourg were not extensive or complicated. There were only about 120 craft sunk in this harbor. The largest was a 17,000 ton Norwegian whale factory ship; most of the craft sunk were barges. A few of the barges were made of reinforced concrete and these were difficult to salvage as they broke up when an attempt was made to lift them with lift craft.

Harbor clearance operations at Cherbourg were hampered by mines the Germans had left in the harbor. It took about a month of work to clear the mines before they could risk bringing in the lift craft, floating cranes or pontoons.

Only two operations at Cherbourg were of technical interest. One was a coaster which was blocking an important slip; the ship displaced about 4000 tons and was lying on its side with 12 feet of water over the high side. The plating of the ship was badly deteriorated as it was sunk before the war. The only practical means of lifting the ship seemed to be the use of lift craft with a compressed air supplement. However when this was attempted, the air leaked from thousands of small holes and one large hole blown in the side. This large hole was patched with concrete and the smaller holes were patched with toothpicks. The salvors ran into great difficulty finding sufficient toothpicks to do the job. They were finally able to build up a large air bubble inside the ship, and three lift craft dragged the ship from the way of the slip.

The second job of interest was the wreck of a German barge which had sunk and partially capsized when it was loaded with mines to be placed in the harbor. The mines were in the holds as well as on deck. They were acoustic, magnetic, contact and snag mines, and they had piled up when they spilled out on the lower side of the deck and lower bilge. If the mines were removed from the water they might have detonated, so the salvage plan was to remove the mines before attempting to raise the barge. A diver removed the detonators from a large number of the mines first and then they were raised by a dock crane. After a number of the mines had been removed in this manner, it was reported that the detonators were still in the retracted position; the remainder could be removed without disarming them. When all the mines had been removed, the barge was towed out to sea and disposed.

The most valuable area of Cherbourg Harbor to the Allies was the unloading area in the three basins of the harbor, which was serviced by a good railway system. The Germans successfully blocked the entrance to one of the basins, unusable because it was not wide enough to permit the passage of modern ships; the salvage team left the German blockade there. The other basin entrances were quickly cleared as the Germans had sunk ships randomly and spaced them far enough apart so that the lift ships could work around them. Had the Germans given more consideration to their efforts of disabling the port they could have denied the use of the harbor to the Allies for a long time.

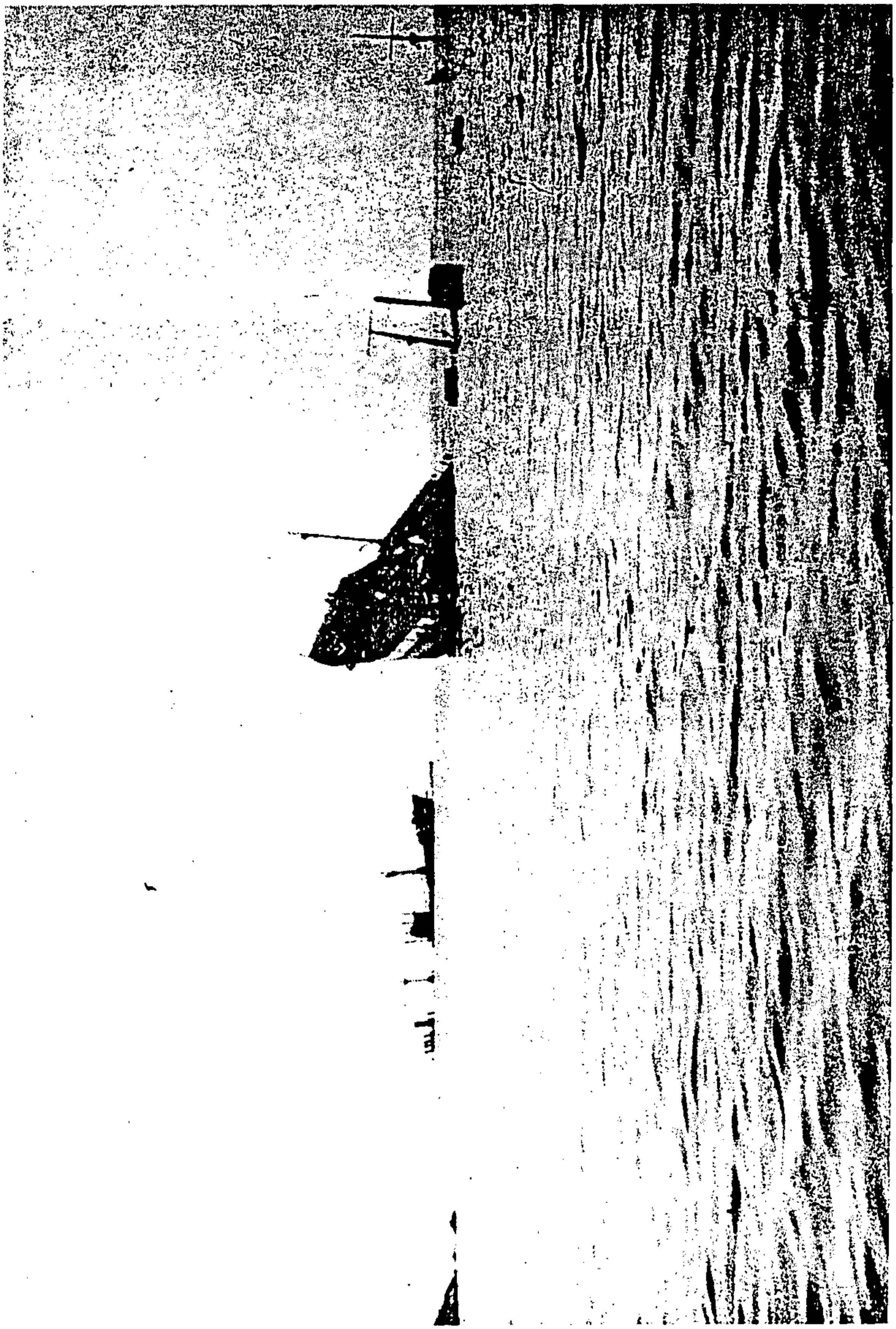
11.11. MANILA, REPUBLIC OF THE PHILIPPINES

The number of ships sunk at Manila was larger than that encountered anywhere in Europe. The salvors had to handle about 750 wrecks before Manila Bay was back in business for the Allied forces.

Work at the beginning was hampered by Japanese suicide squads which would hide out in wrecks until salvage parties came aboard for surveying. They would then rush out with grenades, rifles, and machine guns. Several men were injured or killed the first week, and finally a program for cleaning out the nests of Japanese had to be implemented. The wrecks were cleared out, one by one, and three days passed before it was considered safe enough to resume salvage operations.

The Japanese had successfully blocked the entrance to Manila Harbor by blowing up the magazines of four 700 to 900 ton displacement ships, and sinking them in strategic locations. The wrecks were so badly damaged that compressed air could not be used to lift them, no lift craft were available, and the water at the entrance was too rough to consider cofferdamming. The salvors were very fortunate to find one ship which still had enough deck plating so that divers could afix plate patches to some of the damage. They were then able to pump enough compressed air into the ship to enable them to drag it out of the harbor entrance with heavy anchor rigging on one of the salvage vessels. They lined the sides of the other three ships with a single or double row of Seabee pontoons secured to holes cut in the sides of the ships with one-inch chain. To the buoyancy they obtained by the use of the pontoons,

FIG. 11 NO. 17
NORTH HARBOR AND PASIG RIVER ENTRANCE, MANILA.



ENTRANCE TO THE MAIN HARBOR AT MANILA. SEVERAL BLOCKSHIPS CAN BE SEEN.

FIG. 11 NO. 18

they added all the floating cranes and pontoons they had available. They were able to lighten the wrecks enough to drag them out of the channel using a salvage vessel pulling with beach gear laid out on deck.

The largest number of vessels raised were the "Sugar Charlies", wooden freighters built in various sizes. The "Sugar Charlies" sunk when empty were easily raised, but the ships with cargos, especially ammunition, were more difficult. The salvage teams raised nearly one hundred of them.

A new method of salving ships was developed at Manila Harbor during this operation. A number of inter-island ships, the construction of which would not lend itself to the use of compressed air or cofferdamming, were scattered about the harbor. Lift craft could have handled the ships, but as they were not available serious consideration had to be given to an alternative method. It was finally decided to blow off the masts and some of the deck houses of the inter-island ships, and use derricks and pontoons to roll them upside down. They were then floated out on compressed air.

Another makeshift method was used when pumping out coasters with poor stability. These ships were usually sunk with a list and so a large tank was secure to the high side and partially filled with water so it would just stay afloat. The tank was secured with two sets of purchase gear to heavy girders installed projecting over the deck of the ship. The weight of the tank was used to keep the list of the wreck from increasing; by manipulating the purchase gear the salvors were able to keep the list from five to fifteen degrees away from the tank. The rig worked successfully, however, it is definitely not recommended where time and place would facilitate other means.

In Manila the problem of unexploded ammunition was once again encountered. Fortunately most of the unexploded ammunition had settled into the deep layer of fine silt on the harbor bottom, to a depth below that which the salvage teams worked. However, before the operations were over, an Army dredge was lost when it sucked up a large bomb from the bottom and detonated it. In another incident a derrick barge dropped anchor right on top of a bomb or shell and set off an explosion which blew the anchor out of the water, but did no damage to either the anchor or derrick.

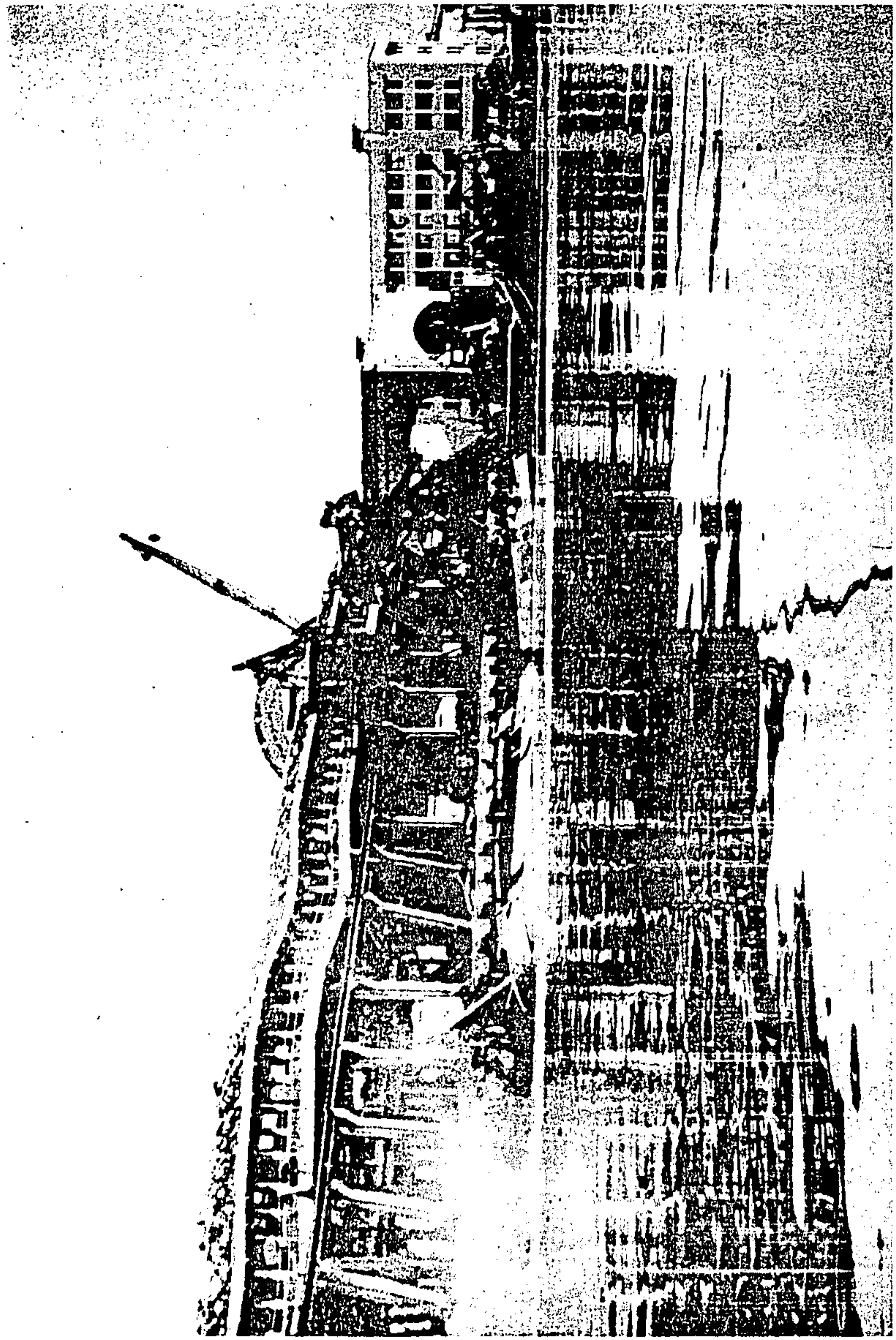
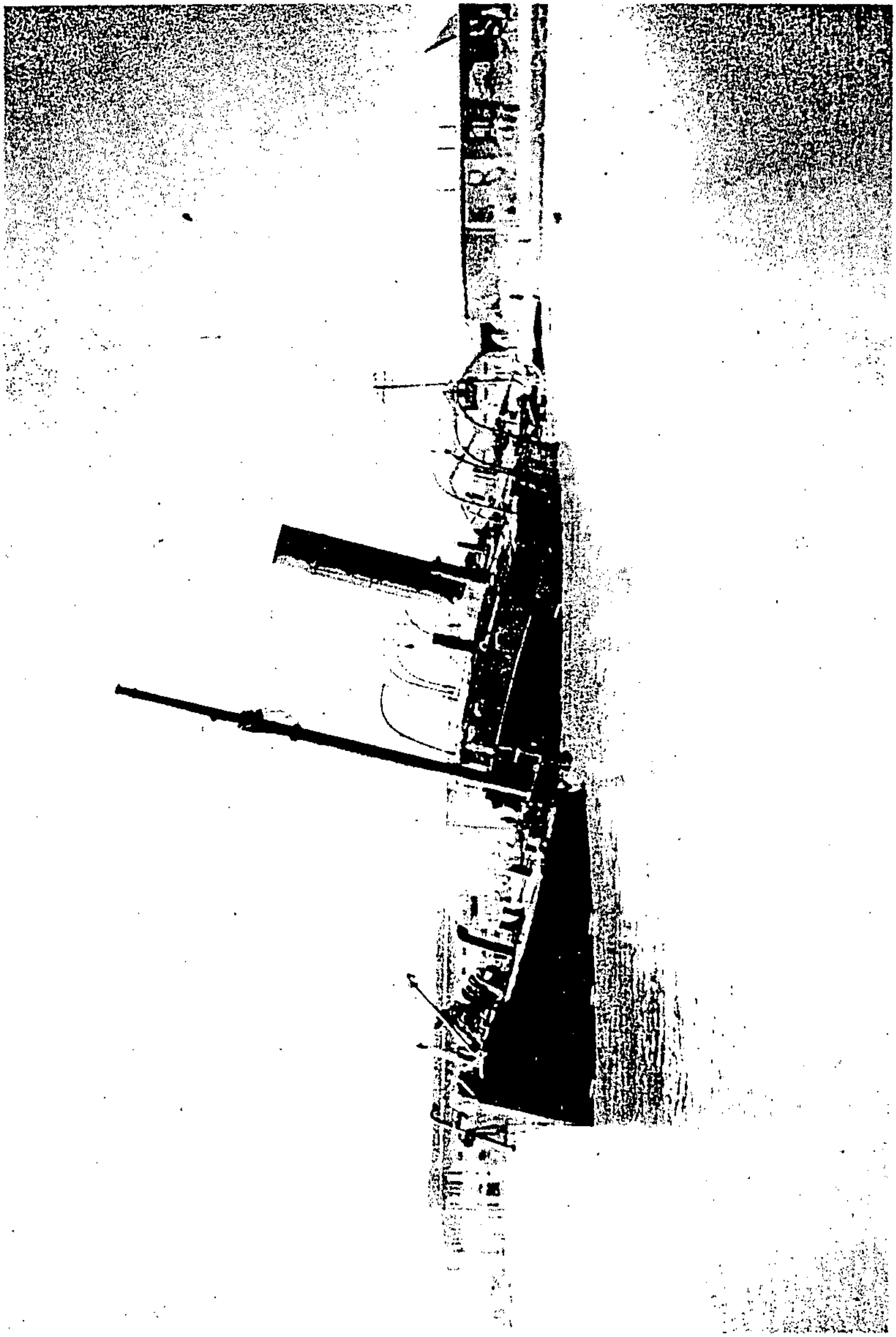


FIG. 11 NO. 19
WRECKAGE OF PIER NUMBER 7, SOUTH SIDE, MANILA.



BLOCKSHIP IN THE PASIG RIVER, MANILA.
FIG. 11 NO. 20

12. PEARL HARBOR

12.1. BRIEF

The notable work performed at Pearl Harbor is a necessary inclusion in any book on harbor clearance, and is important in itself for several reasons.

Obviously the total magnitude of the operation far exceeded any ever undertaken; a number of salvage problems were faced and mastered in unique ways. However, an important lesson the military salvor can learn from Pearl Harbor is that the operation was essentially salvage first and harbor clearance second. The initial estimation of damage and the prospects of salving the lost ships was pessimistic. In no case was it necessary to use emergency cut-and-remove or demolition harbor clearance techniques; in all cases a well-engineered and carefully planned salvage program was developed and then executed by talented, well-supervised men.

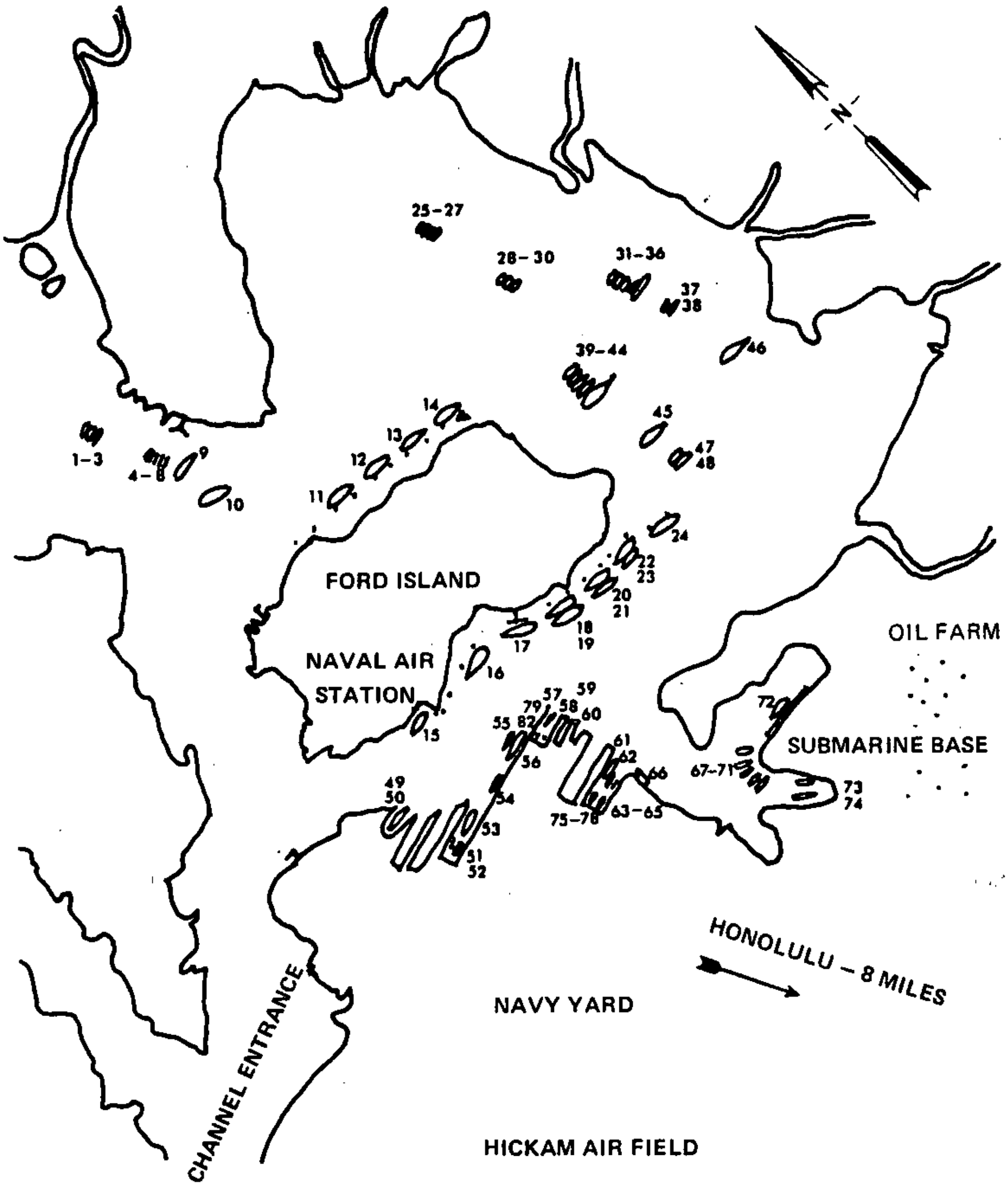
NOTE: We are indebted to the excellent work, and record of Vice Admiral Homer N. Wallin, USN (Retired). His Article "Rejuvenation at Pearl Harbor" and the book *Pearl Harbor: Why, How, Fleet Salvage and Final Appraisal,* were important in the preparation of this brief on Pearl Harbor salvage operations.

Through the efforts of the salvage teams assigned to the task of clearing Pearl Harbor, most of the ships sunk or disabled were subsequently recommissioned. The overall effect of the Japanese attack at Pearl Harbor was minimized, and the rehabilitated Fleet was able to continue operations throughout World War II to assist the Allied forces in their ultimate success.

12.2. 86 SHIPS PRESENT – 9 WERE SUNK

What occurred before and after the attack is well recorded. We know, for instance, that of 86 naval vessels in the harbor during the attack only 9 were sunk and 10 others damaged severely. True, five of our battleships and one large target ship rested on the bottom of the harbor which was dredged to a depth of about 40 feet; three destroyers were sunk in drydock. The total count by number, type, and nature of damage was as follows: *ARIZONA*, battleship, struck by one torpedo (possible) and about eight bombs of various sizes. One large bomb, of about 2000 pounds armor-piercing, apparently entered the powder magazines forward and caused the virtual disintegration of the forward half of the ship. A terrific oil fire burned for two days. Inasmuch as the torpedo hit has not been confirmed, it is likely that the *ARIZONA* was destroyed by bombs alone.

OKLAHOMA, battleship, struck by about four aerial torpedoes causing a very rapid inflow of water which resulted in the capsizing of the vessel in about eleven minutes. The ship rested on the bottom at an angle of about 150 degrees from upright. Only a small segment of the bottom and the starboard bilge were visible above the water.



1. RAMSEY
2. GAMBLE
3. MONTGOMERY
4. TREVER
5. BREEZE
6. ZANE
7. PERRY
8. WASMUTH
9. MEDUSA
10. CURTIS
11. TANGIER
12. UTAH
13. RALEIGH
14. DETROIT
15. AVOCET
16. CALIFORNIA
17. NEOSHO
18. MARYLAND
19. OKLAHOMA
20. TENNESSEE
21. WEST VIRGINIA
22. ARIZONA
23. VESTAL
24. NEVADA
25. MONAGHAN
26. FARRAGUT
27. DALE
28. HENLEY
29. PATTERSON
30. RALPH TALBOT
31. WHITNEY
32. CONYNGHAM
33. REID
34. TUCKER
35. CASE
36. SELFRIDGE
37. HELM
38. BLUE
39. DOBBIN
40. HULL
41. DEWEY
42. WORDEN
43. McDONOUGH
44. PHELPS
45. SOLACE
46. PHOENIX
47. ALLEN
48. CHEW
49. SHAW
50. YFD-2
51. CASSIN
52. DOWNES
53. PENNSYLVANIA
54. CACHALOT
55. OGLALA
56. HELENA
57. ARGONNE
58. SACRAMENTO
59. JARRIS
60. MUDFORD
61. RAMAPO
62. NEW ORLEANS
63. SAN FRANCISCO
64. ST. LOUIS
65. HONOLULU
66. BAGLEY
67. NARWHAL
68. DOLPHIN
69. TAUTOG
70. THORTON
71. HULBERT
72. PELIAS
73. SUMNER
74. CASTOR
75. GREBE
76. SCHLEY
77. SICARD
78. PRUITT
79. TRACEY
80. PREBLE
81. CUMMINGS
82. RIGEL

0 ½ 1 MILES 2

LOCATION OF SHIPS IN PEARL HARBOR ON 7 DECEMBER 1941.
FIG. 12 NO. 1

CALIFORNIA, battleship, was struck by two aerial torpedoes and one bomb. Another bomb which was a near-miss exploded close aboard and opened a large hole in the ship's port side. Another near-miss fell off the starboard bow but caused only minor damage. The *CALIFORNIA* stayed afloat for over three days but gradually settled until her main deck aft was about 17 feet underwater.

WEST VIRGINIA, battleship, was struck by seven aerial torpedoes and two bombs. The ship sank rapidly and rested on hard bottom. Fire damage throughout the ship was severe.

NEVADA, battleship, was struck by one aerial torpedo and five bombs of various sizes. The vessel was able to get underway but the continued inflow of water necessitated beaching her near the entrance channel to Pearl Harbor. She was severely damaged by fire.

UTAH, an old battleship used as an aerial target, was probably struck by three torpedoes. The vessel capsized and came to rest on the bottom 165 degrees from the upright position.

PENNSYLVANIA, battleship, was in drydock and was struck by one medium-sized bomb which caused considerable topside damage and a number of personnel casualties.

MARYLAND, battleship, was struck by two bombs forward which caused considerable flooding and trimmed the bow down about five feet.

TENNESSEE, battleship, was struck by two large bombs which caused minor damage to one turret and several major caliber guns. The limited damage was due to low orders of detonation. The ship suffered serious damage aft due to oil fire on the water near the *ARIZONA*.

HELENA, light cruiser, was struck by one aerial torpedo which caused destruction of about half of the main machinery, and considerable flooding.

OGLALA, minelayer, was struck by the pressure wave from the explosion of the aerial torpedo which struck the *HELENA*. The side of this 40 year old vessel was opened up, and uncontrolled flooding caused her to capsize and lie on her side in 40 feet of water.

HONOLULU, light cruiser, suffered side damage from the near-miss of a medium-sized bomb, causing considerable flooding and damage to electrical wiring.

RALEIGH, light cruiser, was struck by one aerial torpedo amidships which destroyed about half of the main machinery. One bomb hit aft causing extensive flooding.

VESTAL, repair ship, was struck by two bombs causing considerable local damage and serious flooding aft.

CURTISS, aircraft tender, was struck by one large bomb which caused serious local damage. Also one Japanese plane which had been hit by anti-aircraft fire crashed into a crane on board *CURTISS* and caused some damage.

SHAW, destroyer, was struck by three small bombs which caused great damage including the blowing up of the forward magazines, thus wrecking the forward third of the ship. The vessel was on a floating drydock at the time of the attack.

FLOATING DRYDOCK NO. 2 was struck by five bombs which destroyed its watertight subdivision and caused it to sink to the bottom together with the destroyer *SHAW* and the small yard tug *SOTOYOMO*. *CASSIN* and *DOWNES*, destroyers, were docked abreast of each other in a graving drydock. These vessels were struck by three small bombs which exploded on the bottom of the drydock. Hundreds of fragments caused very extensive damage to the hulls and started oil fires which grew to great intensity. The combination of bomb explosions, oil fires and flooding caused the *CASSIN* to fall off the blocks against the *DOWNES*. The first appraisal indicated that these two vessels were total losses.

12.3. EARLY ESTIMATE OF THE SITUATION

The prompt arousal of the natural fighting spirit possessed by Americans following the shock of infamous attack was paralleled by the immediate action toward ship repair and ship salvage. The fine organizational procedures in the Navy were brought into full play at once. The higher brackets of command were furnished from various sources, well-considered estimates of the situation as regards extent of damage, time required for repairs, prospects of salvage, etc. The purpose of the high command was to accomplish the following:

1. To make immediately available to our intact task force at sea all of the undamaged or lightly damaged warships in Pearl Harbor.

2. To complete as soon as possible the regular overhauls which had been underway on a number of vessels assigned to the Navy Yard, Pearl Harbor.

3. To expedite repair of damages to ships not too badly hurt in order that they might be able to fight at the earliest possible date.

4. To lay out a long range program for the refloating and rehabilitation of vessels which had been sunk or seriously damaged.

The ships with minor damages received first attention and were given the utmost priority.

12.4. START OF SALVAGE OPERATIONS

Salvage and rescue work began immediately following the attack, as was necessary to keep ships afloat and to prevent them from capsizing. Ships' crews worked day and might in damage control parties to prevent the spread of flooding, to reduce lists, to jettison topside weights, to fight fires, and to make essential repairs to keep ships' machinery and equipment in operation. Aid and assistance were furnished from other vessels, particularly repair ships and tenders. Civilian personnel from the Navy Yard assisted, as did other civilian personnel drawn from contracting firms.

Tugs like the *ORTOLAN* and *WIDGEON* which had great pumping capacity were invaluable. Other small craft aided wherever practicable. The lowly garbage lighter *YG-16*, sometimes nicknamed the "Violet", won commendation for its 36-hour vigil fighting oil fires.

The *VESTAL* and *RALEIGH* – While the officers and crew of all ships applied themselves to their jobs, mention should be made of the *VESTAL* and the *RALEIGH* as outstanding cases of successful damage control work and consequent self-preservation. The *VESTAL*, a repair ship, was tied up alongside the *ARIZONA* when the attack began. This ship was struck by several bombs and eventually the Commanding Officer was blown overboard from the bridge by the concussion of a severe explosion on the *ARIZONA*. He swam back to his ship, got her underway, and successfully beached her to prevent sinking.

The *RALEIGH* also put up an ideal fight for self-preservation. Due to torpedo and bomb damage a large portion of the vessel was flooded and she was in imminent danger of capsizing. Every measure and artifice known to damage control personnel was utilized to keep her afloat and upright, including the removal of topside weights, many of which were thrown overboard but recovered later by divers.

The *CALIFORNIA* – The damage to the *CALIFORNIA* was extensive, but strenuous efforts were made in order to keep her afloat. At one time it seemed probable that she might capsize as had the *OKLAHOMA* and *UTAH*, but this was prevented by appropriate remedial action by the Commanding Officer and the damage control organization. It was only the lack of adequate pumping capacity which prevented the saving of the *CALIFORNIA*. In spite of valiant efforts the flooding of the ship gained headway and soon all power was lost due to general flooding and to heavy smoke in the fire rooms. This originated from a serious fire on board. After three days the ship finally sank and rested on the bottom. It had been predicted that the soft nature of the bottom would not support the weight of the vessel and that she probably would sink out of sight. Fortunately however, the *CALIFORNIA* finally stopped sinking when her main deck was about 17 feet underwater with a list to port of 5½ degrees. No more strenuous effort had ever been made to keep a vessel afloat.

Ordnance Material – On 7 December a start was made to remove from severely damaged ships, all of the anti-aircraft guns which could be more advantageously used elsewhere, and also ammunition and ordnance material such as range finders, spotting glasses, etc. There was a shortage of such material in the Hawaiian area, particularly around air fields, and it was therefore a welcome relief to see anti-aircraft guns installed around the Navy Yard and the Army's Hickam Field.

Initial Repairs – While preliminary salvage work proceeded, plans were developed for major salvage operations. At the same time repairs on damaged vessels were being prosecuted vigorously by all hands, particularly at the Navy Yard. The battleships and cruisers which were not severely damaged were put into condition to make them seaworthy and able to fight within a short time. Other vessels were drydocked for temporary repairs to permit passage to the West Coast navy yards for final repairs and installation of machinery and equipment which had been destroyed.

It should be understood that the many vessels which had not been damaged in any way, particularly destroyers and submarines, had put to sea following the attack, or as they were readied and supplied for offensive operations against the enemy.

12.5. SCHEDULE OF REPAIR WORK

On the basis of repairing ships in inverse order to the amount of damage suffered, the following schedule of repair work was carried out:

There were three battleships which had received damage which could be repaired in a relatively short time. The Commander in Chief was particularly anxious to expedite repairs on these battleships in order to get them to sea. All essential work was finished in about three weeks, consisting mainly of the following:

1. The *PENNSYLVANIA* required replacement of one 5-inch 25 caliber anti-aircraft gun which together with its foundation was destroyed by a 500-pound Japanese bomb. A similar gun was removed from the *WEST VIRGINIA* and installed on the *PENNSYLVANIA*.

2. The *MARYLAND* received two bomb hits on the forecastle. One of about 100 pounds exploded in the main deck and caused miscellaneous small damage affecting watertightness of the forecastle deck. The second bomb of about 500 pounds passed through the port side of the ship about 12 feet underwater and exploded in a storeroom near the keel. This explosion destroyed flats and bulkheads in the vicinity, and fragments opened numerous leaks through the bottom and shell and scattered stored materials everywhere. It was a difficult job to stop these leaks without going into drydock, but inasmuch as the drydocks were at a premium the repair work on the *MARYLAND* was of a temporary nature. The effort was successful and the 5 or 6 foot trim by the head was corrected, but not without a very trying time.

3. The *TENNESSEE* was hit by two large bombs, probably of the 15-inch shell type. One passed through the armored top plate of No. 2 turret. Fortunately, it was a dud and caused no serious damage. The other struck the center gun of No. 2 turret and caused a large crack which would necessitate the replacement of the gun. The most serious damage suffered by the *TENNESSEE* resulted from the continuous oil fires around her stern adjacent to the burning *ARIZONA*. In spite of all precautionary measures the heat started serious fires aft which spread forward as heavy layers of paint reached ignition temperatures. Much of the hull plating warped and some of the riveted joints were badly strained. Electric cables, including the degaussing lines, were burned out. Repairs were accomplished by working parties from repair ships and from the navy yard.

   One of the most serious circumstances regarding the *TENNESSEE* was that she was wedged tightly between the sunken *WEST VIRGINIA* outboard and the concrete quay inboard. It was possible to remove her only after the quay had been removed by successive applications of dynamite. Some damage to the *TENNESSEE's* port side at the turn of the bilge resulted from contact with the bilge of the *WEST VIRGINIA* as she settled to the bottom after pivoting on her torpedoed port side.

4. The crew of the *VESTAL* did an excellent job in accomplishing repairs caused by two bombs. As in the case of the *MARYLAND*, one bomb exploded in a storeroom in the bowels of the ship. After about ten days of pumping and removing damaged material it was possible to accomplish temporary repairs, which permitted the vessel to remain fully afloat. When the dry dock schedule at Pearl Harbor relaxed somewhat, the *VESTAL* was sent in for permanent repairs.

5. The crew of the *RALEIGH* did an excellent job in keeping their ship afloat. The one bomb which hit aft did not explode but penetrated three decks and the ship's side aft. Temporary repairs to this damage were accomplished by the ship's force. Later the *RALEIGH* was docked and permanent repairs in way of the torpedo hit were effected by the navy yard. Thereafter the *RALEIGH* returned to the mainland for installation of new machinery and equipment to the extent required.

6. The flotation of the *CURTISS* was in no way affected, but there was considerable topside damage from bomb fragmentation and from the gasoline fire caused by a Japanese airplane colliding with the starboard boat crane. The ship's crew went a long way in repairing the damages, which were eventually made good by the navy yard.

7. The *HONOLULU* was tied up at a navy yard pier. One bomb of about 500 pounds struck and passed through the pier and exploded in the water alongside the *HONOLULU* at about frame 40, port. This near-miss opened the side slightly and ruptured a sea chest for a magazine flood, eventually causing the flooding of five magazines and the handling room of one turret. It was necessary to dock the *HONOLULU* for repairs to the shell and to replace some electrical circuits which were flooded out. The ship was ready to sail early in January.

8. The *HELENA* was also moored at a navy yard pier. Her only damage resulted from the torpedo hit in the way of machinery spaces on the starboard side. The *HELENA* was the first ship docked in No. 2 drydock at Pearl Harbor, and was not yet completed on 7 December. Temporary repairs were made to the *HELENA's* hull to make her seaworthy, after which she proceeded to Mare Island for permanent repairs and the installation of machinery and equipment which had been destroyed.

9. The destroyer *SHAW* was an interesting case of repairing a severely damaged vessel. As a result of a bomb hit, the forward magazines of the *SHAW* blew up and wrecked all of the ship forward of the bridge. First appraisals were that the *SHAW* was a total loss but in due time it was found that the machinery and the whole ship, other than the forward area, were in good condition. At the earliest opportunity the *SHAW* was removed from the wrecked floating drydock and redocked on the marine railway. There she was trimmed off neatly and measured up for a false bow, which was eventually fabricated and installed at a subsequent drydocking. About 10 February the *SHAW* set sail for Mare Island under her own power, the first "wrecked" vessel to do so.

10. The floating drydock *YFD-2* was struck by five bombs, four of which affected very seriously her watertight integrity. As work on her proceeded it was ascertained that her watertight compartments were pierced by over 150 fragments; there was also considerable fire damage. Holes

affecting watertightness were patched or plugged so that the drydock could be floated on 9 January 1942. Thereafter permanent repairs were proceeded with so that the drydock was again placed in limited use on 26 January 1942 and continued to serve a most useful purpose throughout the war.

12.6. RAISING AND SALVING OF THE NEVADA

When the Japanese attack began, the *NEVADA* was moored in the berth next to the *ARIZONA*. In accordance with the Fleet doctrine she immediately prepared to get underway, and was able to do so although suffering from one torpedo hit. As she steamed down the channel toward the sea entrance she was heavily attacked by dive bombers and suffered 7 or 8 bomb hits. Two of these hits in the forward areas induced serious flooding. By the time the *NEVADA* reached the entrance she had taken on a great amount of water and it was apparent to the young officer, then in command, that the ship should not enter the channel at the risk of blocking it. Accordingly, he decided to beach her and did a very successful job in so doing.

As the *NEVADA* lay beached near the entrance channel to Pearl Harbor she really was a sorry sight. It was not a pleasant spectacle for new ships arriving to reinforce or support the Pacific Fleet. Her stern was only a few feet from the shore, while her bow was practically submerged in the deep water near the channel. The forecastle was pretty much a mass of twisted steel, and the superstructure up through the bridge had been entirely gutted by fire. The inside of the ship was completely filled with water and fuel oil.

There was considerable doubt in most minds as to whether the ship could ever be floated, and there were very few who even dimly hoped that she could be of any further military value.

Flooding – Immediately following 7 December the crew of the ship had set to work to remove wreckage and to condition the ship for salvage operations. Salvage personnel, including divers, had made a careful check of underwater damage and had found that most of the flooding occurred through three large holes – one torpedo hit on the port side at frame 40, 20 feet below the waterline, and two bomb hits, the first at frame 13 starboard which passed through the forecastle and out through the shell about 13 feet below the main deck. This bomb exploded alongside the ship and opened up a triangular hole about 25 feet long and 18 feet deep, which was responsible for most of the flooding of the ship. It exploded in the water and left a hole about 6 feet in diameter. As a matter of special interest, this bomb passed through the large built-in gasoline tanks without igniting the contents.

Use of Patches – In order to shut off flooding from the torpedo hole a large wooden patch was manufactured by the navy yard. This patch was shipshape, about 55 feet long and 32 feet deep, and extended around the turn of the bilge. The shape of the patch was obtained from measurements taken from the exposed bilge of the *OKLAHOMA* which was a sister ship of the *NEVADA*. The patch was a massive affair and proved unsatisfactory for the purpose intended. The divers were unable to fit the patch to the hull of the ship satisfactorily for a number of important reasons, one of which was that it just seemed too large to handle in one piece. Eventually it was decided to dewater the *NEVADA* without this large patch, on the assumption that some of the bulkheads in the area of the damage would be sufficiently intact to restrict the inflow of water, at least to a degree which would permit internal measures to be taken.

The two holes caused by bombs in the bow area were temporarily patched by wooden patches ordinarily referred to as window frames. The work was done by divers on the outside. The patches were drawn up reasonably tight by hook bolts. The bolts were hooked into holes burned into the small shell plating by underwater cutting torches.

The hull openings were plugged wherever possible by divers. Broken airports underwater were made tight by use of wooden plates and draw bolts. Drain scuppers were plugged with mattresses, wooden plugs, and other similar materials.

Pumps Used for the Work – A large number of gasoline-driven suction pumps were used to dewater the *NEVADA*, varying in size from 3 inches to 10 inches. Inasmuch as the maximum lift of a suction pump under the operating conditions embodied was about 15 feet, it was necessary to install pumps at various levels throughout the ship. The small 3 inch pumps were used for "clean-up" jobs, such as for the final water in cut-up compartments, corners, etc. An excellent organization was developed to operate the pumps continuously, and this organization became very adept at diagnosing troubles and remedying them.

In the case of ships refloated after the *NEVADA* a much improved pump became available. This was the "deep-well" pump which was of the centrifugal type operated by a propeller shaft extending from the topside to the bottom of the vertical piping. Of course such pumps could be used for straight pipe lines only, and were ideally suited for use on trunks such as were common on the battleships under salvage. These pumps came in sizes varying from 8 inches to 12 inches and were capable of handling tremendous quantities of water; the 10 inch pump could handle about 4000 gallons per minute.

Removal of Water – The *NEVADA* was completely filled with sea water and oil. The plan for floating the ship contemplated the installation of a sufficient number of pumps to remove the water faster than it could flow into the ruptured shell with patches in place to the extent mentioned. As the dewatering work commenced it was apparent that there would be no difficulty in floating the vessel. However, the amount of space from which water was removed at any one time had to be governed by a schedule taking into account a large number of considerations. Some of these pertained to stability and list of the ship; others had to do with making temporary repairs inside the vessel as the water was removed, such as stopping off leaks, shoring bulkheads, etc. Others pertained to removal of debris, cleaning, preservation of mechanical and electrical equipment, etc.

Effects of Two Months' Submergence – As the water level was reduced inside the ship it was noted that all surfaces were deeply coated with fuel oil. Steps were taken to organize working parties to remove such coating by hosing down with a hot caustic solution and rinsing with salt water. Sand was placed on the decks to improve footing. As various compartments were uncovered the ships' force removed the wreckage, stores, provisions, and eventually ammunition. Electric motors and certain items of auxiliary machinery were removed as soon as possible after they were dewatered. The motors were sent to the navy yard for reconditioning, as were many pieces of equipment. As the work went on it was found that although the motors had been submerged in salt water for about two months it was possible to recondition them for service in about 95 per cent of the cases. It was also found that items of mechanical machinery that had been protected by the fuel oil were 100 per cent salvable. Even delicate instruments such as electric meters were capable of reconditioning.

As the main machinery spaces were pumped out it began to seem very probable that the machinery could be put in operable condition, and all hands developed an accelerated optimistic spirit regarding the ability of the *NEVADA* to go home under her own power. The crew of the *NEVADA* (about one-third original crew) applied themselves most strenuously to the job of cleaning up the ship and especially toward getting the machinery and equipment in running condition.

As successive stages of pumping were undertaken the bow rose higher and higher in the water, and it soon became clear that no great difficulty would be found in floating the ship. However, it was important to reduce the draft as much as possible, and for this reason it was decided to remove all the oil still remaining aboard and as much of the storeroom and magazine contents as practicable. The removal of oil was undertaken by operating the vessel's fuel oil transfer pumps on compressed air which was furnished by portable compressors. The operation was wholly successful and marked the beginning of self-operation on the part of the *NEVADA*.

Toxic Gas – As the dewatering schedule continued a number of people felt ill effects from the gas which seemed to fill the ship. The very dangerous toxic properties of this gas were discovered on 7 February. On that date Lt. Clarkson was in the pumped-out trunk forward of the steering engineroom and removed the cap from the air test fitting on the door to determine the water pressure within. The water which entered the trunk from the steering engineroom released a large volume of toxic gas and Lt. Clarkson was overcome and collapsed. Other persons entered the trunk to rescue him, with the result that eventually six or more persons were overcome. The final result was that Lt. Clarkson and Chief Machinist Mate DeVries died as a result of gas poisoning. Thereafter a very careful investigation was made of the gas situation and it was determined that the gas was generated by reason of the polluted and stagnated harbor water being under pressure in closed compartments, thus forming hydrogen sulfide which is given off in large volumes in lethal concentrations when the water is released from pressure. Immediately precautionary steps were taken to provide additional ventilation, mostly with suction blowers. Personnel were prohibited from entering compartments without respiratory equipment if the compartments were found to contain dangerous concentrations of gas. There were no more persons overcome on the *NEVADA*, but practically all persons working continuously on the ship were subjected to some gassing.

To the Drydock – The vessel was fully afloat on 12 February 1942 and was scheduled for drydocking two days following. There was some trepidation about towing the *NEVADA* across Pearl Harbor channel because of the possibility of some occurrence which might cause reflooding and possible sinking in the channel, thus blocking it. Careful inspections were made to insure that all bulkheads and patches were reasonably tight and that there was little, if any, possibility of reflooding. The drydock was put in readiness and tugs took the *NEVADA* in tow at 0600 on 14 February. Within a few hours the first vessel to be raised was safely in Drydock No. 2.

12.7. RAISING AND SALVING OF THE CALIFORNIA

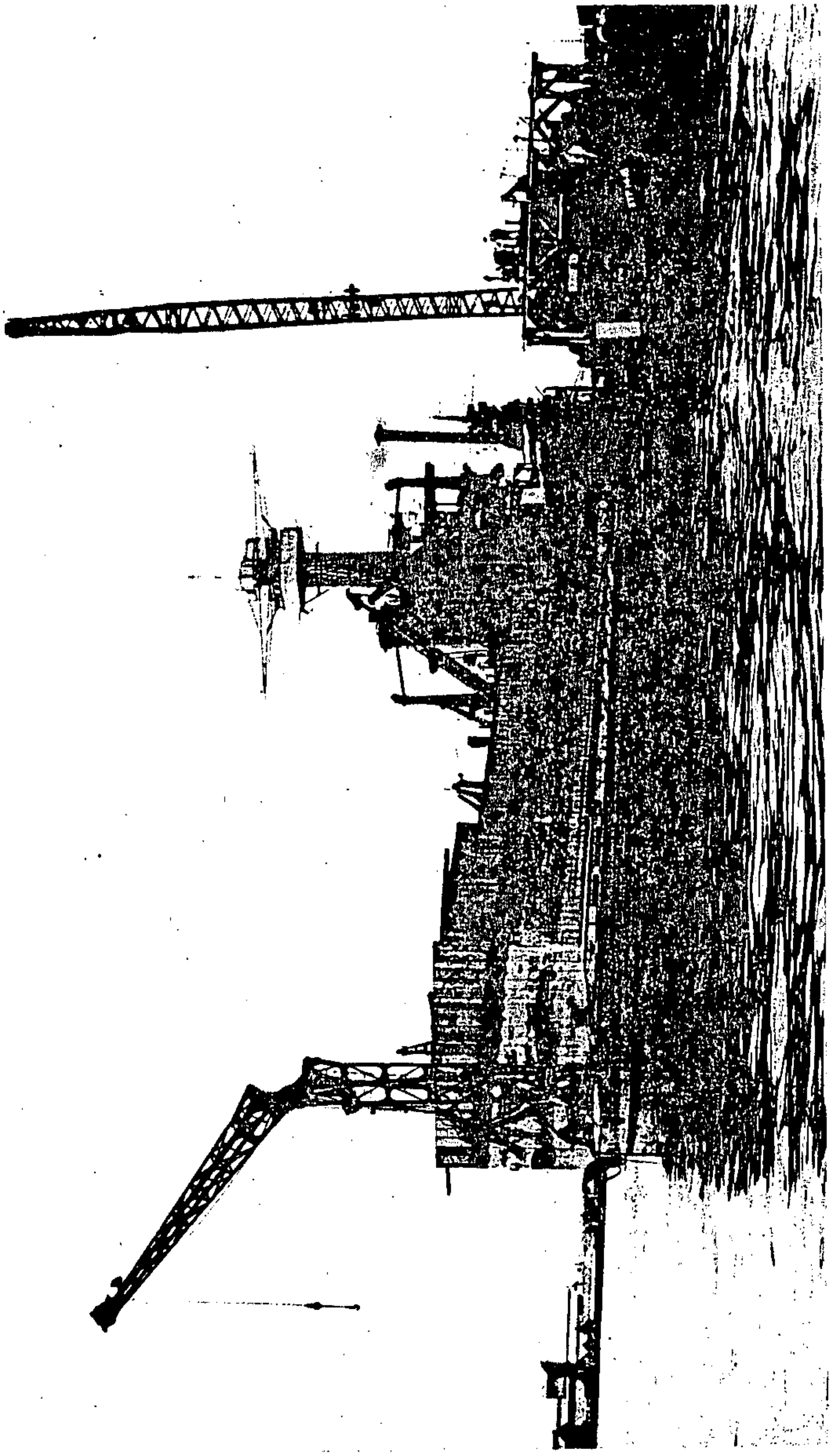
The refloating of the *NEVADA* without undue difficulty brought a feeling of increased optimism regarding the much more difficult jobs of refloating the *CALIFORNIA* and the *WEST VIRGINIA*. True, the *CALIFORNIA* had shown a strong disinclination to sink. The battle to keep her afloat had gone on for three and a half days, and was lost only because of inadequacy of pumping equipment. This was a favorable consideration in refloating the ship because it was ample proof that the inflow of water was reasonably well restricted by watertight compartmentation and closures. However, the fact that the main deck of the vessel, on the low side, was over 17 feet underwater presented a major problem which did not exist in the case of the *NEVADA*.

The assistance of the Navy Yard Design Section was utilized in technical studies of the problems of stability and hydrostatic pressures on various parts of the ship's structure. For instance, it was readily determined that the deadweight corresponding to 17 feet of water on the quarter deck was more than the structure of the ship would stand. This fact ruled out any thought of pumping out the inside of the ship to obtain the buoyancy required for flotation. Some means had to be found to remove the water above the quarter deck; this could be accomplished only by some kind of cofferdamming.

Shortly after 7 December it seemed to be agreed by the salvage experts that complete caissoning of the *CALIFORNIA* and *WEST VIRGINIA* would be necessary. This would consist of driving steel sheet piling into the bottom of the harbor entirely around the ship in order that external and internal repairs could be made when the water was pumped out, leaving the vessel sitting on the bottom in a make-shift drydock. Of course this would be a complex and hazardous job, and there was some doubt as to a successful outcome because of the softness of the bottom soil. It was clear that unless the caisson piling was driven very deep the hydrostatic pressure of some 40 or 45 feet would cause a "blow-up" of the bottom and consequently unintentional reflooding of the caissoned area. Finally a simpler cofferdam arrangement was adopted.

Type of Cofferdam Used – The cofferdam decided upon consisted of a wooden fence structure erected around the edge of the quarter deck. It consisted of vertical heavy 8 inch planking made up in sections, each section being about 30 feet long and 20 feet high. The planking extended down the side of the ship 2 or 3 feet. The weight was taken on the deck and waterway. Bolts passing through the quarter deck stanchion feet were used to draw the sections hard up against the side of the ship. Extensive internal shoring was instilled to resist external pressures which would occur as the water within the fence was removed. Large bins were built near the top of the fence for holding sand bags used to overcome the buoyancy of the wood.

Handling of these cofferdam sections was accomplished by cranes mounted on barges. The exact positioning and securing was handled by divers. Watertightness was accomplished by use of various puddings, or packing materials such as old hose, oakum, sawdust, etc.



USS CALIFORNIA FULLY AFLOAT WITH
FENCE-TYPE COFFERDAM ERECTED AROUND
THE SHIP.
FIG. 12 NO. 2

A fence of somewhat similar but of much lighter construction was installed on the port forecastle which was under varying depths of water up to about 5 feet. The excellent design and most of the work of installation of this structure was performed by the Pacific Bridge Company, who had the contract for drydock construction when the Japanese struck.

It was decided that no attempt would be made to patch the two torpedo holes in the port side of the *CALIFORNIA* externally because exploratory work plus some considerable knowledge of the efficacy of torpedo bulkhead protection indicated that the flow of water through such areas could not be of great volume. However, a large patch, about 30 feet square, had already been manufactured to cover the 15 foot triangular hole forward at about frame 40. This was properly rigged and secured. Divers did a great amount of work in plugging up other hull openings through the vessel, such as gunports, broken airports, drain scuppers, etc.

Pumping Procedure – The general scheme of pumping was to erect a large number of deep-well pumps of the Peerless and Pomona type at numerous locations, especially trunks. The purpose was to provide sufficient pumping capacity to remove the water faster than it could flow in. With this tremendous pumping capacity it was realized that there might be a possibility of setting up large hydrostatic pressures and moments due to differences in water levels on opposite sides of bulkheads, etc. It was therefore decided to facilitate the flow of water without restriction throughout the ship. For this reason all doors and hatches were opened by divers before pumping commenced. In later stages holes were cut in certain bulkheads for the same reason.

Finally the day came to test the ability of the pumps. Happily it was soon demonstrated that they were capable of lowering the level of water inside the fence structure. As pumping proceeded, with greater and greater difference in the level of water inside and out, it was easy to note any serious leaks near the surface. Divers immediately increased the watertightness of the work. Within a few days the quarter deck was cleared of water and at that time a schedule of pumping operations was drawn up. This schedule allowed time to clear out wreckage as spaces were pumped out, to remove electric motors for reconditioning before long exposure to the air, to recover valuable personal property and place it in proper custody, and to recover bodies which were known to be in the ship.

As in the *NEVADA*, it was found that the *CALIFORNIA* was thoroughly coated with a heavy film of fuel oil. Arrangements were made for a tug alongside to furnish high pressure on salt water hoses to wash down all surfaces as they were dewatered. Later, but before the fuel oil hardened, a thorough job was done by hosing with hot caustic solutions and washing down with sea water. This general method was used thereafter on all vessels.

The plan of salvage included the lightening of the weight of the *CALIFORNIA* as much as possible by the removal of such items as the conning tower, cage masts, 14 inch guns, etc. This was done by the navy yard's 150-ton crane. The anti-aircraft battery had been removed and reinstalled elsewhere.

As spaces were emptied of water the reduced ship's force of about 300 men turned to on all work such as the removal of debris, cleaning of spaces, unloading of stores and provisions, removing ammunition, etc.

Due to rupturing of oil tanks by the two torpedo explosions there was a very large amount of loose oil all through the ship. Attention was given to means for picking up such oil in order to reduce the fire hazard and minimize the amount of cleaning which would be necessary. A Wheeler system installed on a barge did a very successful job in handling such oil, and recovered about 200,000 gallons floating on the surface of the water in various parts of the ship. Oil which was still in stowage tanks was pumped out eventually by the ship's fuel oil transfer pumps operating on compressed air.

Condition of the Machinery – While the machinery of the *NEVADA* was found to be in good condition, it had been believed from the start that the electric propulsion machinery of the *CALIFORNIA* and *WEST VIRGINIA* would probably be a total loss. However, in view of the fine record made in reconditioning the low voltage motors of the *NEVADA* and other vessels, there were a few optimists who felt that it would be possible to recondition the main machinery of the *CALIFORNIA* and the *WEST VIRGINIA* at least sufficiently for return to a mainland navy yard. This general question was discussed at great length and it was finally decided that one or two units would be reconditioned while the other two units would be broken down and completely rebuilt in place. Arrangements were made with General Electric Company, the original supplier, to send out a force of experts to handle the job. About 60 of them arrived in due course. The work of cleaning and drying out commenced immediately after the machinery was dewatered. This force was supplemented by navy yard personnel, ship's personnel, and Navy Mobile Repair Units Nos. 2 and 3 which were assigned to the salvage organization. With respect to the success of this work, it might be stated that although a very optimistic undertaking, the results were very satisfactory. Eventually the *CALIFORNIA* left Pearl Harbor under her own power on two rebuilt units, as did also the *WEST VIRGINIA.* A very large number of electric motors were sent to the mainland for reconditioning after proper preservation procedure was taken on the ship. This program was very successful.

Condition of Boilers – As in the *NEVADA*, the boilers were found to be in good condition except for bricking. All that was required was cleaning, both inside and out, and complete rebricking.

Recovery of Bodies – Based on the total number of personnel missing, it was anticipated that 48 bodies would be recovered within the ship. However, only 32 complete bodies were found. Due to the advanced state of decomposition, it was necessary to work out a method of removing the bodies with a minimum of handling. This consisted in stopping the pumps when several feet of water still remained on each deck, at which time a search was made for bodies floating in the water. Large canvas bags were made up so that the bodies could be floated into the bags and carried intact from the scene. This arrangement proved very effective in all respects.

Fire Protection – Great care was taken by the salvage organization to guard against fire. The vast amount of oil throughout the ship would have caused a holocaust if a fire once got started and heated the oil to ignition temperature. A large amount of fire extinguishing equipment was readily available at all points, and personnel were organized and instructed. A rather large number of small fires occurred, usually from short circuits of temporary lighting leads. But none of these fires was permitted to gain headway on any of the ships under salvage, except in the case of the *OGLALA* which is hereinafter referred to.

Gas Hazard – The lessons learned on the *NEVADA* were put into full effect on the *CALIFORNIA* and all succeeding salvage jobs. A generous quantity of exhaust ventilators were kept running continuously to prevent the accumulation of toxic or explosive gases. There were no gas poisonings on the *CALIFORNIA* or succeeding ships, although it was frequently necessary to remove personnel from certain areas in which water under pressure was being released. Gas concentrations were continuously checked by specialists.

Removal of Meat – One of the more difficult jobs on the *CALIFORNIA* and *WEST VIRGINIA* was the removal of tons of decomposed meat from the refrigerated storerooms; there was no way of performing this job in a pleasant way. A maximum of forced ventilation was pumped into spaces and gas masks were worn by members of the crew. As they brought the meat from storerooms into passageways it was picked up by cargo nets and hooks and hoisted by cranes onto barges alongside. The meat was then transferred to other barges and towed to sea where it was dumped. Later, on the *WEST VIRGINIA* it was found that high pressure water hoses had the effect of shredding the meat so that it could be pumped overboard by the salvage pumps.

Protective Clothing – In the hot Hawaiian climate, especially on kona days, the personnel assigned to salvage work on board the ships had a very difficult job. Fuel oil was everywhere, hydrogen sulfide fumes were in most places, and part of the time there was a general atmosphere of things going very, very slowly. Some sort of protective clothing for the men was essential. Boots and gloves were issued in some cases, but there was a great shortage of such items. In lieu of boots, "nips" were made up by wrapping burlap around the feet; this offered some protection against fuel oil which covered the decks in a heavy scum when the water was pumped out. Also there were "goon gowns" as the sailors called them, which were manufactured by the navy yard. These were a coverall of light slate-colored cloth such as is issued for targets. They were fitted very loosely and secured with tie-ties instead of buttons, and were very comfortable. They became pretty well soaked with oil after a day or two of use, at which time they were turned in and sent to a dry cleaning plant in Honolulu. Within a few days they could be reissued.

Means of Controlling Inflow of Water – As previously mentioned, the damage to the under hull of the *CALIFORNIA* was caused by two torpedo explosions and one bomb explosion close aboard. It was certain that the torpedo protection built into the ship was fairly effective and that the amount of water entering due to the two torpedo hits could be fairly well controlled by interior work performed by divers, including the full utilization of watertight doors, ventilation closures, pipe line stops, and other actions.

The large hole in the port bow caused by the bomb explosion, however, was not in the vicinity of torpedo bulkheads, although the subdivision of the ship in the general area of frames 9–15 was very favorable for limiting the spread of flood water.

A patch to place over this 15-foot by 15-foot triangular hole was manufactured. It was made up of wood reinforced by steel and was installed without difficulty. It proved very effective and was regarded as an excellent patch job until it was blown off and wrecked by an internal explosion in the ship.

Four days before the *CALIFORNIA* was scheduled to go into drydock she was beset by an incident which at first appeared likely to cause a considerable delay. On a quiet Sunday afternoon a violent explosion occurred below the third deck forward. The immediate result was the rapid settling of the bow of the *CALIFORNIA* which was now well afloat. At first there was some suspicion of sabotage, but it was concluded that the explosion resulted from the accumulation of gasoline vapor, inasmuch as the gasoline system and stowage just forward had been set off by a short circuit in the temporary lighting system.

With the help of a diver and the barge crane, the patch which had been doing such a fine job was picked off the bottom and brought to the surface. It was badly splintered and torn out of shape and obviously of no further use. Instead of waiting for the manufacture of another patch it was decided to do the best with what was at hand. Divers were sent down into the flooded area of the ship to close the watertight hatch at the lowest level possible, which proved to be the third deck. All water above the third deck was then removed and steps were taken to make watertight the partially distorted third deck hatch. A considerable portion of the lowered buoyancy of the bow was thus regained and docking was carried out as scheduled.

Safe in Drydock – The scheduled date for placing the *CALIFORNIA* in drydock was 9 April 1942, and in spite of the explosion casualty and other difficulties this date was met. When the dock was pumped down, the usual discovery was made; the underwater damage was less than anticipated. Permanent repairs to the underwater hull were instituted immediately by the navy yard and the work was carried on rapidly in order to have the dock available for use of major vessels. The repairs to the *CALIFORNIA* were scheduled in such a way that it would be possible to remove the ship from dock on not more than 72 hours' notice. Fortunately this was not necessary.

After flood water was entirely removed from the inside of the ship, a careful inspection was made to determine the types of damage which permitted the spread of flood water throughout the ship. In general such flooding was caused by ruptured pipe lines, ventilation ducts, drains, and some damaged closing plates over oil tanks and voids. The importance of the design of pipe lines, sea connections, and ventilation ducts was amply demonstrated.

12.8. RAISING AND SALVING OF THE WEST VIRGINIA

Salvage work on the *WEST VIRGINIA* proceeded rapidly during the latter stages of work on the *CALIFORNIA* as additional shipments of essential pumps and other materials arrived in Hawaii. By the time the *CALIFORNIA* was drydocked the salvage operations on the *WEST VIRGINIA* were moving forward at high speed. Even though the floating of the *WEST VIRGINIA* was a much greater job than in the case of the *CALIFORNIA*, she was fully afloat on 17 May 1942 and placed in drydock on 9 June.

Nature of Damage – Unlike the *CALIFORNIA* there was very little water on top of the main deck of the *WEST VIRGINIA* because of the shallower water and harder bottom on which the *WEST VIRGINIA* rested. The extent of damage to the *WEST VIRGINIA* was however, many times greater than in the case of the *CALIFORNIA*. The ship had been struck on the port side by six torpedoes and the whole side for a length of nearly 200 feet was virtually wrecked. Another torpedo had struck near the rudder and had destroyed the external steering arrangements and most of the internal steering system. Very serious oil fires had been started by either bomb or torpedo explosions, and the fire damage throughout the ship had destroyed considerable structural strength as well as the contents of various compartments. Thus the salvage of the *WEST VIRGINIA* was a new problem. Obviously, some sort of external patching would be necessary to shut off the flow of water along the port side, as it was apparent that the damage to the multiple bulkheads was too great to permit controlling the inflow of water in any other manner.

Type of Patch Installed – The Navy utilized the Pacific Bridge Company in designing and installing the two patches required, one from frame 43 to 52, the other from 61½ to 97½. These patches were made up in sections about 13 feet long. Each section extended from the turn of the bilge to a point well above the main deck, a total height of about 50 feet. The sections were a composite design of steel, heavy timbers, and concrete. The general makeup consisted of 24-inch steel "I" beams running longitudinally, with vertical 4 inch planking on the waterside. These sections were shored against the side, including the armor plates. The upward thrust of buoyancy pressures was transmitted from the "I" beams to the underside of the armor belt. The outer edge of the sections was about 2 feet from the original shell of the ship. Each section was hauled up snugly at the bottom and was held in place by hook bolts taken up in holes burned by divers through the shell of the ship. The joints between sections were made reasonably tight by old rubber hose and other packing materials. Draw bolts were used to hold sections together snugly. The forward patch consisted of three sections, while the large patch consisted of 11 sections. The barge cranes were used to place the patch sections in proper location; negative buoyancy was obtained by use of lead weights placed on a shelf near the bottom. These weights were removed for future use after each section was secured.

Use of Concrete – After the sections were all installed and properly secured, concrete was poured underwater to seal off the patch along the bottom. This produced reasonable watertightness between the damaged hull and the patch and at the same time provided means for taking up the buoyancy pressure of the patch against the bottom. The concrete was a rich mixture, that is, one part cement to three and a half parts of aggregate. Similarly, concrete was used to seal off each end of each patch. The fore and aft thickness of the concrete was about 4 feet. For the whole job about 650 tons of concrete were used.

It was foreseen that when the buoyancy support of the patches was lost in drydock it would be necessary to support the patches in place. Accordingly, heavy steel rods were rigged in a vertical position and welded to intact portions of the hull, so that these rods would take the weight of the patch in drydock.

It might also be mentioned, as a point of interest, that access doors for divers were provided about every 40 feet so that divers could move in and out as required to fit and secure the patches in place. Before pumping started these doors were secured and made watertight.

Pumping Procedure – For a week prior to final readiness of patches, a number of the large capacity pumps were operated for several hours per day to circulate the water within the ship. Much of the water was stagnant and under pressure for nearly six months, and experience on the *CALIFORNIA* and *NEVADA* had indicated that such water would be heavily charged with dangerous concentrations of hydrogen sulfide gas. Insofar as possible all main compartments were opened to permit removal of old water and inflow of new. Of course it was not possible to remove the stagnant water from small compartments such as storerooms, for which reason some difficulty with toxic gas was later experienced.

After the patches had been installed the whole battery of pumps was started to ascertain the tightness of the patches and their ability to control the inflow of water. The water level within the ship was lowered readily and there was soon a difference of three or four feet between the inside level and the outside level. But such happy results were short-lived as the pumps were unable to lower the water any further, indicating that very large leakages existed somewhere. Divers inspected both inside and out and gradually found the causes for the inflow and remedied them. Within a few days the patches were made reasonably tight, air ports were plugged, and fragment holes not previously detected were stopped-up. It was soon determined that the plan and procedure would prove entirely satisfactory.

Use of Compressed Air – Compressed air had been used to some extent on the *CALIFORNIA* but it was used very greatly on the *WEST VIRGINIA*. It became necessary to remove all the water and oil which could be pumped or blown in order to reduce the draft sufficiently to dock in Drydock No. 1. It was preferred that the larger drydock be left available for the battle-damaged combatant vessels. The planners did not wish to tie up Drydock No. 2 for the time required to make flotation repairs to the *WEST VIRGINIA*, if this could be avoided.

Compressed air was used extensively in partially damaged oil tanks, and for the operation of machinery such as fuel oil pumps, winches to hoist 16-inch ammunition, stores, and trash; even 5-inch ammunition hoists were operated by hooking up air drills. The steering engineroom had been badly wrecked by a torpedo hit on the rudder and it was not practicable to patch this area and pump out the flooded space. Instead, air pressure was applied to force out some of the water and considerable buoyancy was gained.

Possiblity of Damage to the Large Patches – As the vessel came afloat it was recognized that a serious hazard existed in the possible failure of the large patches, either due to inadequate design or to damage, either of which might cause collapse. Such collapse would permit the sudden inrush of water which might endanger many lives, and could cause the ship to capsize. The side of the ship, and the decks in way of the patch, were so badly destroyed that any sizable failure would certainly cause the ship to sink and under certain conditions might cause capsizing. Steps were taken to recondition many watertight doors and hatches that had been damaged on the port side. A schedule of counter flooding of the emptied oil tanks and voids on the starboard side was set up and men on watch were instructed accordingly. Care was taken to insure that tugs and running boats gave the patched area a wide berth.

The possibility of serious teredo damage to the wooden patch sections that had been installed for two or three months was considered. Also the possibility of air raid damage was ever-present, and an air raid bill was worked up to insure the most practicable manner of handling such damage sustained; this included a fire fighting crew with necessary equipment. It also included the availability on the crane barge of several heavy collision mat patches. Fortunately none of the possible hazards materialized, due in large part to the fact that possibile air raids were turned back at the Battle of Midway.

Toxic Gases – The amount of hydrogen sulfide in the *WEST VIRGINIA* greatly exceeded that found in the *CALIFORNIA*. Additional precautions were taken under the expert direction of a medical officer. A bulletin board was kept up to date to indicate compartments which were safe and those which were considered unsafe. The latter ones could only be entered by using a rescue breathing apparatus or suitable face mask with air hose. Hydrogen sulfide was found in greatest concentrations in storerooms containing a large amount of paper or many cardboard containers. In addition to hydrogen sulfide, there were many cases of oxygen deficiency and a few cases of carbon monoxide. These were remedied by proper ventilation, which was available.

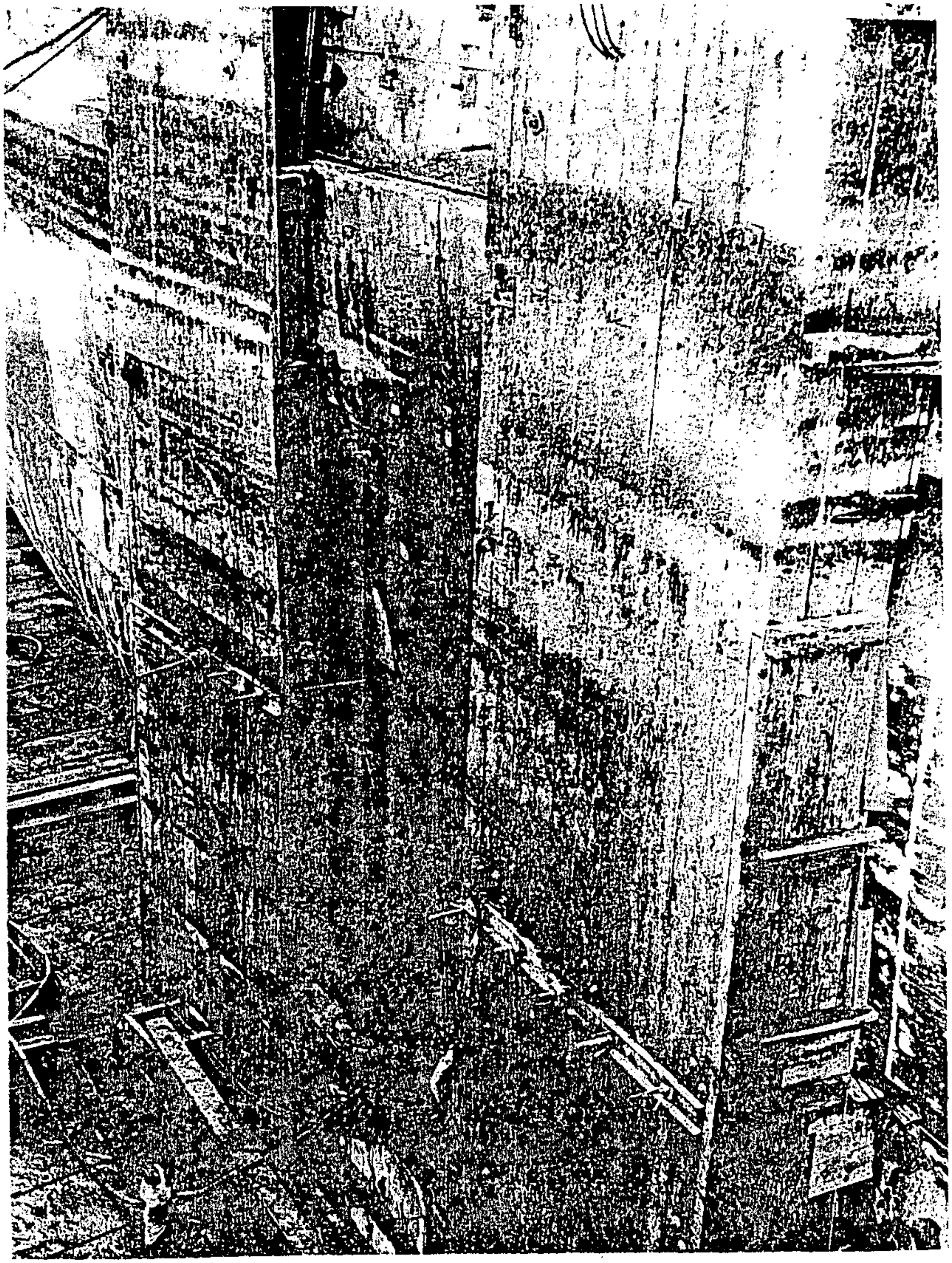
Recovery of Bodies – Sixty-six bodies were recovered from the *WEST VIRGINIA*, and were handled very satisfactorily in the same manner as in the *CALIFORNIA*. There were some exceptions inasmuch as bodies were found in unusual locations. In the after engineroom a number of bodies were found lying on top of the main steam pipes; it is likely that the men sought that location because of the air bubble which existed in the upper spaces of the flooded area. Three bodies were found on the lower shelf of a clothing storeroom which had not been flooded. These were clad in blues and jerseys instead of the regular whites. A calendar was found in this compartment on which each date had been checked off from 7 December to 23 December 1941. The battle station of these men was apparently in the adjacent pump room. It was noted that the emergency rations had been consumed. A manhole to the fresh water tanks below the pumps had been removed. The indications were that the men had finally succumbed to oxygen deficiency.

Reduction of Mean Draft to 33 Feet – In order to dock the ship in Drydock No. 1 it was necessary to get the mean draft down to about 33 feet. This required strenuous efforts on the part of all hands in removing all weights aboard that could be handled, such as loose water, oil, stores, provisions, meat, shells, powder, wreckage, personal effects, guns, armored turret tops, etc. The officers and crew of the *WEST VIRGINIA* won great admiration by their devotion to their task and its very successful fulfillment. The crew at that time was considerably less than 400.

Transfer to Drydock – The *WEST VIRGINIA* was floated on 17 May and was placed safely in drydock on 9 June 1942. Immediately following drydocking the navy yard undertook the difficult job of effecting permanent repairs to the port side damage. Prefabricated sections of the heavy multiple-sided structure were installed more rapidly than had been anticipated. The slowest job was found to be the construction of a new rudder and steering engine parts – slow, due to the great shortage of steel casting capacity throughout the country.

As in the case of previous ships, electric motors and instruments were removed for preservation treatment very soon after they were exposed to the air. A large number of such items were reconditioned for future use in the vessel; all major circuits were shipped to the mainland for rewinding.

A view of the *WEST VIRGINIA* in drydock exposed the very great damage suffered by the ship, but on the other hand it also showed that a large proportion of the ship was still there. A great amount of manpower and material was necessary, of course, to bring back the ship as a fighting unit of the Fleet, however, aggressive action of the shore-based facilities accomplished this within a reasonable time.



USS WEST VIRGINIA IN DRYDOCK. REMOVAL OF ONE SECTION OF THE FORWARD SMALLER PATCH SHOWS SOME DETAILS OF CONSTRUCTION AND SECURING METHODS. FIG. 12 NO. 3

12.9. FLOATING AND SALVING OF THE OGLALA

Perhaps the most interesting salvage job at Pearl Harbor was that of the *USS OGLALA*, the flagship of Commander Minecraft Force. It was interesting because of the variety of problems presented in her salvage and the many difficulties which seemed to beset the work.

At the time of the Pearl Harbor attack the *OGLALA* was tied up outboard of the *HELENA*. An aerial torpedo passed under the shallow draft *OGLALA* and exploded against the side of the *HELENA*. The force of this explosion was sufficient to cause some damage to the *OGLALA*, at least enough to permit sufficient flooding to cause the vessel to capsize some two hours after being damaged. Such capsizing would not have occurred except for the fact that the *OGLALA* was a vessel 40 years old, with very inadequate compartmentation and structure. In her younger days she had plied between Boston and New York on the Old Fall River Line; she was acquired by the Navy in World War I.

Possibilities of Salvage – When the smoke of battle cleared away comments were freely cast about as to what should be done about the ugly duckling, the *OGLALA*. She was considered a total loss, and she fouled one of the most valuable piers of the navy yard. Her removal was therefore considered of high priority. Many schemes were put forth looking to her removal, but none of them contemplated full salvage and future use of her antiquated hull. One proposition was to blow out the water by use of compressed air, floating her so she could be towed on her side either for beaching or into drydock for righting. It was soon found that her structure was not sufficiently strong or tight to hold the air pressure necessary. Another proposition was to blow up the ship with dynamite and pick up the pieces for scrap. A modification was to cut her up with underwater cutting torches and remove her piecemeal by cranes. Still another scheme was to rig her between two pairs of large lifting barges so that she could be cleared of the bottom and towed to a shallow beach. Barges of the type required were at a premium so that ultimately this scheme had to be abandoned.

Nearly everybody had some ideas as to what treatment should be accorded to the *OGLALA*, but for some reason or another none of them proved to be as simple and efficacious as the orthodox salvage procedure which was finally adopted. Of course there was some delay in getting started on the *OGLALA* because of lack of salvage material previously referred to, and also because the work was given priority following the battleships, even through clearing the dock space was very important.

Plan of Salvage – The *OGLALA* lay on her port side in about 45 feet of water, so that the starboard side amidships was only a few feet out of water. The plan consisted of two steps. The first was to right the *OGLALA* by use of salvage pontoons, and the second was to refloat her by the same technique as employed on the *CALIFORNIA*.

Ten submarine salvage pontoons were available in Pearl Harbor and the use of these was authorized by the Navy Department. These pontoons were sunk in appropriate locations along the weather deck of the ship and were secured to heavy chains which passed under the ship and to stoppers welded to the starboard side. As the water in the pontoons was displaced by compressed air a turning force would be exerted of some five to seven hundred tons. In order to assist the pontoons in breaking away from the mud, two other forces were applied. The first was the use of compressed air in the hull of the

OGLALA to the maximum extent possible. Another was a pull of some 50 to 100 tons exerted by winches on a barge anchored outboard of the *OGLALA*. Rough calculations indicated that the forces to be applied would be sufficient for the job.

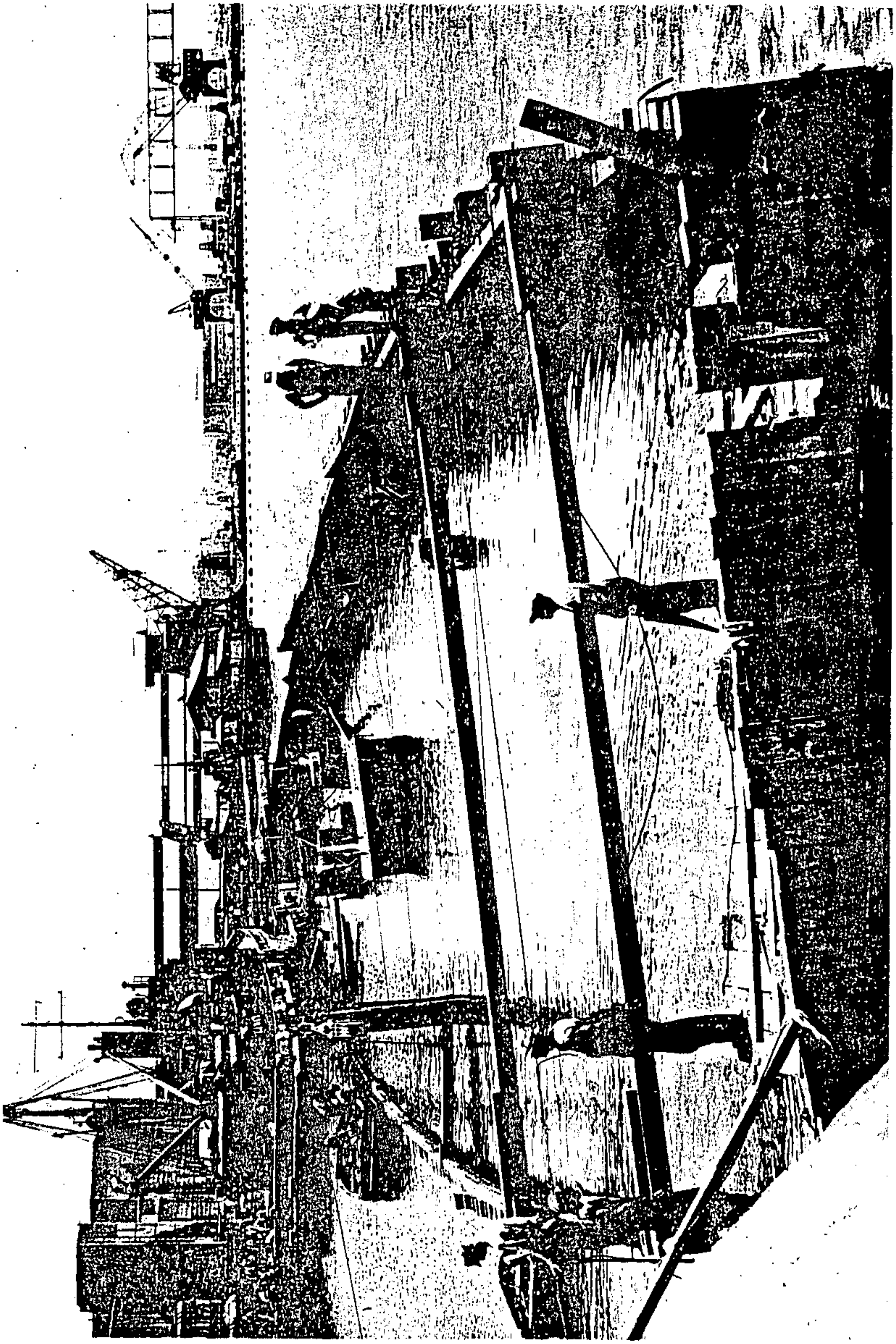
Righting the Vessel – At the appointed time on 11 April 1942 an attempt was made to right the ship. However, as the pontoons were blown they came to the surface one by one, indicating some failure in the chain attachments. This first effort was a failure and it was found that the bridles attaching the two chains to each pontoon had parted. They were old and worn items, like the ship they served, which had been recovered from the scrap heap. It was necessary to replace them with new and stronger material. The second attempt was made on 23 April and was entirely successful. The ship came to rest on her bottom with an initial list to port of about 20 degrees which was gradually reduced to something under 7 degrees.

Use of the Fence-Type Cofferdam – The quarter deck cofferdam used so successfully on the *CALIFORNIA* was modified to suit the *OGLALA*. The cofferdam was installed around the deck edge from stem to stern. The depth of water above the deck varied from 6 feet forward to something over 25 feet aft. The installation arrangements were similar to those described for the *CALIFORNIA*. Before the cofferdam could be installed satisfactorily; it was necessary to remove practically all of the wooden deck house and top hamper. This was done by hoisting cranes assisted by divers.

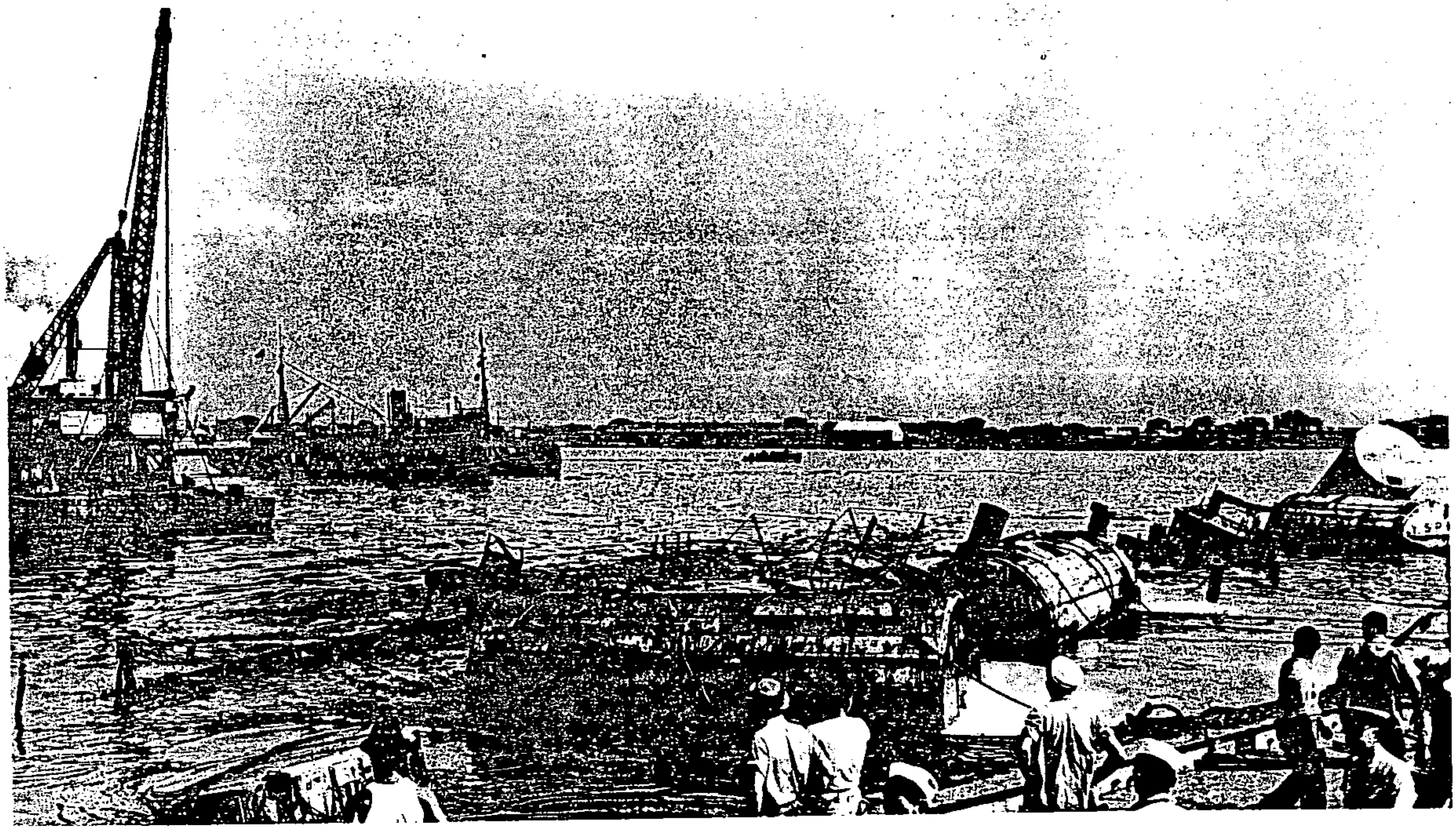
Pumping Out the Ship – The pumping arrangements were similar to those previously used. It was decided, however, that in view of the poor compartmentation of the *OGLALA* it would be well to install a patch over the damage found in her port bilge after the vessel had been righted. Divers took the necessary measurements, and the patch was built on the dock and installed by divers. It was soon concluded that the refloating of the vessel would be comparatively easy.

Trouble, Trouble – The *OGLALA* came to be known as the Jonah ship because of the various troubles encountered in salving her. The first failure occurred when the water level inside the cofferdam was pumped down about 7 feet. At that time two of the *CALIFORNIA* cofferdam sections which had been lengthened showed signs of distress and gradually failed. This was not a design failure, but resulted from the action of some "practical men" in the field, substituting 12 inch by 12 inch timbers for the steel "H" beams called for by the blueprint.

After this failure was remedied the pumping was resumed and the vessel came afloat on 23 June 1942. However, drydock considerations required that the draft not exceed 37½ feet. As the vessel rose higher in the water the stability was greatly reduced because the weight of the cofferdam totaled 1300 tons, and also because of the large amount of free water surface within the ship. Calculations indicated that these adverse factors would produce negative stability well before the draft could be reduced to 37½ feet. Some remedial steps were taken to reduce the topside weight, but it became apparent that the draft could not be reduced much below 40 feet without undue impairment of stability, or without accepting other risks in connection with removing part of the cofferdam structure.



FENCE-TYPE COFFERDAM INSTALLED ON THE
DECK EDGE OF THE USS OGLALA.
FIG. 12 NO. 4



WITH THE ASSISTANCE OF SUBMARINE SALVAGE
PONTOONS, THE USS OGLALA IS RIGHTED ON
23 APRIL 1942.
FIG. 12 NO. 5

The next casualty was nothing less than the resinking of the ship during the night of 25-26 June. This was somewhat sad, of course, but was a very interesting and instructive casualty. It was caused by the plugging up of float-controlled pumps which were depended on to keep the bow of the ship well up. When these pumps failed the bow gradually settled, and as it settled water ran forward at an ever-increasing rate, because there were no athwartship bulkheads on the mine deck. Unfortunately, the bow went down until it came to rest on the bottom in 48 feet of water. Soon the stern followed, as might be expected. This was an excellent example of the loss of longitudinal stability due to free surface. The salvage crew went to work with considerable vim the next morning, in spite of some discouragement; the vessel was brought afloat again the following day.

The next casualty was another "practical man" failure. This time the stern section of the cofferdam collapsed on 29 June due to failure of two 10 inch by 12 inch timbers. The designer realized this weak spot and on the plan called for tie-rod supports at three points, but the tie rods had been omitted by the field force. The result was that the *OGLALA* once more sank to the bottom. Repairs were soon made to the cofferdam and the vessel was refloated two days later.

The next casualty was a fire which broke out within the cofferdam during the evening of 1 July 1942. The fire was started during a gasoline refueling operation on one of the 6-inch pumps. Some of the gasoline splashed onto the hot exhaust manifold and immediately ignited. This caused the attendant to drop the 5 gallons of burning gasoline into the water, and this in turn set on fire a heavy layer of fuel oil on the surface of the water within the cofferdam. The fire was brisk indeed for about twenty minutes, at which time it was extinguished by the prompt and efficient action of the fire watch on board, the crew of the *USS ORTOLAN* and the navy yard fire department. Damage to the cofferdam proved to be superficial only, so that this near-serious casualty did not set back the work.

Docking of the OGLALA – Drydock No. 2 was ready to receive the *OGLALA* on 3 July 1942. At that time the vessel had a mean draft of a few inches less than 40 feet. She was placed in drydock looking for all the world like Noah's Ark except that there was no roof over the straight sides of the cofferdam. Very little of the *OGLALA* itself was in sight above the water; only a small portion of the bow area.

The damage to the underwater hull was found to be very moderate and the yard proceeded to make permanent repairs. The cofferdam was quickly removed and steps were taken to rehabilitate the vessel. There was considerable discussion as to what use the *OGLALA* might be put. Admittedly she had rather small value as a naval vessel, but in those times any kind of ship was a valuable commodity. Eventually she was reconditioned and put into service as a repair vessel and tender for motor torpedo boats.

12.10. SALVAGE WORK ON THE CASSIN AND DOWNES

These two vessels were a sorry spectacle following the 7 December attack. They were docked abreast of each other in Drydock No. 1. The first bomb passed through the deck edge of the *CASSIN* and exploded between the two vessels. The fragments riddled the side of the *DOWNES* and exploded in the chart house. A third bomb exploded between the two vessels causing further riddling of the sides of both ships and increasing the intensity of the oil fires. The tremendous heat of the oil fires resulted in many oil tank explosions and the detonation of warheads in one of the torpedo tubes of the *DOWNES*. It was necessary to flood the drydock in order to protect the *PENNSYLVANIA* and to help control the oil fires which were now raging. Eventually the *CASSIN* capsized and caused serious damage to her main hull structure. The high temperatures of the oil fires caused serious and widespread damage to the hull plating and the strength members. The first appraisal was that both ships were total losses.

Saving Something From The Wreck – As the *CASSIN* and *DOWNES* were inspected in detail under more favorable circumstances it was ascertained that considerable portions of the vessels were still intact, especially the machinery components and much of the equipment in spite of some damage due to water, oil, and heat. The pessimists proposed to cut up the vessels for scrap or to tow them out to sea and sink them. The optimists wanted to recondition the vessels with a minimum of work necessary to make them suitable for patrol or escort duty. Arguments were traded back and forth for some time and eventually it was decided by the Navy Department that new hulls would be constructed at Mare Island and that the Navy Yard Pearl Harbor would ship to Mare Island as much of the hull structure as would be worthwhile and the bulk of the machinery and equipment. The salvage job was eventually handled on that basis, and parts not shipped were cut up as scrap.

Work of the Destroyer Repair Units – Reference has been made to the valuable contributions to salvage work on the part of Destroyer Repair Units (afterwards called the Pearl Harbor Salvage and Repair Unit). This very worthy component was transferred from San Diego to Pearl Harbor shortly after 7 December and consisted of some 600 working hands plus additional numbers for housekeeping and maintenance. Their spirit and devotion to duty was most commendable and they performed outstanding service in handling certain aspects of battleship salvage. Usually they handled specialty work such as temporary lighting, removal of electric motors for reconditioning, preservation of machinery components, tending pumps during the night watches, etc. On the *CASSIN* and *DOWNES* they did practically all of the work.

On these two vessels they did a tremendous amount of patch work by electric welding to close up the hulls so the vessels could be floated out of drydock. In the case of the *DOWNES* it was necessary to reconstruct a considerable portion of her side in way of the torpedo explosion. The *DOWNES* was floated out of drydock on 6 February 1942. The *CASSIN* was righted on 5 February 1942 and was floated out on 18 February 1942. This made the dock available for Fleet use, particularly for the battle damage repairs, which was a matter of first consideration.

Both before and after removal from drydock the *CASSIN* and *DOWNES* were stripped of their machinery components, shafting, equipment, etc., and later were placed in drydock for removal of important hull sections for shipment to Mare Island. It is estimated that approximately 50 per cent of the two ships was installed in the new hulls bearing their names.

12.11. WORK ON THE ARIZONA AND UTAH

Reference has been made to the fact that the *ARIZONA* was substantially destroyed by the explosion of her forward magazines and that the *UTAH* was resting on the bottom nearly upside down. Due to the time which their salvage would entail, and the need for conservation of labor and materials, it was decided to refrain from major work on these two vessels. However, a very large amount of work was done in connection with removal of valuable items, such as guns, ammunition, safes, etc. Fuel oil also was a most valuable commodity and very scarce in the spring of 1942. Accordingly, a large amount of oil was pumped from the intact oil tanks of these vessels, and about a million gallons were recovered from the *OKLAHOMA*.

12.12. WORK ON THE OKLAHOMA

Salvage work on the *OKLAHOMA* was restricted to the removal of materials such as mentioned above, but arrangements were made for a long-term salvage operation which involved the manufacture of major equipment necessary to bring the ship to an upright position so that she could be refloated. The scheme consisted of setting up about 20 high-geared hauling winches on Ford Island. These winches were operated by fractional horsepower electric motors and were rigged with high leverage to exert a tremendous turning moment on the ship. It was also contemplated that some submarine salvage pontoons be employed to help break the ship out of the mud and that compressed air be used inside the ship to blow out the water on the outboard side and thus to exert an additional righting moment.

This work was given a low priority, but went along in due course, and eventually the *OKLAHOMA* was righted and refloated. The cost of reconditioning her as a naval unit appeared disproportionate to the value of the ship, so she was eventually sold for scrap. Unfortunately during the tow to the mainland scrap yard she was lost at sea. Even though the vessel was not put to any useful purpose her salvage constituted one of the most difficult salvage operations and is a great credit to the personnel who carried the work through. Her removal released a very valuable berth for use by large combatant ships.

12.13. DIVING OPERATIONS

Without a very large number of highly qualified divers the salvage work at Pearl Harbor could not have been accomplished. The underwater work performed by divers was revealed after some ships were placed in drydock – most persons were amazed at the extent and the proficiency of the work.

The divers of the salvage division were drawn from a number of sources – some from the ships under salvage, some from the navy yard, some from the civilian contractor, a considerable number from Destroyer Repair Units, many from the *USS ORTOLAN* and the *USS WIDGEON* and a few from the Submarine Base. In all there were nearly a hundred. The work was divided up into special assignments depending upon individual proficiency, such as inspection and measuring of underwater damage, removal of underwater wreckage, installing and attaching cofferdams, patches and closures, operation of watertight doors and hatches inside the ship, interior inspections to find inflow of water, operation of ships' pumps on compressed air, utilization of pumping systems and valves, removal of submerged guns and ammunition, recovery of confidential matter, etc. It is noteworthy that all of the diving work in the salvage operation, much of it hazardous, was accomplished without a single severe casualty. The total work consisted of approximately 3,000 dives totaling about 9,000 diving hours. Most of the diving work was done on the *OGLALA*, the *WEST VIRGINIA*, then the *NEVADA* and *CALIFORNIA*. Later a large amount of diving work was done on the *OKLAHOMA* which is not included in the above totals.

12.14. THE NAVY YARD, PEARL HARBOR

Rejuvenation at Pearl Harbor in material matters was handled in great part by the officers and civil service employees of the Pearl Harbor Navy Yard. Their spirit was not lagging. Essential materials and manpower were hurried from the mainland to build up the repair capacity. Thousands of mechanics and other ratings throughout the country volunteered for service at the Navy Yard. The force available at the yard to serve the Fleet grew quickly from a few thousand to ten times that number. Throughout the war this great military outpost contributed to the success of naval arms. The Navy Yard's accomplishments in repairing the damages suffered by vessels of the Fleet on 7 December were a marvelous performance.

13. SUEZ CANAL CLEARANCE

13.1 BRIEF

The task of clearing the Suez Canal was begun in 1956 after it had been effectively blocked by Egyptian forces during the invasion of that country by France, Great Britain, and Israel. It was imperative to clear the canal as quickly as possible because 1/7th of the world's ocean-going commerce used the international waterway.

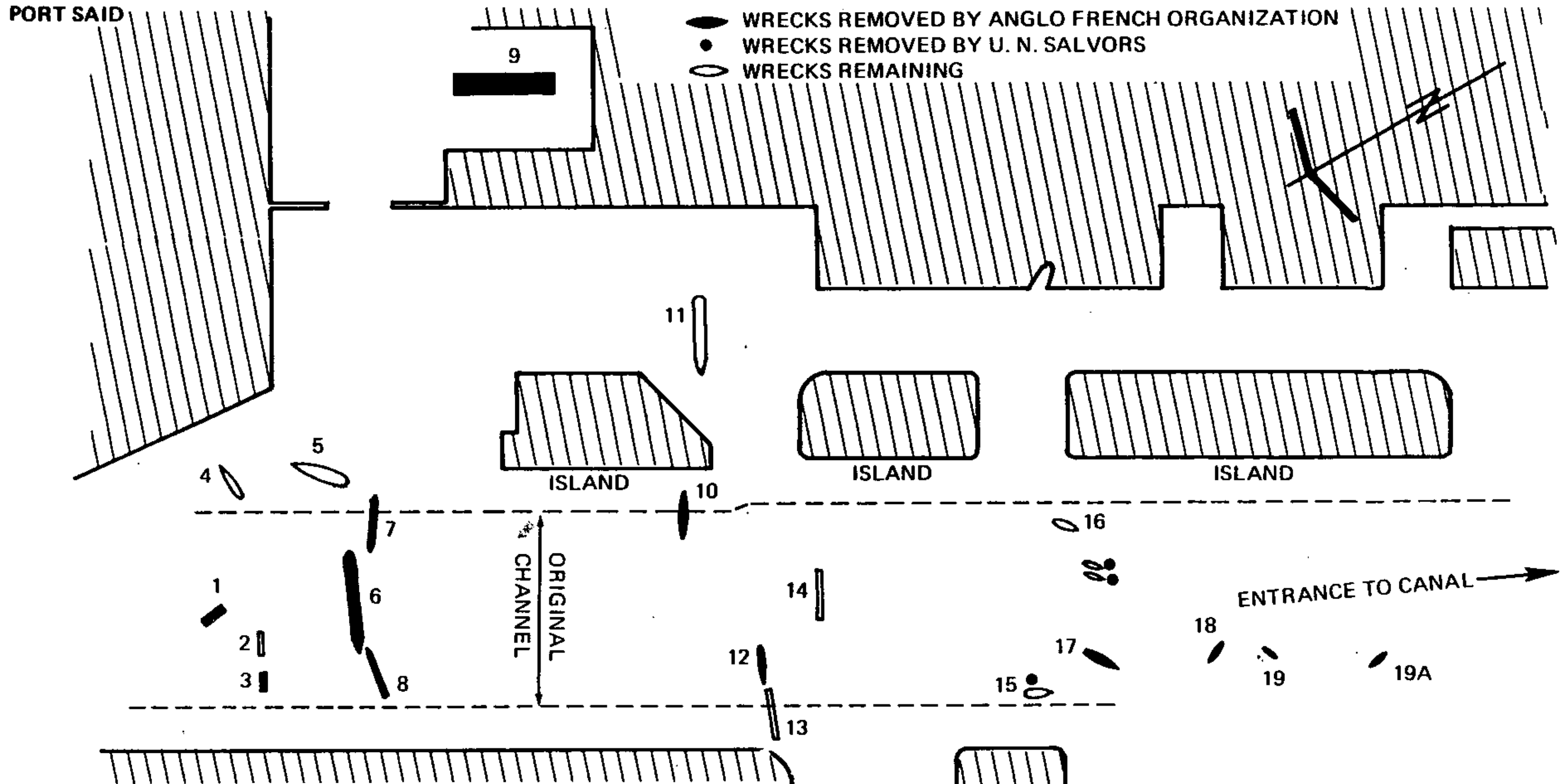
Potential economic disaster threatened the European countries if the Canal could not be cleared in all haste. After the cease-fire an ordinary salvage organization was not possible because of the hostilities still evident among the nations involved. A United Nations team organized and directed, a chartered salvage force composed of members from seven nations. The task was formidable as the Canal was blocked by sunken vessels of all sizes and varieties, including a fractured railway bridge. The heaviest concentration of wrecks was in the vital northern mouth of the Canal. The three-stage salvage operation was successfully completed at a cost of $8,300,000 in only four months, and the Canal was reopened to all international shipping.

13.2. HOW THE CANAL WAS BLOCKED

The nationalization of the Suez Canal, by the government of Egypt, produced an international crisis that led to the invasion of Egypt by forces from Israel, Great Britain, and France. Military action ceased on 6 November 1956, when the four nations involved accepted a United Nations appeal for a cease-fire; the U. N. had been authorized by its members to create a U. N. Emergency Force to police the cease-fire. During the course of the fighting, the canal had been blocked by Egyptian action, and in accepting the cease-fire the governments of France and Great Britain proposed that technicians accompanying their forces in Europe begin clearance work. On 20 November the Egyptian government requested U. N. assistance in clearing the canal and the U. N. Secretary General asked that he be authorized by the General Assembly to negotiate with salvage firms in suitable nations. This authority was granted on 24 November and arrangement for clearance under U. N. direction proceeded immediately, replacing the clearance effort that had been undertaken by the Anglo-French forces.

13.3. INITIAL ANGLO-FRENCH CLEARANCE OF PORT SAID HARBOR

As shown in Figure 13, No. 1 twenty-two ships were sunk by Egyptian forces in Port Said Harbor. These ships varied in size from about 4,000 to 100 tons displacement. (See Table 13, No. 1.) Of these, some were completely submerged, some had only masts and superstructures above water, and some were sunk in shallow water. Six of these wrecks were clear of the main channel but the remainder obstructed navigation to varying degrees. At one place the channel was completely blocked except for use by very small vessels. A number of the wrecks had been sunk by blowing holes in their bottoms with explosives to make salvage particularly difficult.



WRECK NO.

1	150 TON FLOATING CRANE	14	DREDGER NO. 19
2	80 TON FLOATING CRANE	15	TUG 'ARDENT'
3	15 TON FLOATING CRANE	16	TUGS 'AGILE', 'CHEDDID' & 'OIRSH'
4	SALVAGE VESSEL 'POLLUX'	17	TUG 'HERCULE'
5	DREDGER 'PELUSE'	18	PILOT BOAT 'LEHARDI'
6	SUCTION DREDGER 'PAUL SOLENTE'	19	TUG 'GARII'
7	HOPPER 'NEPTUNE'	19A	TUG 'BARQ'
8	HOPPER 'TRITON'		
9	FLOATING DOCK		* TUG 'BASSEL' INSIDE DOCK
10	HOPPER NO. 37		
11	MERCHANT SHIP 'IACOVOS'		TUG 'ACTIF' (NO. 20) SUNK IN ABBAS HILNA BASIN. NOT SHOWN ON CHART.
12	HOPPER NO. 44		
13	DREDGER NO. 16		

POSITION OF WRECKS IN PORT SAID.
FIG. 13 NO. 1

WRECKS IN PORT SAID HARBOR

Table 13, No. 1

No.	Name	Type	Displacement Tonnage
1	#823	150 ton floating crane	1,700
2	# 80	80 ton floating crane	1,300
3	#827	15 ton floating crane	365
4	POLLUX	Salvage craft	1,500
5	PELEUSE	Bucket dredger	2,900
6	PAUL SOLENTE	Suction dredger	4,000
7	NEPTUNE	Hopper	1,500
8	TRITON	Hopper	1,500
9	—	Floating dock	2,700
9A	BASSEL	Tug	400
10	#37	Hopper	1,450
11	IACOVOS	Merchant Ship	2,500
12	#44	Hopper	1,000
13	#6	Dredger	1,200
14	#19	Bucket dredger	1,900
15	ARDENT	Tug	190
16A	AGILE	Tug	190
16B	CHEDDID	Tug	280
16C	QUIRCH	Tug	280
17	HERCULE	Tug	1,200
18	LE HARDI	Pilot boat	490
19	GARII	Tug	235
19A	BARQ	Tug	350
20	ACTIF	Tug	115
		TOTAL DISPLACEMENT TONNAGE	29,245

A salvage unit had accompanied the Anglo-French forces and on 6 November, the day of the cease-fire, the Surveying Ship, *H.M.S. DALRYMPLE*, entered Port Said and commenced a survey of the harbor and the wrecks. The following day two Salvage Vessels, *H.M.S. KINGARTH* and *R.F.A. SEA SALVOR*, entered the harbor and started work on opening a channel for ships of 25 feet draft along the west side of the harbor. Meanwhile the British Admiralty began to mobilize all available salvage craft and by mid-December the number of salvage vessels had risen to fourteen British, three French and two large German lift craft, *ENERGIE* and *AUSDAUER*, which had been chartered by the Admiralty and towed from Hamburg and were considered to be the world's most powerful lift craft. Eleven more salvage vessels were in the Mediterranean on their way and eight were held at Aden and Djibouti in readiness to move up to Suez. Altogether some forty salvage ships were employed or held in readiness.

On 24 November, the Western channel through Port Said was opened to ships of 25 feet draft and this was increased on 30 November to a depth of 36 feet. The way was then clear for the Anglo-French Salvage Fleet to proceed with the clearance of the rest of the Canal. Since this was not possible because of the desire of the Egyptian government to have clearance undertaken by the United Nations, work was continued at Port Said and by 15 December an eastern channel past the main block had been cleared to a depth of 36 feet.

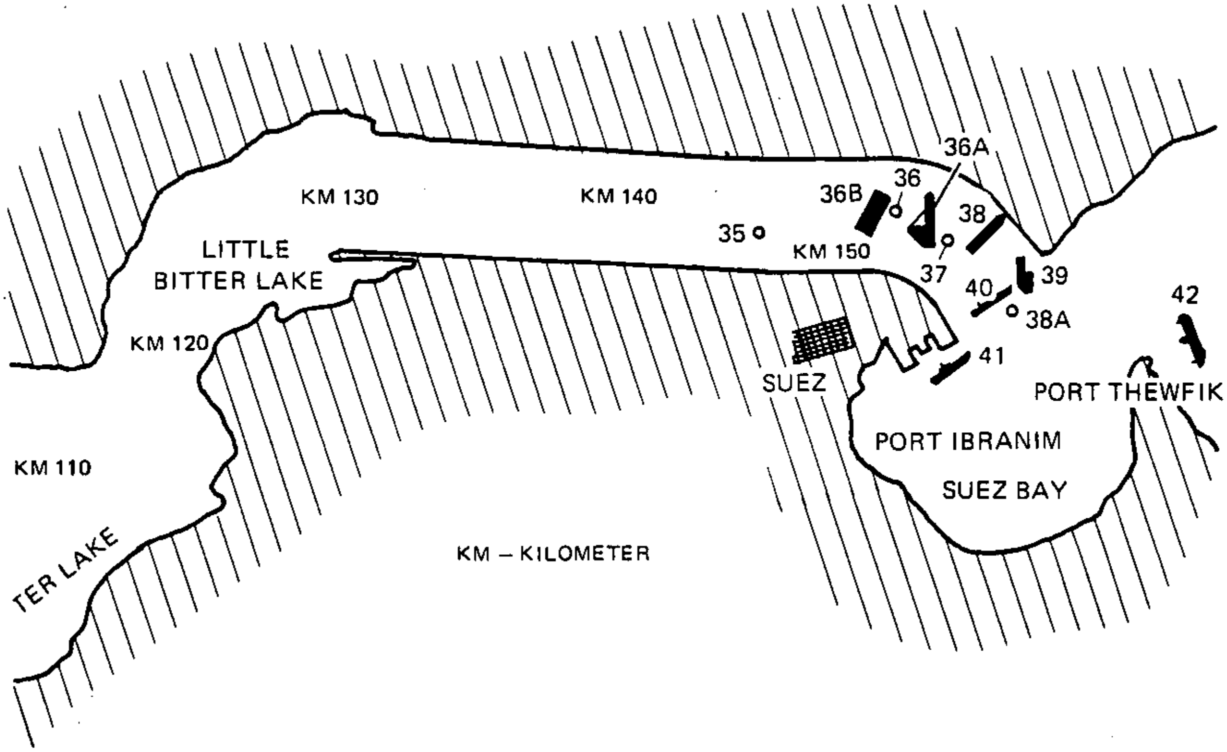
All salvage work was suspended on 20 December until after the Anglo-French withdrawal on 22 December when the number of salvage vessels was reduced to eleven, with certain support ships, and placed under United Nations control for the U.N. salvage operation; the crews wore plain clothes and the ships flew the United Nations flag. The two German ships were released to work with the United Nations further down the Canal.

13.4. THE MAGNITUDE OF THE TASK

The Secretary-General appointed Lt. General Raymond A. Wheeler, (USA, Ret.) as special assistant for the clearance operations. While the salvage fleet was moving toward the Canal from the North, Baltic, Adriatic, Red and Mediterranean Seas, and from the Canary Islands, General Wheeler and his 19-man team of U.N. staff members and contractors' representatives arrived in Egypt for an on-site inspection of the operation. This inspection showed the task to be a formidable one. The canal was blocked by sunken wrecks of many sizes and varieties, including a fractured railway bridge. These wrecks (listed in Table 13, No. 2) were found throughout the length of the canal, with the heaviest concentration at the vital northern mouth. (Fig. 13, No. 2 shows the placement of obstructions throughout the canal.)

13.5. PLAN OF OPERATION

The plan of operation drawn up for the United Nations Suez Canal Clearance Operation (UNSCO) was divided into three stages:



ITY)

LIST OF WRECKS

26 – LOUIS PERRIER DREDGER, 5400HP, 2200 TON
30 – EL FERDAN BRIDGE, 2 SPANS 300 TON EACH
31 – EDGAR BONNET TUG, 4500HP, 1390 TON
32A – CAR FERRY, 14 TON
33 – AKKA LST, 3750 TON (LOADED)
36A – BUCKET DREDGER NO. 3, 1300HP, 1200 TON
36B – ROCK BREAKER, 500 TON
38 – CASTOR LIFTING CRAFT, 400HP, 1350 TON
39 – ATLAS TUG, 3240HP, 1300 TON
40 – ABOUKIR FRIGATE (ESTIMATED 2000 TON)
41 – ZAMALEK FRIGATE, 1566 TON
42 – OPALIA TANKER, 6195 TON (NOT UN RESPONSIBILITY)
33A – MUSTAFA KAMAL TUG, 50 TON

SUPPOSED OBSTRUCTIONS

(PROVEN NON-EXISTENT BY UN SURVEY)

23 – MAROONED SHIP LATER RELEASED (SS MARY)
27 – PTOLEMEE UNDAMAGED DREDGER LEFT UNDER OWN POWER
28 – NOTHING FOUND
29 – NOTHING FOUND
32 – PONTOON BRIDGE (REMOVED PRIOR TO UN SURVEY)
34 – NOTHING FOUND
35 – FLOATING SHEERLEGS UNDAMAGED AND TOWED AWAY
36 – NOTHING FOUND
37 – NOTHING FOUND
38A – PENELOPE UNDAMAGED BUCKET DREDGER LEFT UNDER OWN POWER

POSITION OF WRECKS AND OBSTRUCTIONS THROUGHOUT THE CANAL.

FIG. 13 NO. 2

WRECKS IN THE SUEZ CANAL OUTSIDE PORT SAID

Table 13, No. 2

No.	Position	Name and/or Type	Displacement tonnage
21	23 km.	?	Supposed wreck 100' long, not found
22	40 km.	Bucket dredger	1,600
23	41 km.	?	wreck proved to be marooned ship MARY
24A		Tug YAKEZ	235
24A		Car ferry	140
24B		Car ferry	140
24C		Rail ferry	395
25	55 km.	Tug DARFIL	152
26	54 km.	Suction dredger LOUIS PERRIER	2,200
27	54.3	Bucket dredger PTOLEMEE	Undamaged, left under own power
28	64.5	4 barges	Not found
29	67.2	3 vessels	Not found
30	68.2	FERDAN Bridge	Two sections, each of 300 tons
31	75.5	Tug EDGAR BONNET	1,390
32	76	Pontoon bridge	Not found
33	81.4	LST AKKA	3,250 tons plus 1,800 tons cement load
34	99.5	3 vessels	Not found
35	149	Floating sheerlegs	Not found
36	153.5	Floating dredger	Not found because removed to Suez
36A	154	Bucket dredger	1,900
36B	156.1	Rock breaker	500
37	157.2	3 vessels	Hoppers, found moored & undamaged
38	159.5	Salvage vessel CASTOR	1,500
38A	160.3	Bucket dredger PENELOPE	2,900
39	160.8	Tug ATLAS	1,300
40	160.7	River Class Frigate ABUKIR	1,600–2,000
41	Port Ibrahim	SS ZAMALEK	1,566 GRT
42	New Port Rocks	OPALIA	Tanker, 6195 GRT, not UN responsibility

I. The canal was to be cleared as rapidly as possible of obstructions to permit limited transit by ships with up to 25 feet draft (roughly ships of 10,000 tons displacement).

II. Removal of additional obstructions in the main channel to permit transit of ships of maximum draft.

III. Removal of remaining obstructions in ports, basins and channels, and restoration of the Canal's base installations such as workshops.

13.6. TERMS OF CONTRACT BETWEEN U. N. AND SALVORS

Under the terms of their contract with the U.N., the salvage firms involved undertook to carry out the plan of operations "as a matter of high priority." The key element in the contracts provided for the employment of the salvors and their subcontractors' equipment and services on the basis of agreed daily rates for each vessel.

In addition, the United Nations reimbursed the salvors for specified additional expenses and paid them an over-all management fee. All rights to salvage awards and any other claims which may have resulted from the salvage operations were assigned by the salvors to the United Nations, which in turn waived all its rights of a salvor in respect of any salvaged property belonging to the government of Egypt. The salvors were not to claim any lien or other right in the wrecks on which they worked; any such rights which the salvors or their personnel would be entitled to enforce by law were to be assigned to the United Nations. All wrecks and other obstructions recovered by the salvors were to be placed at the disposal of the United Nations and delivered, stored or otherwise dealt with in such a manner as the United Nations might direct.

By chartering salvage equipment on the basis of a daily hire, the United Nations was able to make more flexible and efficient use of its salvage resources than if it had made arrangements for clearing the wrecks under the usual terms allowing the salvor the right to a salvage award proportionate to the value of recovered property. The salvors continued to receive the same compensation for each salvage craft whether it was working on salving a valuable wreck or on removing and dumping valueless junk. No difficulties could therefore arise as a result of a preference of the participating enterprises to work on salving valuable property. Moreover, there were no obstacles to shifing salvage vessels from one partially salvaged obstruction to another so as to take best advantage of the particular technical characteristics of each vessel. Salvage equipment from different enterprises could be put to work together in order to bring to bear the maximum concentration of lifting power and skill essential for a speedy conclusion of operations. At the same time, vessels could be phased out and released from charter as soon as there was no longer any need for them, and the United Nations retained full control over the utilization of each salvage craft.

13.7. EQUIPMENT REQUIRED

The total resources made available to the UNSCO included 35 ships manned by 479 officers and men. There were 27 salvage vessels and tugs, four lift craft, and four floating cranes. In addition 14 camels were used in the operations. These ships arrived wearing the flags of seven countries: Belgium, Denmark, the Federal Republic of Germany, Italy, the Netherlands, Sweden, and Yugoslavia.

13.8. UNSCO OPERATIONS

When the United Nations' salvage fleet was permitted to start its operations on 28 December, eleven wrecks were still blocking the main channel; only one of these "stage one" wrecks, a small tug, was in the Port Said area. In order to attain most rapidly the first objective of the clearance operation, the opening of an initial channel for ships of 25 feet draft, the operational program for the United Nations salvage fleet had to be based on a concentration of its effort in the first place in the central and southern part of the Canal. A destroyed railroad bridge (El Ferdan Bridge, wreck No. 30) was blocking the Canal at km 68 and preventing United Nations salvage vessels from Port Said to reach the wrecks further south.

NOTE: In accordance with the above notation of wreck number and location, all wrecks hereafter will be designated by:

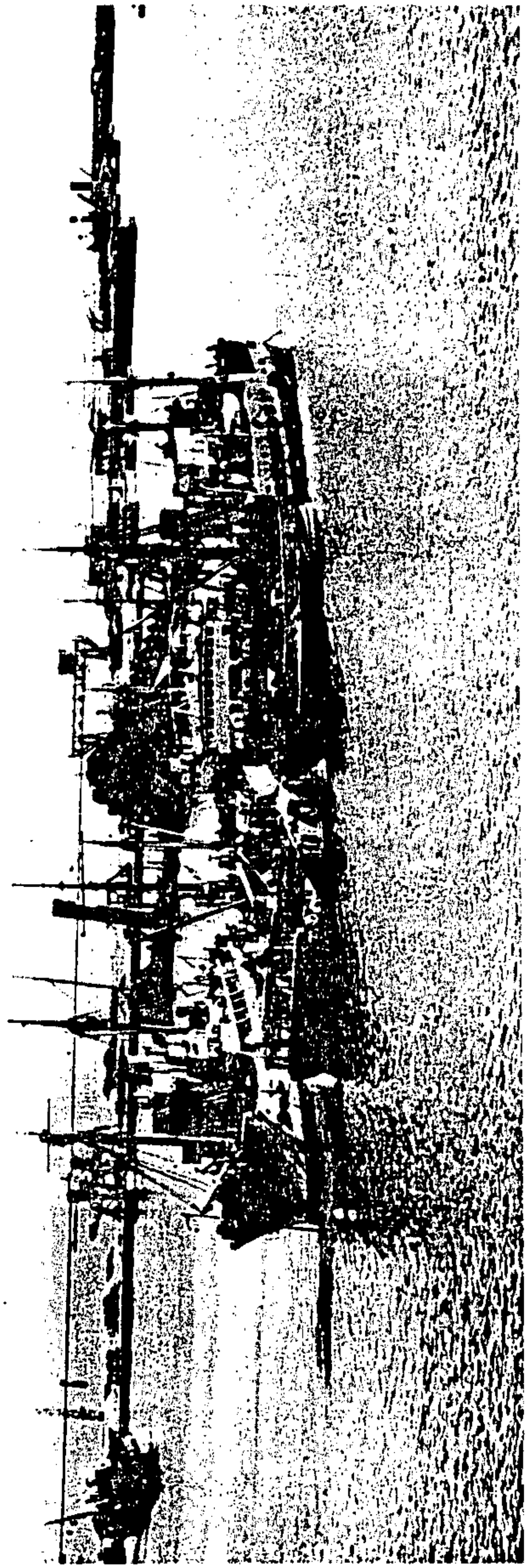
(___) = Wreck Number

___km = Distances in the Canal measured from the Port Said Lighthouse at the northern mouth.

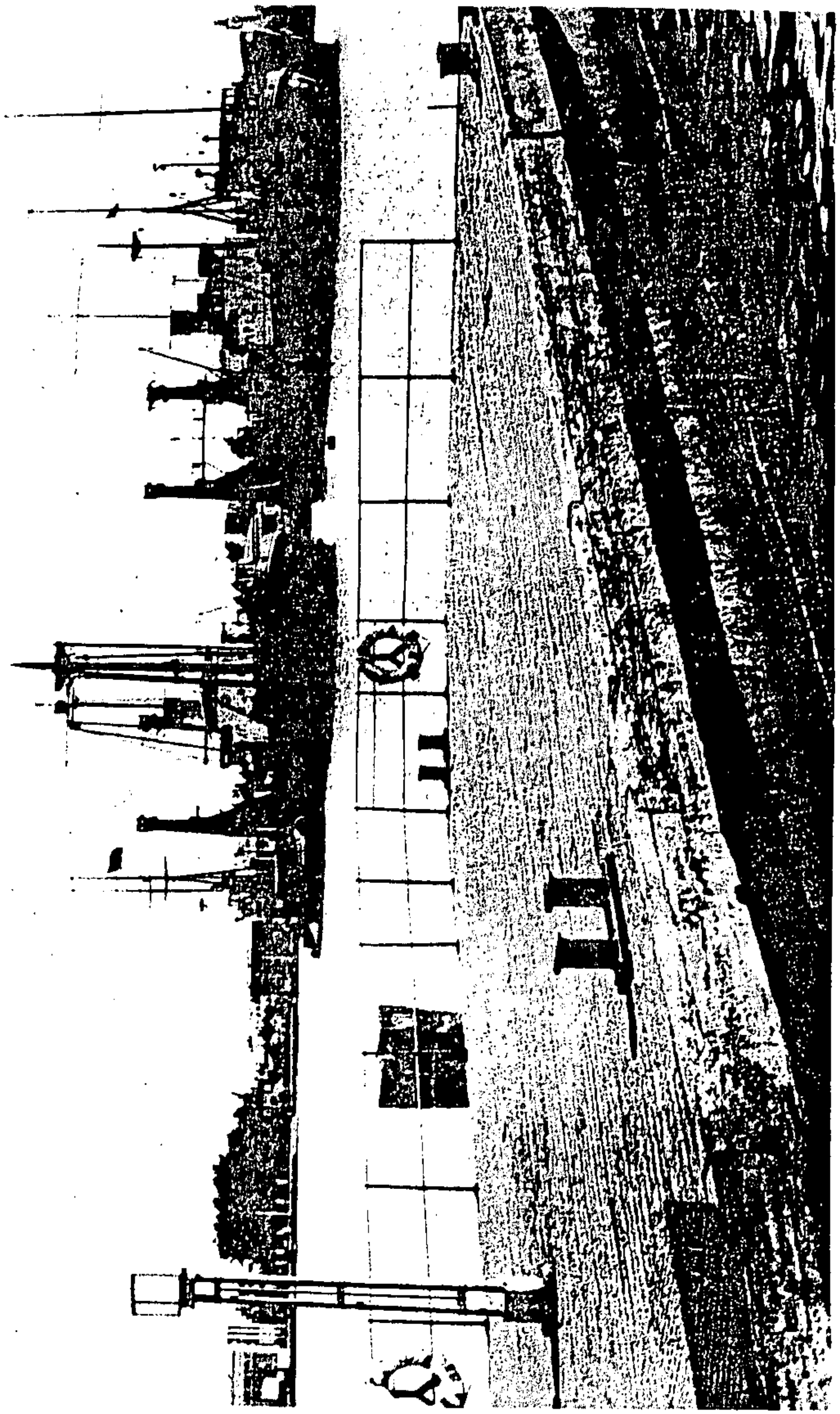
The first priority was therefore assigned to the removal of the bridge. The German lift craft were allocated the task of moving the eastern span of the bridge out of the channel, and Dutch sheerlegs were assigned to remove the west span and to place both spans ashore.

The next highest priority was assigned to the removal of wreck No. 33, the *LST AKKA*. Not only was this wreck blocking the channel across its whole width, but it was the heaviest wreck in the Canal and because of its position and damaged condition, it was likely to require the longest time for removal. Again the German craft, which alone had a lifting capacity sufficient to remove the wreck in one piece, were assigned to the task; a large Danish salvage vessel was to assist in the preparatory work and sheerlegs would be used to provide additional lift during the parbuckling of the wreck.

Two sunken bucket dredgers were lying across the fairway of the Canal, one about 40 km south of Port Said (22) and one near its southern entrance (36-A). Both were severely damaged by explosions and required lengthy preparatory work before they could be righted from their capsized positions and removed from the channel. Large salvage vessels and craft equipped with cranes were immediately put to work, first to cut off and then remove pipe lines, projecting towers, and other obstructions so as to clear an emergency passage around the wrecks for the release of merchant ships marooned in the



SALVAGE TUGS ENGAGED IN CLEARANCE OPERATIONS.
FIG. 13 NO. 3



THE GERMAN HEAVY LIFT CRAFT "ENERGIE"
AND "AUSDAUER".
FIG. 13 NO. 4

middle of the Canal, and thereafter to complete other preparations required in order to permit the removal of wrecks as soon as lift craft became available. Danish lift craft due to arrive about the middle of January were scheduled to raise wreck No. 22 and German lift craft were assigned to work on wreck No. 36-A, after they had completed the removal of the *AKKA*.

A large tug (31) was effectively blocking the navigation channel 75 km south of Port Said. Dutch sheerlegs, salvage vessels and tugs were assigned the task of refloating this wreck with the help of camels. However, they could reach the wreck only after the remains of the El Ferdan bridge had been cleared, and were meanwhile put to work on lifting and refloating a cluster of six smaller tugs in Port Said Harbor. While the removal of all these wrecks was not required for the reopening of a limited channel, the sheerlegs were able to lift and refloat these wrecks so efficiently that all six were salved in about a week, long before the sheerlegs were required elsewhere. Another advantage of the early refloating of the six tugs was that they could be rehabilitated and returned to service before the Canal was reopened, thus avoiding the need to hire tugs.

Three ferries (24 A, 24 B and 24 C) and a 500 ton rockbreaker (36 B) were lying in the fairway and required removal before the "stage one" clearance of the Canal could be considered complete; they did not block the whole width of the channel. These smaller wrecks could be cleared in a much shorter time and would normally have received lower priority. However, as their removal did not require the use of lift craft and as there were sufficient other salvage craft available, clearance operations on these obstructions were scheduled to take place simultaneously with those on other "stage one" wrecks. In addition, spare salvage equipment and divers could also be assigned to work on clearing an adequate passage into Port Ibrahim Harbor by cutting off the stern of wreck No. 41 lying in its entrance.

The last remaining "stage one" obstruction, wreck No. 40, required the use of the powerful German lift craft. There was a narrow channel available around it which permitted the passage, by exercising due caution, of vessels with 25 feet draft. Wreck No. 40 was therefore assigned a lower priority than other stage one wrecks and the German lift craft were to work on it only after completing the removal of the *AKKA* and of wreck No. 36 A. Meanwhile, it was expected that a second much wider but shallower channel could be cleared on the other side of wreck No. 40 by removing a sunken tug with the help of Danish craft.

As stated earlier, under UNSCO's initial operational plan, the United Nations salvage fleet was assigned to work primarily on those obstructions which had to be removed before vessels of 25 feet draft could safely transit the Canal. Within this category priority was given to the clearing of an emergency passage around the wrecks standing in the way of the removal of vessels marooned in the Canal. Next highest priority was given to those "stage one" obstructions which were expected to require the longest time for removal because of their weight, position or damaged condition. The limiting factor in achieving the rapid clearance of a "stage one" channel was the availability of lift craft needed to raise and remove heavy wrecks which could not be sealed off and floated. This limitation could be to some extent by-passed through the use of sheerlegs in combination with camels. UNSCO therefore gladly availed itself of the opportunity to acquire a third powerful and modern sheerleg. With its big crane-lifting capacity and camels, the United Nations fleet was eventually able to raise wrecks of over 2000 tons without using its lift craft on them. The United Nations had enough salvage equipment of other types available to permit its simultaneous assignment for the clearance of all "stage one" obstructions and to spare part of it for beginning preparatory work on some of the other wrecks.

Because of the priority assigned to the clearance of an initial channel, salvage operations on some wrecks were interrupted and postponed to a later date after the wreck had been removed from the main channel. The salvage equipment was shifted to other obstructions with a higher clearance priority. Such a policy, though necessary for the achievement of priorities, was inefficient from the over-all point of view of completing the whole clearance job for which the United Nations was responsible. Each time work had to be interrupted on a wreck, time was lost and additional expense incurred by the need to remove wires and bring them under the wreck again later, to disconnect and shift equipment, and sometimes even to repeat the lifts and other operations done previously. Consequently, after the United Nations was denied permission to work on two wrecks which effectively blocked the navigation channel, and when it became evident that the original plan to open a limited channel at an early date could no longer be implemented, the procedure of interrupting work on a wreck after it was moved out of the channel was discontinued. The operational planning was revised so as to make the most efficient use of the available salvage resources and to complete the whole United Nations clearance operation at the earliest possible date at a minimum cost. No differentiation was made between "stage two" and "stage three" wrecks as long as the United Nations was permitted by Egyptian authorities to remove the two remaining "stage one" wrecks still blocking the Canal. By the end of the first week in March, clearance operations were either completed or in progress on all known wrecks on which work was permitted to proceed.

NOTE: Wreck 33 A, a small tug lying on the west bank of the Canal at km 87.7, was discovered on 6 April when a final sweep of the Canal was made.

In the late evening of 9 March, UNSCO was notified that operations on the tug *EDGAR BONNET* (31) would be allowed to resume on 11 March and that work on the frigate *ABOUKIR* (40) could start a few days thereafter. The removal of these two obstructions completed the clearance of the main channel and the speed with which they could be removed determined the date on which the Canal could be reopened for normal traffic. Moreover, an initial channel for limited traffic would be available as soon as wreck No. 31 was cleared, provided that due caution was exercised when passing wreck No. 40. An important decision had to be made by UNSCO in choosing between two alternative methods by which it could clear these last two obstructions to navigation. One alternative was to use the German lift craft to do both jobs: they would first raise wreck No. 31 only to the extent necessary to shift it out of the Canal into Lake Timsah and would then move on to lift wreck No. 40, while other available salvage craft would continue refloating operations on wreck No. 31. The second alternative was to work on both wrecks simultaneously, by using Dutch sheerlegs, salvage vessels and camels on wreck No. 31 and German and Italian craft on wreck No. 40. The following considerations had to be taken into account:

a. The German lift craft would under normal circumstances require only one week for placing their wires and for making the short lift necessary to move wreck No. 31 out of the channel; it would take about 20 days to refloat the wreck on the spot by sheerlegs and camels.

b. There was always the possibility that the placing of the heavy lift wires used by the German craft would take more time due to unforeseeable obstacles or to the condition of the channel bed; if this occurred, the shifting of the wreck from the channel into Lake Timsah would take as long as its refloating on the spot.

c. The sheerlegs and camels were available immediately without the need to interrupt work on another wreck; the German lift craft were connected to wreck No. 2 which they were about to remove from the channel at Port Said, and they would have to abandon this wreck with a loss of all their preparatory work.

d. It was estimated that the removal of wreck No. 40 by the quickest method would require at least as long as the removal of wreck no. 31 by the slower method of refloating it on the spot.

e. Even though wreck No. 31 was the last one which completely blocked the channel and limited traffic could be resumed as soon as this wreck was moved, the Canal Authority indicated that it would not open the Canal until all the wrecks, including those which were not an effective obstruction to traffic, were cleared from the main channel.

After weighing all these considerations, UNSCO adopted the second alternative and directed that the Dutch sheerlegs, salvage vessels and camels move immediately to wreck No. 31 so as to be ready to start work on it as soon as permitted. The German and Italian vessels continued to work on their current assignments but were alerted to drop them at a moment's notice. The permission to work on wreck No. 40 was further delayed and was not obtained until ten days later; the German vessels were able to complete their operations on wreck No. 2.

Although the United Nations was not permitted to work for nearly two months on two of the obstructions effectively blocking the Canal, an initial channel which permitted passage to vessels of 25 feet draft was cleared by 25 March, only ten days later than was foreseen in the original estimates; the Canal was officially opened for vessels of 10,000 tons displacement on 30 March. The full width of the main channel throughout the length of the Canal and all required harbor space, was clear of all obstructions by 8 April, 38 days earlier than scheduled, and the Canal Authority permitted the resumption of near-normal traffic on 11 April. All three stages of the United Nations Suez Canal clearance operations were completed on 28 April, well in advance of the target date for completion of stage two operations.

"How was it possible to accomplish this enormously complicated task so quickly?" The answer was given by General Wheeler in an article ("Clearing the Suez Canal") that appeared in the January-February 1958 issue of the MILITARY ENGINEER. "The answer," Gen. Wheeler says, "lies in the fact that by drawing on seven nations, the U.N. was able to obtain exactly the right ships, equipment, and technical skills needed. For example, there were the Italians, known throughout the world for their great underwater cutting and patching feats. There were three of the most powerful floating cranes that exist today — two Dutch and one Yugoslav, and there were two big German lifting craft, used for the very heavy jobs.

"The work was done not with nationalistic rivalry but with friendly competition among the crews. They taught each other their own specialties and showed a keen desire to get an important job done. There never was any question of working hours. Some of the operations went on around the clock, with the same crew working 24 hours. It was not unusual for a salvage team to work 14 to 16 hours a day for a week at a stretch."

13.9. OBSERVATIONS ON SELECTED ASPECTS OF THE CLEARANCE OPERATION

There is no single criterion by which to compare the various clearance and salvage operations undertaken by the United Nations salvage fleet on the 32 different wrecks on which it worked. So many factors affected these operations that each of them must be considered individually on its own merits. However, in order to provide at least superficial means of comparison, the following circumstances must be taken into consideration:

a. The total weight of the obstruction;

b. The dimensions and shape of the wreck and distribution of its weight;

c. The nature and amount of damage to the wreck;

d. The configuration of the ground at the site of the wreck and mooring facilities;

e. Tidal currents, swell and weather conditions;

f. Accessibility of the wreck to divers for survey and underwater visibility;

g. The position of the wreck within the channel in particular; whether on an even keel or capsized; and whether on level ground or an incline;

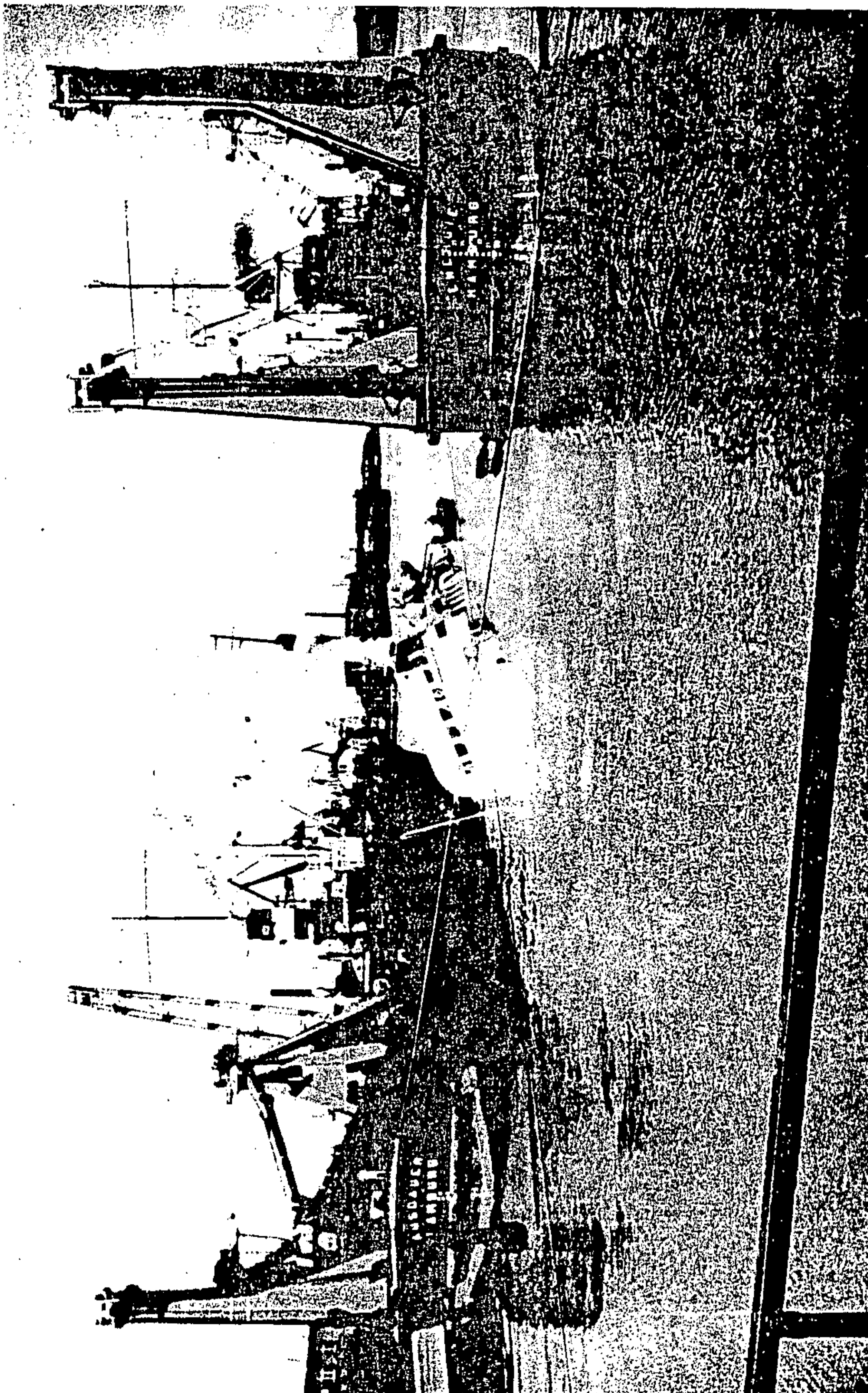
h. Amount of preparatory cutting, welding or dismantling operations required before the wreck could be parbuckled or raised from the ground;

i. Presence of explosives or other elements requiring special safety measures;

j. The number of lift wires which had to be placed under the wreck and the number of camels which had to be brought into position and secured;

k. Amount of sealing, patching and welding required to restore the watertightness of compartments which had to be pumped or blown to provide additional buoyancy;

l. If lift craft were used, the extent of vertical lift needed to remove the wreck from its site to a dumping ground or to raise it to the surface.



HEAVY LIFT CRAFT RECOVERING WRECK.
FIG. 13 NO. 5

The type and amount of salvage work required also depended on the objective of the operation; that is, whether the wreck was to be cleared by removal from the channel and dumping, by scrapping or by delivery afloat or ashore. If the wreck was to be refloated, any cutting or dismantling required for the lift operation had to be meticulously performed in such a way as to prevent or minimize any further damage. Moreover, before the wreck could be made floatable, holes in the hull and in bulkheads had to be patched, loose or missing rivets had to be replaced, and other repairs had to be performed by divers working underwater and sometimes in several feet of viscous mud surrounding the wreck.

The Total Weight of the Obstruction – The main effect of the total weight of a wreck was the need to provide a commensurate lifting capacity, and to use salvage equipment which had the required power to raise the wreck and the strength to hold it. Sufficient lifting capacity could sometimes be obtained only by a combination of different types of salvage equipment and by carrying out simultaneously several different types of lifting operations. For example, a lift might be accomplished by raising one part of the wreck by cranes or lift craft, blowing camels secured to other parts of the wreck and at the same time adding to the buoyancy of the wreck by pumping out some of its compartments. Such a combination of different equipment and operations involved delicate calculations, complicated arrangements for attaching the lifting equipment to the wreck in such a way as to assure a perfect balance of the lift applied at various points, lengthy work on sealing off compartments and connecting them by cofferdams to the air surface, and other time-consuming preparations. Wrecks weighing less than 4000 tons could be raised by a single pair of pontoon-type lift craft. But even where this type of equipment was used alone, the greater weight of a wreck was reflected in more difficult and longer preparatory work because of the need to place a greater number of lifting wires, each wire able to hold a load of 120-150 tons, and to prepare the lift more carefully. Moreover, the vertical distance that a wreck could be raised in each single lifting operation decreased proportionately with the weight of the wreck, reaching zero when the weight of the wreck equalled the maximum theoretical lifting capacity of the craft, i.e. 4000 tons for the German and 1600 tons for the Danish craft. Heavier wrecks required more consecutive lifts than lighter ones before they could be raised high enough to be moved out of the channel or refloated.

The Dimensions and Shape of the Wreck and the Distribution of its Weight – The clearance of wrecks which had a heavy tower or superstructure, such as bucket dredges, floating cranes and other service vessels, presented additional difficulties due to uneven distribution of weight within the wreck. Another instance of such difficulties was the wreck of the *LST AKKA* (33) with its heavy load of cement which shifted to one side when the wreck capsized, and solidified in that position. If the weight of a wreck was unevenly distributed, there was a danger that the wreck would shift within the lifting wires and that it would not have the required stability during parbuckling and lifting operations.

The Nature and Amount of Damage to the Wreck – The nature and amount of damage to a wreck affected not only the possibility of its salvage by refloating, but also had an important bearing on clearance operations which aimed only at the removal and dumping of the wreck. Damage to the wreck could have caused a shifting of its center of gravity, or in weakening its structure, make it impossible or too dangerous to move the wreck in one piece and hence requiring the time-consuming work of cutting the wreck or parts of it underwater. Jagged, ripped steel plates blown outward by explosions prevented the placing of messenger wires and threatened damage or cutting of lifting wires unless trimmed and smoothed first; the hull often had to be reinforced by welding steel plates onto those parts where wires were to be placed. A particular problem was presented by the damage to the *AKKA*. This heavy wreck had a large part of its bottom and side blown off. Therefore, the conventional salvage method for large wrecks, lift combined with internal buoyancy by blowing the holds of the vessel, could not be used in this case. Fortunately, the lifting capacity of the German craft, carefully and precisely applied, was sufficent to raise the wreck.

Ground Configuration and Mooring Facilities – Mud or silt which had accumulated around a wreck sometimes had to be dredged or pumped away before clearance or lifting operations could begin. Conversely, if a wreck was lying hard on a rocky bottom and in particular if the keel was embedded in it, serious difficulties were encountered in placing lifting wires under the wreck. Deep mud, as much as eight feet of it, was found around most wrecks in Port Said Harbor; some silt drifted up around the *AKKA* and the *EDGAR BONNET* (31); the rocky bed of the channel at the Canal's southern entrance caused delays in placing wires under the tug *ATLAS* (39).

Tidal Currents, Swell and Weather Conditions – Operations on wrecks at the southern end of the Canal were also hampered by strong tidal currents, while lifting operations in the Avant-Port at Port Said had to be suspended on some occasions because of the swell in this unprotected part of the harbor during northwesterly storms. Unfavorable conditions for anchoring or mooring the wreck and the salvage vessels working on it required, as in the case of the *LOUIS PERRIER* (26) and Dredger No. 3 (26a), the placing of heavy shore anchors, and operations were delayed until the ground could be prepared.

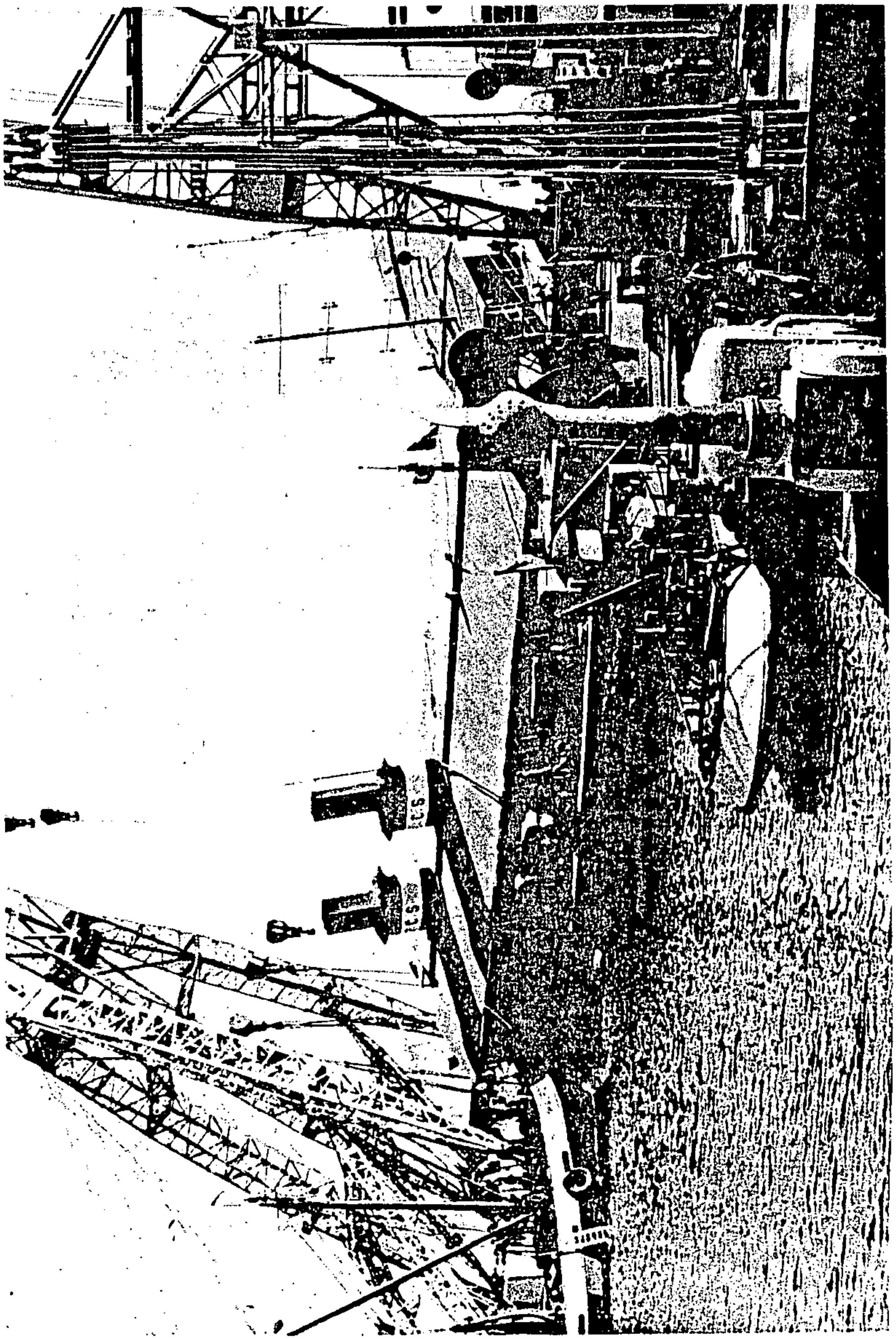
Accessibility of the Wreck to Divers – Before clearance operations could be undertaken on a wreck, it had to be surveyed by divers in order to determine its size, position, extent of damage, and other relevant information. This survey took much longer if the wreck was lying in muddy and opaque waters, such as those of Port Said Harbor where surveys often had to be done by feel rather than by sight. Moreover, the nature and extent of damage to the part of the wreck lying on the ground and inaccessible from the inside could be discovered only by removing the mud or silt from underneath the wreck. Explosion damage presented a particular problem in this instance, as the existence and position of holes could not be predicted. Cases in point were wrecks of the *POLLUX* (4), *PELUSE* (5), *PAUL SOLENTE* (6) and *DREDGE NO. 6 B* (14), where the full extent of damage could be ascertained only after lifting or pumping operations took place.

Position of the Wreck Within the Channel and the Amount of Preparatory Work – With few exceptions, the explosions that sank the vessels also capsized them, so that they came to rest on their side or upside down, and had to be parbuckled (righted to an even keel) before they could be cleared away. These parbuckling operations required a great amount of underwater preparatory work such as mooring the wreck so that it would turn over, but not slide; placing wires for applying vertical lift and horizontal pull; removing all obstructions to the turning motion; dismantling or cutting off the projections on the wreck's superstructure which would be in the way of the salvage vessels, or which by their weight could upset the balance of the wreck or counteract the power applied to turn it. Thus, considerably more time and effort had to be spent on capsized wrecks than would have been required for a conventional salvage of vessels sunk on an even keel. If the wreck came to rest on the steeply inclined bank of the main channel, such as had the *LOUIS PERRIER* (26) and *CASTOR* (38), added precautionary measures had to be taken to prevent the wreck from slipping down during the clearance operations. Of lesser importance from an operational point of view was the position of the wreck in relation to the axis of the channel; while a number of wrecks had to be turned lengthwise in the Canal before they could be removed, this was usually done in the stride of lifting operations and caused no appreciable delay.

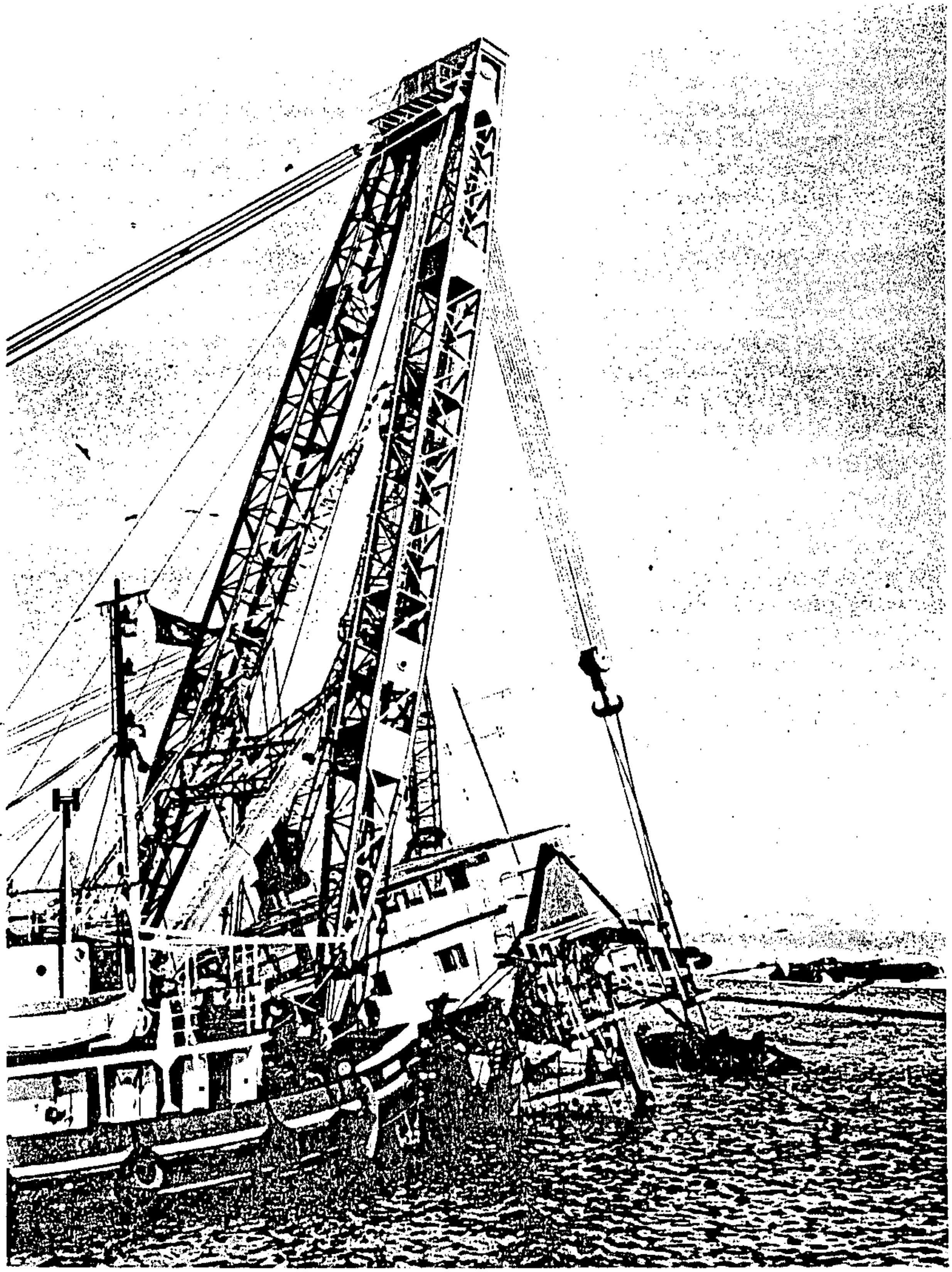
Presence of Explosives – A number of wrecks blocking the Canal required special care for they still contained undetonated explosives. The removal of mines and explosives was a responsibility assumed by Egyptian authorities; it might have delayed the operations if their assistance was invoked each time explosives were found or suspected in a wreck. A particular problem in this connection was the removal of Wreck No. 40, the frigate *ABOUKIR*. UNSCO was, for nearly two months, refused permission to clear this wreck on the grounds that the ammunition, depth charges and other explosives left in the wreck had to be removed by Egyptian Navy divers; when permission to work on the wreck was eventually obtained, it was found that the explosives were still inside the ship in magazines to which access was difficult because of the damage to the wreck and its capsized position. As the early opening of the Canal to normal traffic depended on a rapid clearance of this wreck, salvage crews were instructed to proceed with the removal of the wreck without further attempts to clear it of explosives.

The Number of Lifting Wires and Camels Required – Simultaneously with the cutting, patching, dismantling and other operations necessary to prepare the wreck for lifting, thin messenger wires were placed under the wreck either by sweeping and pulling them in from its fore and aft ends or, if that was not possible, by tunneling through mud or silt underneath the wreck, and laying out the wires so that when the wreck was parbuckled, its keel came to rest on them, or by first partially lifting one end of the wreck to make way for bringing the wires in under its center. The heavy lifting wires which connected the wreck to the salvage equipment were then attached to the messenger wires and pulled through into the desired position under the wreck. Camels could either be attached to lifting wires or to grips welded or clamped on to the hull of the wreck. Sheerlegs, on the other hand, used as a rule only a pair of wire slings brought under each end of the wreck. The lift craft required the placing of sometimes as many as 34 nine-inch (circumference) steel cables, as in the case of the *AKKA*, to hold the weight of the heavy wrecks, and careful calculations were necessary for distributing the wires under the wreck so that none of them would have to bear a load which would strain it beyond its breaking point.

The Restoration of Watertightness and Characteristics of a Lift – While the preparations for lifting a wreck required in some cases up to seven weeks' intensive work, the lifting operation itself took only a fraction of that time. If the wreck was lifted by sheerlegs alone, it could break the surface within one or two hours after the slings were placed and the wreck was prepared for the lift. If additional lifting power had to be provided by using camels, or by blowing air into sealed-off compartments of the wreck, the lifting operation took longer, depending on the amount of air that had to be forced into the camels or the compartments and on the capacity of the pumping equipment. Unless the camels had to be repositioned or other complications arose, the wreck could be raised to the surface by these methods in one continuous operation, usually within a day or two. The lift craft, on the other hand, could raise a wreck only a few feet at a time; after each such lift, the wreck had to be moved up a



SHEARLEGS IN OPERATION.
FIG. 13 NO. 6



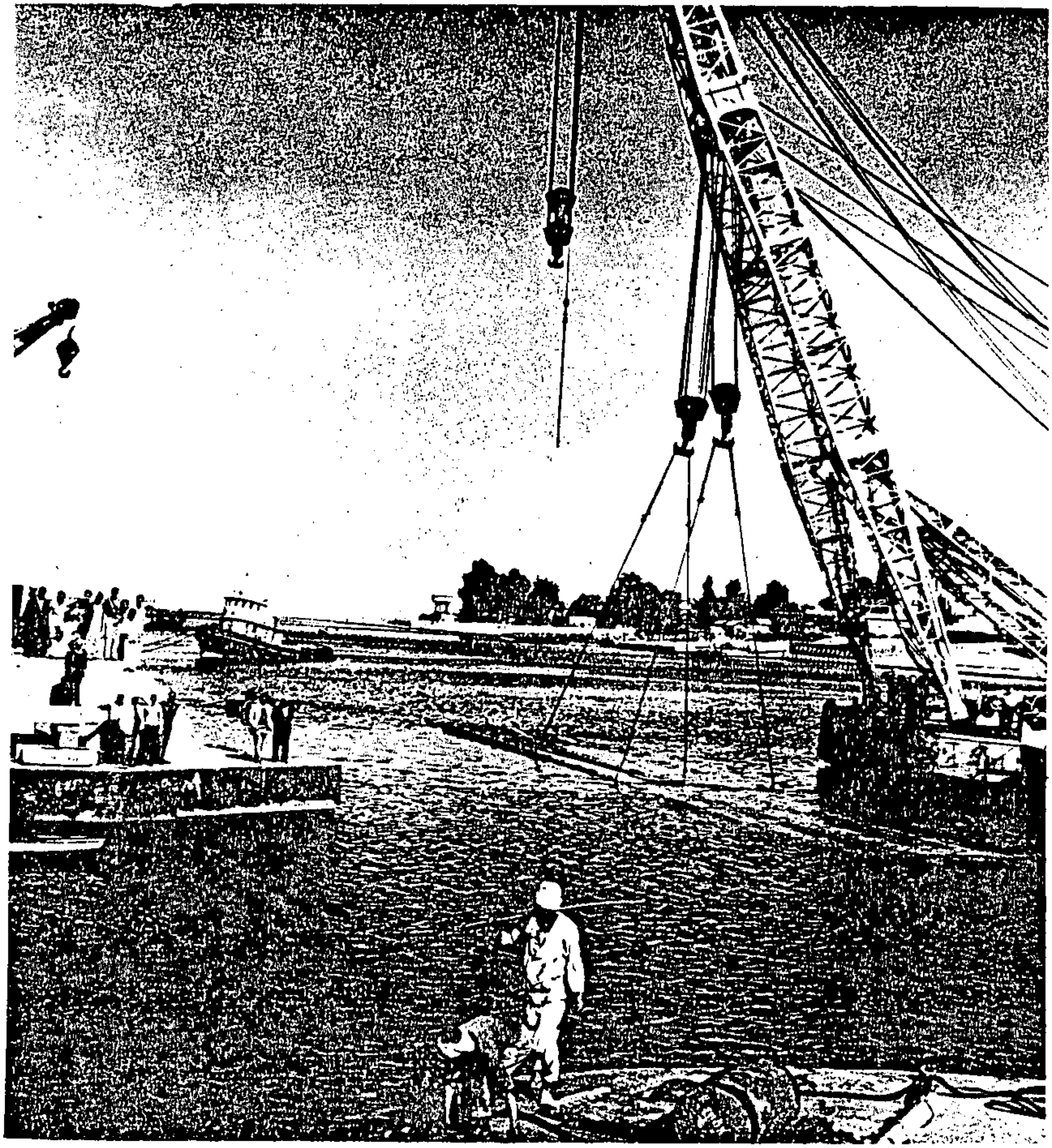
SHEARLEGS RECOVERING CANAL CRAFT.
FIG. 13 NO. 7

slope until it touched ground again, the pontoons of the lift craft had to be flooded to bring them down, the wires had to be tightened and any shifts corrected, and the lift craft's pontoons pumped out again to provide the next lift. At best, two lifts daily were possible, provided that the turn of the tides did not interfere with the lifting schedule. In each single lifting operation the German lift craft could raise a wreck from three to seven feet and the Danish craft from two to five feet, depending on the weight of the wreck. While one to three such lifts were as a rule sufficient to shift the wreck from the channel to a deep-water graveyard, many more lifts were necessary to raise it all the way to the surface or into shallow water. The only convenient slope available in the northern part of the Canal for such operations was in Port Said's Outer Harbor, but this slope was deep and muddy and after each lift the wreck settled back into the mud and a large portion of the height it had been raised was lost again. The refloating operations by lift craft on Wrecks Nos. 2 and 22, as well as the dumping of Wreck No. 14 which was raised into shallow water to facilitate later scrapping, took from eight to sixteen days, while the lifts necessary to move the wrecks into the dumping ground in the Great Bitter Lake, or into the graveyard established by the Anglo-French vessels in the Basin des Blocs, could be accomplished in one to three days.

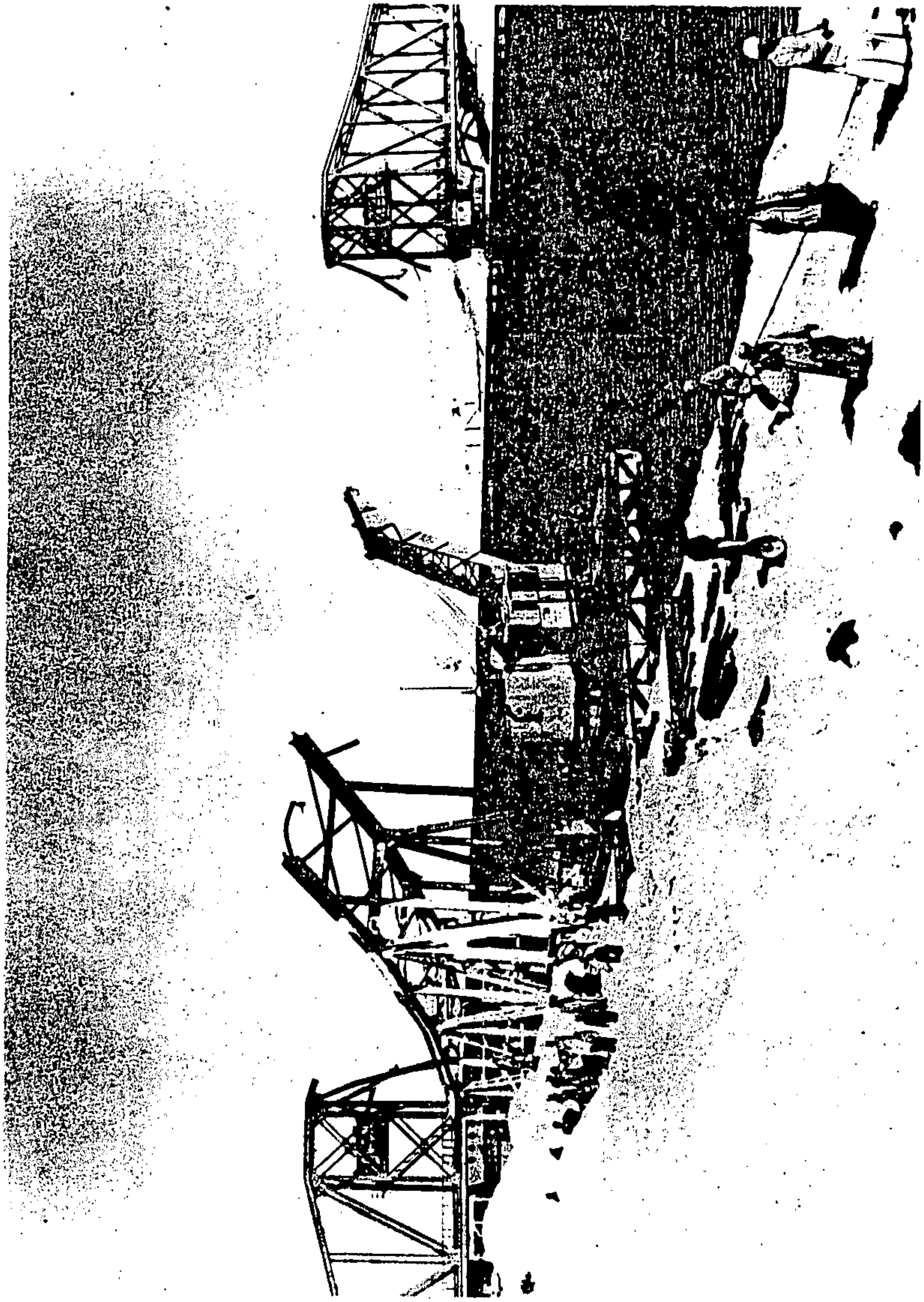
Nine Small Tugs and a Pilot Boat – Nine smaller tugs and a pilot boat (15, 16, 16A, 16B, 18, 19, 19A, 20, 25, and 33A), weighing less than 500 tons each, were scuttled in the Canal without using explosives and were lying on an even keel. Their clearance could be accomplished on the average of about two days per wreck, by using one or two sheerlegs to raise and refloat the wrecks. In addition, one or two small salvage vessels or a tug were used to move the sheerlegs into position, assist in placing the lifting slings, pump out the wrecks after they were lifted above the surface, and tow them to the Canal Authority's workshops where they were delivered for rehabilitation.

Four Ferries and the El Ferdan Bridge – Three car-ferries (24A, 24B, 32A) weighing about 140 tons each were lifted by sheerlegs and refloated or placed ashore for repairs, after a salvage vessel had cut off the guide wires and other obstructions to the lift. A railway ferry (24C) weighing about 400 tons whose bridge stood in the way of the release of the vessels marooned in the middle of the Canal, was dismantled underwater and its two pontoons and bridge were lifted separately by a sheerleg and placed ashore. The east span of the 600-ton El Ferdan bridge (30) was lifted and cut loose from its supports by using the stern cranes of two lift craft, a salvage vessel and two tugs; the west span was lifted by two sheerlegs and two tugs. Both spans were then moved to the Canal bank by two sheerlegs assisted by three salvage vessels and a tug; later, after the ground had been prepared, the sheerlegs lifted both spans ashore for repairs.

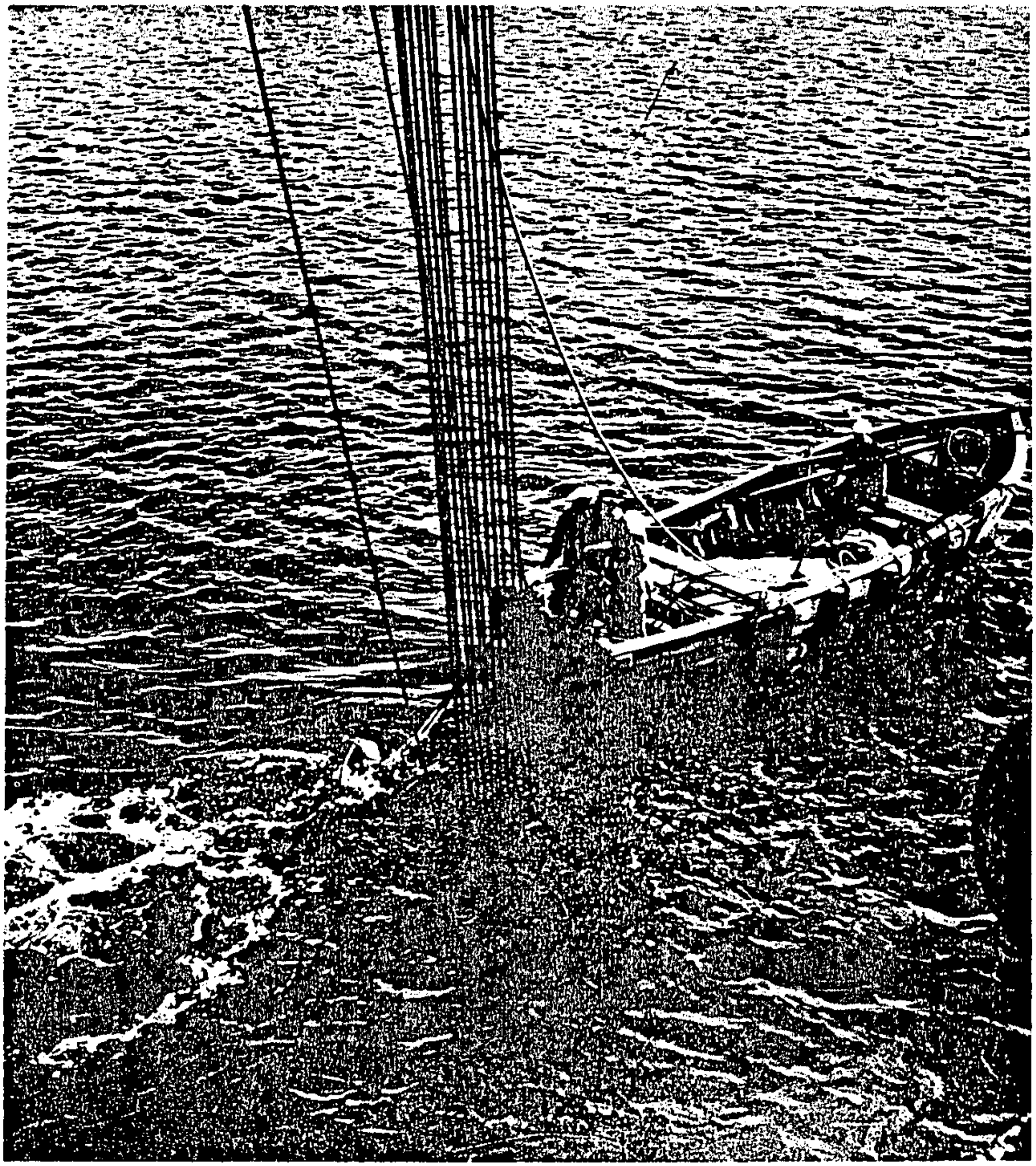
The HERCULE, EDGAR BONNET and ATLAS – Two large tugs, the *HERCULE* (17) weighing 1200 tons and the *EDGAR BONNET* (31) of 1400 tons, were refloated by the combined lift of two sheerlegs and six to eight camels, with four to five salvage vessels or tugs assisting in the preparations for the lift and in pumping out the wrecks. Great care had to be taken to space and align the camels alongside the wreck so that, when secured to the hull and blown up, they would provide a balanced lift together with the sheerlegs. A third large tug of 1300 tons, the *ATLAS* (39) was raised to the surface by two lift craft and two camels and pumped afloat. Eventually two salvage vessels assisted in the preparations for the lift which took over a month because of difficulties encountered in trying to place lifting wires under the keel of the wreck which was deeply embedded in the rocky bed of the Canal.



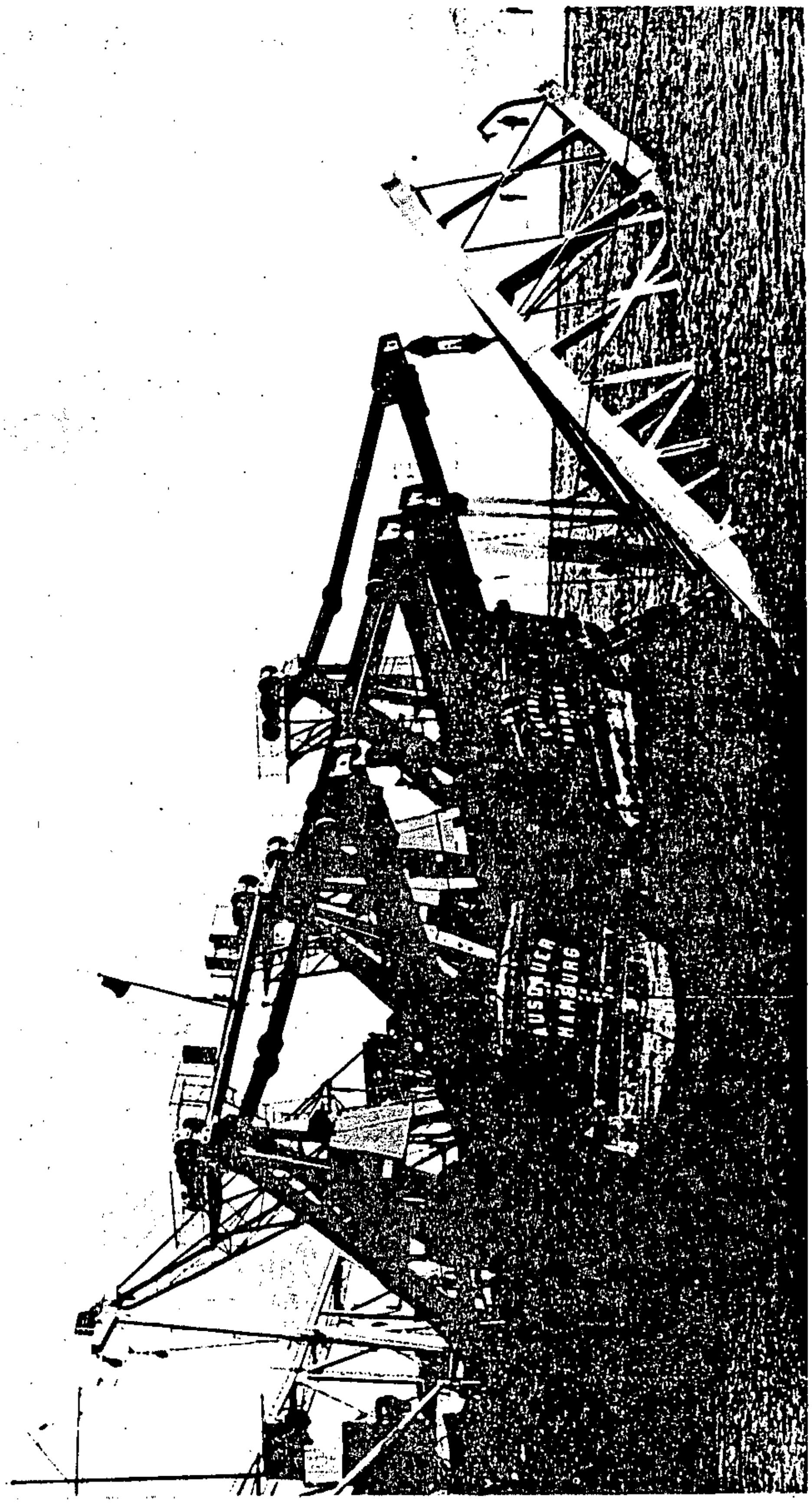
FLOATING CRANE "CONDOR" LIFTING FERRY PONTOON.
FIG. 13 NO. 8



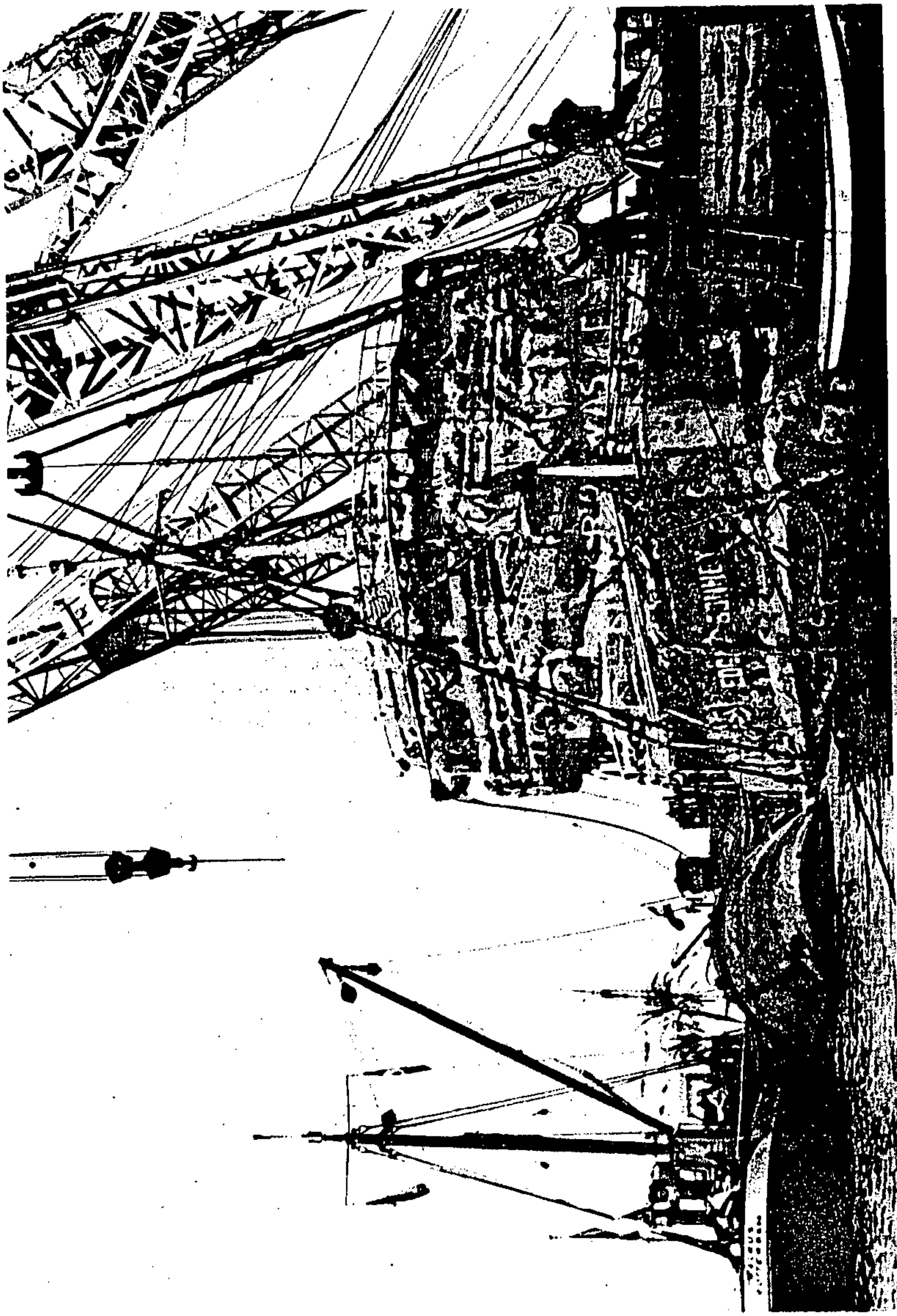
LIFT CRANE WORKING ON THE REMOVAL
OF THE EL FERDAN BRIDGE.
FIG. 13 NO. 9



DIVER CONNECTING LIFT BRIDLE FOR AN EL FERDAN BRIDGE SECTION LIFT.
FIG. 13 NO. 10



LIFT CRAFT REMOVING A SECTION OF THE EL FERDAN BRIDGE.
FIG. 13 NO. 11



RECOVERY OF THE 1400-TON TUG "EDGAR BONNET"
FIG. 13 NO. 12

The LOUIS PERRIER – The salvage of the suction-dredge *LOUIS PERRIER* (26) of 2200 tons was accomplished by three sheerlegs, ten camels, two salvage vessels and four tugs, in a technically remarkable operation requiring utmost precision in planning and coordination in execution. In addition to the lift provided by cranes and camels, some of the inside compartments of the wreck itself were sealed off and pumped out with the help of cofferdams in order to improve the buoyancy and trim of the wreck during the refloating operation. The preparatory work was further complicated by the need to seal off pump intakes and to remove underwater the 45-ton spuds which would have obstructed the lifting operation; the wreck was lying precariously on the bank of the channel at a 30 degree angle and had to be moored by ground anchors.

The Lift Craft, POLLUX and CASTOR, and the Bucket Dredge PELUSE – The Canal Authority's two lift craft of 1350 tons each were sunk by explosions and were found to be lying down by the stern with their bows ashore. One of them, the *POLLUX* (4), damaged near the water level, could be salved and refloated within two days by a sheerleg which lifted the stern of the wreck and a salvage vessel which pumped it out. The second lift craft, *CASTOR* (38), was patched and refloated by a team of Canal Authority technicians with six United Nations' salvage craft assisting in the operation and United Nations' divers securing four camels under the submerged stern of the wreck. The severely damaged ocean-going Bucket Dredger *PELUSE* (5), weighing 2700 tons, was lying on even keel with decks awash. It was refloated by pumping the tanks and holds of the wreck, after some twenty large explosion holes in them were patched underwater. This work occupied one of the large salvage vessels and its crew for 40 days.

Bucket Dredge No. 23 – The preparatory work for lifting Bucket Dredge No. 23 (22), weighing 1600 tons, required nearly a month's effort by three salvage vessels. They dismantled the bucket chain, removed the buckets and ladder of the wreck, patched explosion holes in the pontoon, cut off railings and other projecting parts of the superstructure which were an obstacle to parbuckling the wreck, and placed messenger and lifting wires. The wreck was then straightened on an even keel with the help of a fourth salvage vessel and two lift craft. Four camels were secured to the wreck and its boilers and other heavy parts were removed in order to increase the vertical lift which the two lift craft could provide, and to facilitate the shifting of the wreck out of the fairway and to the side of the main channel. There the wreck was left; the lift craft returned to it later after completing other priority assignments. Suspended between two lift craft, the wreck was towed by salvage vessels to the Outer Harbor at Port Said, where successive lifts continued for sixteen days until the forepart of the wreck was high enough to permit it to be pumped out and refloated with the aid of a sheerleg.

An 80-ton Crane – A salvage vessel and a crew of divers worked for twenty days on the wrecked 80-ton crane (2), to cut off buckled steel plates and to cover explosion holes with permanent steel patches. In the meantime, a sheerleg assisted by the crew of a tug, dismantled underwater and lifted ashore the jib of the crane and its counterweight, taking care to inflict the least possible damage to avoid cutting or breaking away any parts unless absolutely necessary. Another week was spent by the four vessels in placing parbuckling wires under the 1300-ton wreck, rotating the tower of the crane underwater into a neutral position and locking it in that position by clamps to permit parbuckling. After the wreck was successfully brought on even keel with the assistance of an additional salvage vessel, lifting wires were placed under the wreck and it was handed over to two lift craft and two tugs.

They raised the wreck; towed it to the Outer Harbor and continued lifts into shallow water until they reached the limit of their draft. They then disengaged from the wreck and lifting operations were continued by three sheerlegs, with the help of four camels and two small salvage vessels, until the deck of the pontoon broke surface and the wreck could be pumped afloat.

Bucket Dredge No. 6 B – The 1200-ton Bucket Dredge No. 6 B (14) lying in the channel at Port Said was at first thought to be salvable and preparations were started for its refloating. Its buckets were carefully dismantled and placed ashore, and a large salvage vessel spent two weeks patching explosion holes. The wreck was lying in deep mud and covered by marine growth; it was only gradually discovered that the hull of this 40-year old dredge was so badly corroded and weakened by the explosions that it could not be made floatable again. Patching operations were therefore stopped, but a team of divers, a sheerleg and a salvage vessel had to work another two weeks to bring wires under the wreck and to reinforce the hull in places where lifting wires had to be passed. The wreck was parbuckled by two lift craft, three salvage vessels, sheerlegs and a tug; the same vessels lifted the wreck out of the channel and it was towed to the Avant-Port. There, two lift craft and a salvage vessel, with the occasional assistance of a sheerleg, continued lifting operations for another two weeks until the vessel was raised into shallow water outside of the anchorage area.

Bucket Dredge No. 3 – Bucket Dredge No. 3 (36A), identical to Dredge No. 6 B, was blocking the Canal near its southern entrance. A salvage vessel, a floating crane and a tug worked for two weeks to prepare it for parbuckling; two lift craft and two tugs worked another two weeks placing wires, righting the wreck to an even keel, lifting it out of the channel and towing it to the Great Bitter Lakes where the wreck was dumped near the western shore.

The LST AKKA – The heaviest wreck obstructing the Canal was the *LST AKKA* (33), with its load of solidified cement, it weighed well over 3000 tons. A partial pumping of the wreck to lessen the weight by internal buoyancy was impossible because of the extensive damage to the hull, so lifting power capable of dealing with the hull weight of the wreck had to be applied. A very careful preparation of the lift was essential if breaking of wires was to be avoided and if the lift was to succeed without accident. Two lift craft, two tugs, and one other large salvage vessel worked for five weeks on cutting away obstructions, reinforcing the hull, removing explosives and other objects from the wreck, dredging away silt to provide a pocket into which the wreck would fit when parbuckled, carefully spacing out 34 lifting wires under the wreck, and making other preparations for the lift. An additional sheerleg and tug were used to assist in the parbuckling. The *AKKA* was raised, turned lengthwise in the Canal, towed away and dumped at the edge of Great Bitter Lake by two lift craft and two tugs.

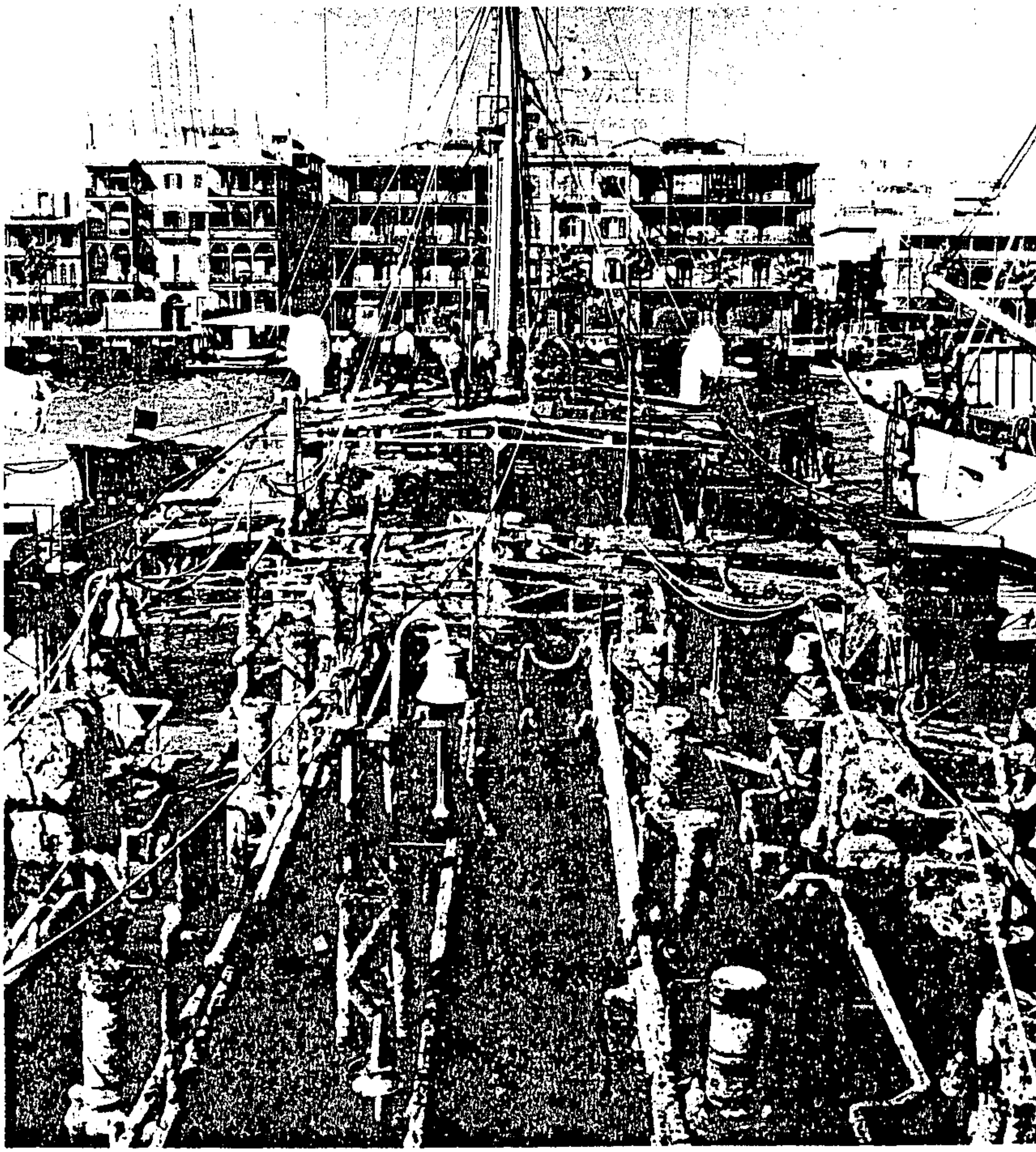
The ABOUKIR – Two lift craft and two tugs also parbuckled, lifted and towed to its dump in the Great Bitter Lake the frigate *ABOUKIR* (40) estimated to weigh about 2000 tons; they were aided by a salvage vessel and two divers' boats in cutting off projections from the wreck, reinforcing its hull by welding plates on it for passing wires, and making other parbuckling and lifting preparations. The work had to proceed carefully because of explosives inside the wreck, but nevertheless was completed in less than three weeks. Because the *ABOUKIR* was the last wreck in the channel, it was planned that the wreck would first be pulled to the side of the channel where the lifting preparations would continue. The weakened condition of the hull would not permit such a maneuver and the wreck had to be left lying across the fairway until it could be parbuckled and lifted.

ZAMALEK, Bucket Dredge No. 19 and a Rockbreaker – Three wrecks, a 500-ton rockbreaker (36B), the 1566-ton freighter *ZAMALEK* (41) and the 1900-ton Bucket Dredge No. 19 (13) which were damaged beyond repair, were scrapped by cutting them into pieces underwater. The time spent on such operations equalled or exceeded that which would have been required to remove and dump the wrecks in one piece with the help of lift craft, but other factors had to be considered. The tower of the rockbreaker was blocking the passage south of two merchant freighters stranded in the Canal. The freighter was lying across the entrance of Port Ibrahim and at least its stern had to be removed to provide an adequate entrance to the harbor. The lift craft which could have removed these two obstructions in one piece were at that time engaged in clearing wrecks with higher priority, and sufficient other equipment and divers were available to cut the wrecks and remove them in pieces. The Bucket Dredge No. 19 was lying with its forepart close against the slip of the ferry connecting Port Said and Port Fouad, and this essential ferry service would have been disrupted for several days if lift craft were to work on the clearance of the dredge before its forepart was cut off and removed. An additional consideration was that by cutting the wrecks into pieces, it would be possible to lift them ashore and recover some of the scrap.

The rockbreaker was scrapped in three weeks by two salvage vessels, a floating crane and a tug; all its pieces were lifted ashore by a sheerleg. Meanwhile, another small salvage vessel and two divers' boats cut off the stern of the *ZAMALEK*, lifted it with the help of four camels and a tug, and dumped it into shallow water. Both salvage teams combined thereafter to dismantle and lift ashore the more valuable parts of the *ZAMALEK* and to cut the remainder of the wreck into several pieces which were dumped near the Port Twefik breakwater. This work took another three weeks.

The scrapping of the 1900-ton Bucket Dredge (13) progressed slowly because of deep mud and opaque water which hampered the work of the divers. The buckets and ladder, and later the boilers and other more valuable scrap, were dismantled and placed ashore; two sections of the forepart as well as the aft section of the ship were cut off and removed to a dump. Three salvage vessels, two divers' boats and a sheerleg spent about six weeks on these operations. One lift craft, one sheerleg and one salvage vessel then tried to parbuckle the remaining middle portion of the wreck, but although it weighed less than 1000 tons, they did not succeed because the tower had embedded itself too deeply into the mud. Ten days later, after the mud was partly pumped away and twice as much equipment was used, the remainder of the wreck was parbuckled. The difficulties did not stop there; the wreck kept sinking into the mud with an increasing list. It was necessary again to delay lifting operations until more mud could be dredged away. In addition to the two lift craft originally assigned to do the job, a sheerleg, three salvage vessels, and four camels were used. This misfortune threatened to disrupt the coordination of phaseout plans, but it was eventually possible to arrange the return of all the equipment involved in this operation without any further delay or financial loss. Dredge No. 19 was the last wreck requiring clearance by the United Nations salvage fleet, and with the dumping of its last portion on 28 April, 75 days after work on this wreck began, the United Nations Suez Canal clearance was completed.

PAUL SOLENTE, HERCULE and a Floating Crane – Also, as stated previously, eight British and one French salvage craft worked under United Nations direction on the removal of three wrecks which they had begun to clear from the channel at Port Said before the withdrawal of Anglo-French forces.



THE RECOVERED DREDGE "PAUL SOLENTE".
FIG. 13 NO. 13

One of these wrecks was a 150-ton floating crane (1); which was damaged beyond repair. Four British salvage craft cut off and dumped the crane's jib which they had tried, unsuccessfully to break off; removed 350 tons of pig iron from its counterweight; and lifted, moved and dumped in the Outer Harbor the pontoon of the crane. The second wreck was the suction dredge *PAUL SOLENTE* (6) on which two large British salvage vessels had worked since 11 November patching its foreship. After the United Nations took over the direction of their work, patching continued and enough inside compartments were temporarily sealed off in the foreship wings and middle section of the wreck so that the bow of the ship could be raised by internal buoyancy. Lifting wires were then swept underneath the middle and stern portions of the wreck. Two lift craft and two salvage vessels raised the wreck just off the channel bed and moved it to the Outer Harbor where it was dumped in about 35 feet of water. The third wreck was the tug *HERCULE* (17) on which a French salvage vessel had worked since 16 November, sealing off hatches on inside compartments for pumping. After the United Nations takeover, the French salvage vessel, assisted by two British craft, secured camels to this wreck and shifted it into one of the harbor basins. Attempts were made to refloat the wreck but they were not successful; camels slipped off or upended, and on 20 January the lifting wires parted and the wreck slipped back and sank. The British and French craft abandoned further attemps and left the wreck for the United Nations salvage fleet to refloat.

3.10. SUMMARY OF CLEARANCE OF THE ANGLO-FRENCH FORCES

Before the withdrawal of Anglo-French forces, in the six-week period from 6 November to 19 December, 1956, 17 British and French salvage craft with their tugs and supporting vessels performed the following clearance operations:

a. An undamaged floating dock (9) was refloated by closing the seacocks, connecting the air compartments to the surface by cofferdams, and pumping the dock afloat. The tug *BASSEL* (9A) was inside the floating dock and was raised in it when the dock surfaced.

b. A small crane of 365 tons (3), two hoppers of about 1400 tons (7, 8) and two hoppers of 1000 tons (10, 12), were picked up by lift craft with the assistance of salvage vessels or tugs, and dumped in a deep water graveyard in the Outer Harbor of Port Said. These five wrecks were damaged beyond repair, but they were lying on an even keel and no substantial preparatory work was required before they could be lifted and moved from the channel.

c. A pilot boat (18) and a small tug (19) were shifted from their position in the main channel in Port Said to one of the harbor basins and a second small tug (19A) was shifted to the bank of the channel where it slipped back into the fairway. These three wrecks were eventually lifted and delivered afloat by the United Nations salvage fleet.

3.11. CONCLUSIONS

As may be noted from the above summary of salvage operations, most of the time and effort was expended on the clearance of those wrecks which required extensive preparatory work before they could be lifted. Some of these preparations were necessary in any event in order to permit the clearing of the wreck from the channel; the cutting off of projections, dismantling of the superstructure and removal of heavy parts, reinforcement of the hull, placement of lifting wires and the parbuckling of the wreck belong in this category. Other preparatory work such as the underwater patching, welding, and riveting operations, was performed for the sole purpose of permitting the salvage and delivery afloat of vessels which had been wrecked by explosions. The refloating of such wrecks involved not only more preparatory work, but if lift craft had to be used, additional weeks of lifting operations. On the other hand, the refloating of substantially undamaged vessels, scuttled by opening their seacocks and allowing them to sink on an even keel, required relatively fewer preparations and could sometimes be accomplished in a few days. Despite the fact that unconventional salvage methods sometimes had to be used in order to complete the clearance work in the shortest possible time, the United Nations Suez Canal clearance was accomplished without any loss of life or any serious accident due to salvage operations, at a cost of $8,300,000, far below original estimates that ranged from a minimum of $20,000,000 to a maximum of $40,000,000.

14. HARBOR CLEARANCE UNIT-ONE

14.1. BRIEF

Between 1964 and 1969 when the conflict in Southeast Asia was at its height, American forces found it necessary to implement a permanent, highly professional, yet flexible harbor clearance force in the Western Pacific. Harbor Clearance Unit-One was established to fulfill this requirement.

Harbor Clearance Unit-One has had the responsibility, since its inception in 1966, for keeping the harbors, rivers and channels of waterways in Southeast Asia open for Allied use. This unit, the first of its kind commissioned since World War II, has proven to be remarkably able and efficient, and of inestimable value. Concurrent with the general recall of Allied forces from certain areas of Southeast Asia, and the reduction of logistic support in the early 1970's, the Unit was slowly withdrawn and equipment and knowhow was turned over to the South Vietnamese under the "Vietnamization" program.

14.2. THE MISSION OF HARBOR CLEARANCE UNIT-ONE

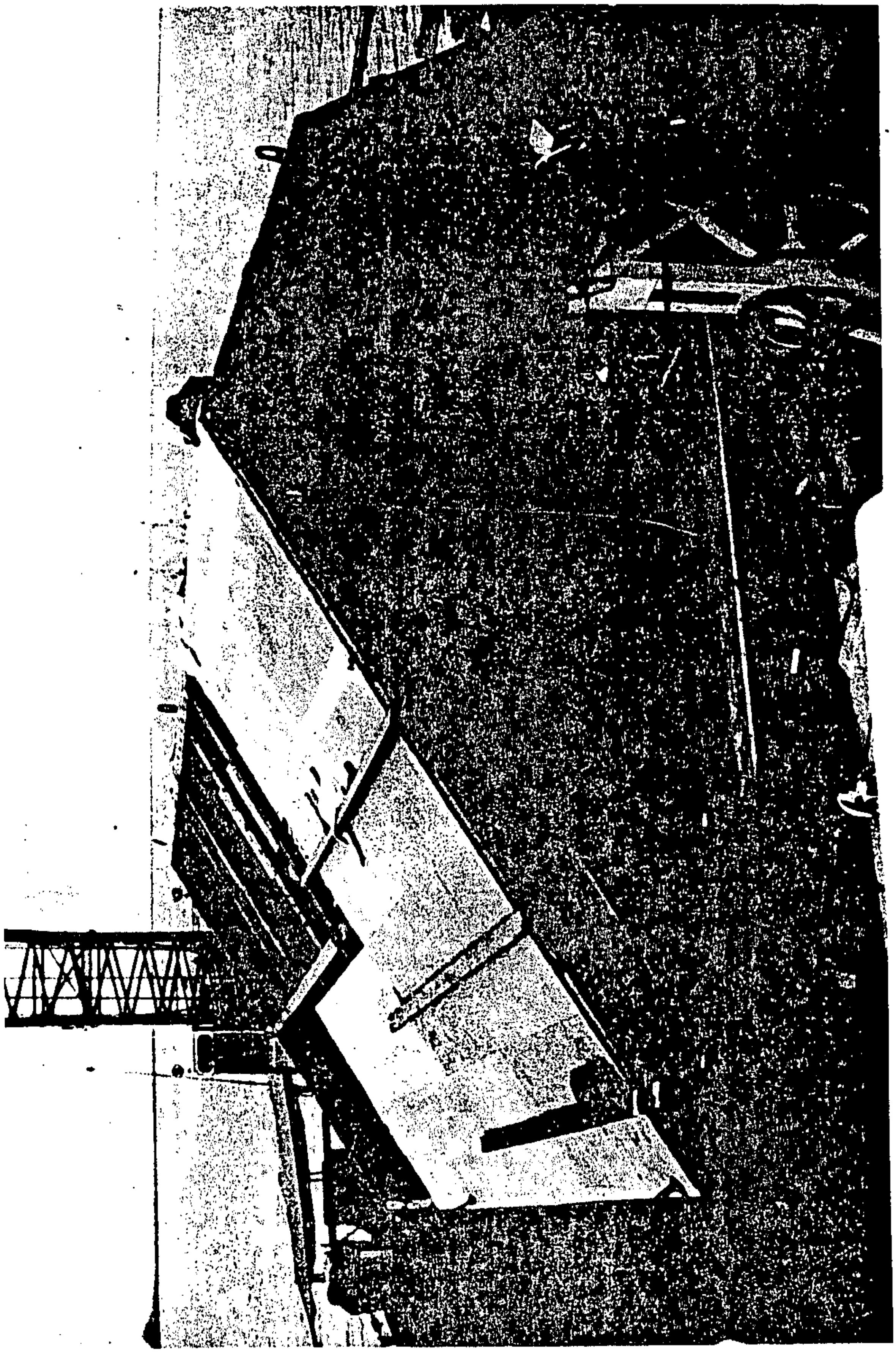
The responsibilities of the Unit as delineated in its commissioning were to support salvage operations, provide diving and rescue services in rivers and restricted waters, and conduct harbor and river clearance operations in the Western Pacific.

14.3. HISTORY

HCU-One was a direct descendant of the World War II harbor clearance units and was commissioned on 1 February 1966. Its first salvage task was the salvage of the merchant ship *SEA RAVEN* aground in Chu Lai, South Viet Nam. The second major salvage operation and the first entire unit job using the craft's tender, the Subic Bay staff and all the support personnel, was the *SS BATON ROUGE VICTORY*, also in Viet Nam. For this job the salvage team designed and fabricated the world's largest salvage patch, costing over $50,000 (Fig. 14, No. 1). The second entire unit job was in January and February 1967, when HCU—One was called upon to salve a mined dredge, the *JAMAICA BAY*, in Dong Tam, South Viet Nam. This was the first of three such dredge salvage jobs, all similar in size and configuration, and all sunk in Dong Tam, not much more than a half mile apart.

Though the majority of HCU jobs have been smaller operations, requiring the deployment of small independent teams and craft in-country, they have often been called upon to tackle major jobs requiring the mobilization of many craft, personnel and materials.

In its first three years of operations Harbor Clearance Unit-One conducted the following salvage and clearance operations as well as many smaller but equally as important tasks that were assigned as part of the daily routine:



PORT SIDE PATCH FOR THE SS BATON ROUGE VICTORY.
FIG. 14 NO. 1

1. Eleven large stranded ships were refloated;
2. Four large sunken ships were refloated;
3. Six large ships obstructing channels were demolished or removed;
4. Twenty-nine barges were refloated;
5. Four barges were demolished to clear channels;
6. Six tugs were refloated;
7. Three tugs were demolished to clear channels;
8. The wreckage of twenty-two aircraft was salved;
9. Fifty-one Swift, PBR and Riverine boats were salved or saved from sinking;
10. Twelve demolished barges were cleared from rivers;
11. Five sunken dredges were salved;
12. Two sunken dredges obstructing channels were demolished;
13. Two tanks, four amphibious tractors, and eight Army trucks were salved;
14. Eight sunken mooring buoys were raised and refloated;
15. Five concrete pontoon ferry landings were refloated;
16. Two mobile support bases utilizing ammi pontoons were moored in position;
17. Two refuse trucks were salved;
18. Two forklifts were salved;
19. Six major fires were fought and extinguished.

14.4. THE ORGANIZATION

When Harbor Clearance Unit-One was at its height in terms of operations, personnel, and materials, a Harbor Clearance Unit team was composed of about 18 men, skilled in diving, non-diving technical work, support activities and other related marine salvage operations. The teams were led by an Officer-in-Charge and an assistant, both Diving Officers. The teams were designed to be as mobile as possible as they were deployed anywhere in Viet Nam or the Western Pacific on a moment's notice. Operationally the teams worked in groups of three to five men on small jobs. They carried what gear they could in order to perform the job, and utilized local labor, materials and equipment wherever possible. When large operations were required all available teams worked as a group supplying the backbone of the personnel required.

14.5. HCU-One Salvage Craft

The two largest salvage craft in the world were used by HCU-One, the heavy lift craft *CRILLEY (YHLC-1)* and *CRANDALL (YHLC-2)*. These craft each have a tidal ballast lift of 2,400 tons. Manned by an Officer-in-Charge and 25 men, when on the job they also provided command headquarters, and berthing and messing facilities for the team. The heavy lift craft were first employed by HCU-One in Dong Tam, RVN on the dredge *SANDPUMPER*.

Three light lift craft, converted landing craft that offer a variety of capabilities, were among the salvage craft of HCU-One. The light lift craft are capable of a 25-ton lift with an A-frame derrick mounted forward and a 100-ton ballast bow lift. The YLLCs were also used as salvage platforms. Equipment carried aboard the YLLCs included air compressors, three complete sets of beach gear, two 1,000 gpm at 200 psi jetting pumps, and cutting and welding gear. Two 200 kw AC generators powered the ship's machinery and provided power for emergency use while on site. The YLLCs were manned by an Officer-in-Charge and 16 men. While deployed in Viet Nam they often operated independently and were vital to a major salvage job.

Combat salvage boats were also a part of the HCU-One fleet. There were four, converted from landing craft, which were designed for riverine salvage work. Each CSB was manned by a crew of six to eight men, four of whom were divers. Because of its smaller size the CSB is able to perform salvage operations in lesser rivers and channels than can the YLLC. It is capable of entirely independent salvage operations and was considered the mainstay of the salvage support forces of the Mobile Riverine Group. It is equipped with a ten ton A-frame derrick mounted forward, two jetting pumps, air compressors, cutting and welding facilities, and an excellent fire fighting capacity.

In addition, HCU-One operated two Yard Diving Boats. These boats were a vital part of every salvage operation because of their utility. The 64 foot craft are mainly used as diving platforms and are equipped to handle all types of diving gear. They are also used in time of need as tugs, ferries, provision craft, quarters, scout boats, communications stations, firefighting platforms, or liberty boats. They have very good maneuverability and can get into tight areas where other craft are unable to operate. They were manned by a crew of four to six men, and have been rotated between Subic Bay, base headquarters, and Viet Nam.

HCU-One operated the Navy's deep diving system, the Advanced Diving System Four (ADS IV). It was used for deep water search and salvage for a depth of 600 feet. It consists principally of one personnel transfer capsule, two on-deck decompression chambers and entry locks, a control van, and associated support equipment. The system is normally operated from the deck of an ARS, ASR, ATF or YHLC and it can be airlifted to locations anywhere in the world.

The main support base and Command Headquarters was the Repair Salvage Tender, YRST-1, a non self-propelled tender having an Officer-in-Charge and a crew of approximately 35 men, including several divers. It is equipped with repair shops capable of servicing nearly all the equipment in the command. During major salvage operations, it provided shops for fabricating salvage patches, electrical power to the salvage site, and issued and repaired all salvage equipment. The headquarters group operated from the YRST-1 under the command of the Commanding and Executive Officers. It was composed of a Naval Engineering Officer, a Diving Medical Officer, a Supply Officer and an Administrative Officer with allied support personnel.

14.6. THE SALVAGE OF THE DREDGE JAMAICA BAY

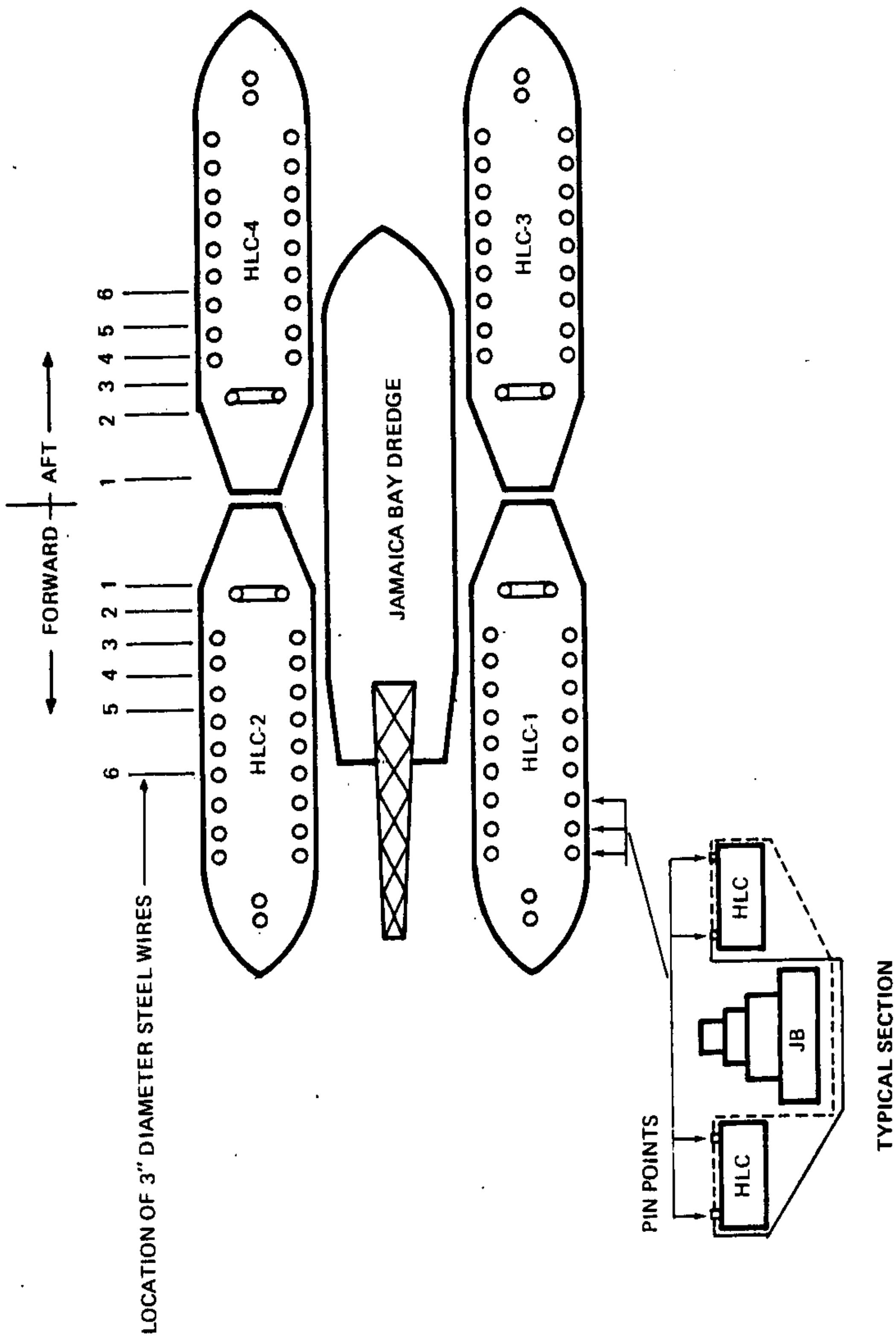
Several of Harbor Clearance Unit-One's jobs have been of major interest technically and logistically. Three of the dredge salvage operations undertaken by HCU-One give an idea of what type of work the salvage teams did and the conditions under which they operated in Southeast Asia.

HCU-One's second major job, the salvage of the dredge *JAMAICA BAY*, was unique for the U. S. Navy. The fourth largest dredge in the world, *JAMAICA BAY* was contracted to the U. S. Navy for dredging operations in the Western Pacific. The dredge was mined and sank within three minutes in the Mekong River, RVN. It was strategic to operations in the area and assumed a high salvage priority for the following reasons: 1) a significant proportion of the U. S. Navy salvage capability was located at the site and was thus extremely vulnerable to attack; 2) the *JAMAICA BAY* hulk would block dredging progress in Dong Tam Base development and had to be removed from the site before the arrival of the dredge *NORFOLK* in early March 1967; and 3) the dredge blocked the LST landing area for logistic support of the base.

The technically unique operation involved the use of four newly acquired British lift craft to bodily lift the 2,100 ton dredge. Structural strength and upright stability problems existed throughout the operation because of the large, flimsy, non-subdivided box design of the dredge. Two recent additions to the salvage art were used during the operation with marginal but promising success, the velocity-powered stud gun and foam-in-place materials.

The dredge was successfully raised, but sank again before reaching the shipyard; attempts at a second salvage were abandoned.

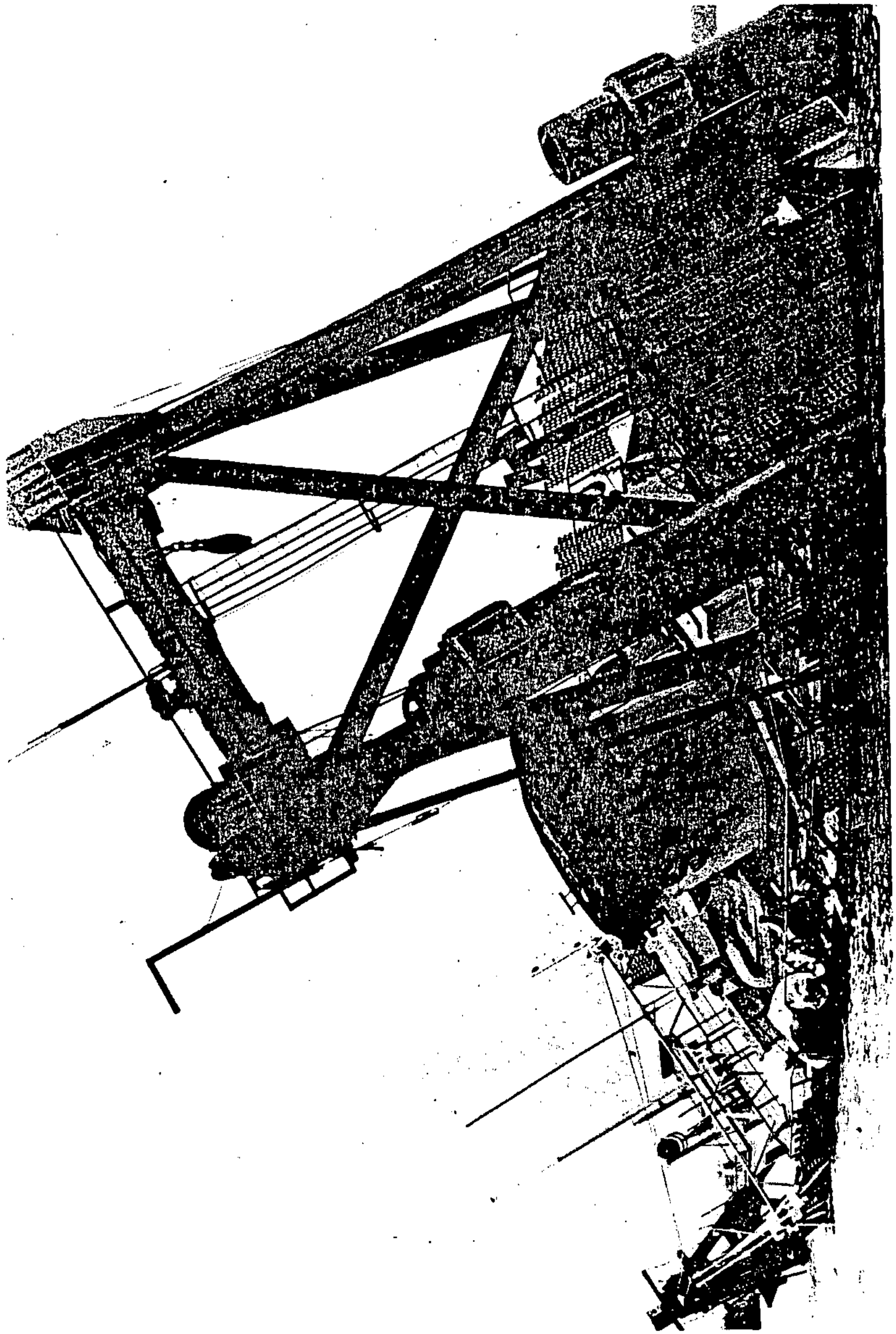
A comprehensive report of the *JAMAICA BAY* salvage operation has been published; NAVSHIPS publication 0994-002-8010, Report Number 2956, *Salvage of the Dredge JAMAICA BAY, January to March 1967, My Tho, Viet Nam*, presents the dredge salvage in detail.



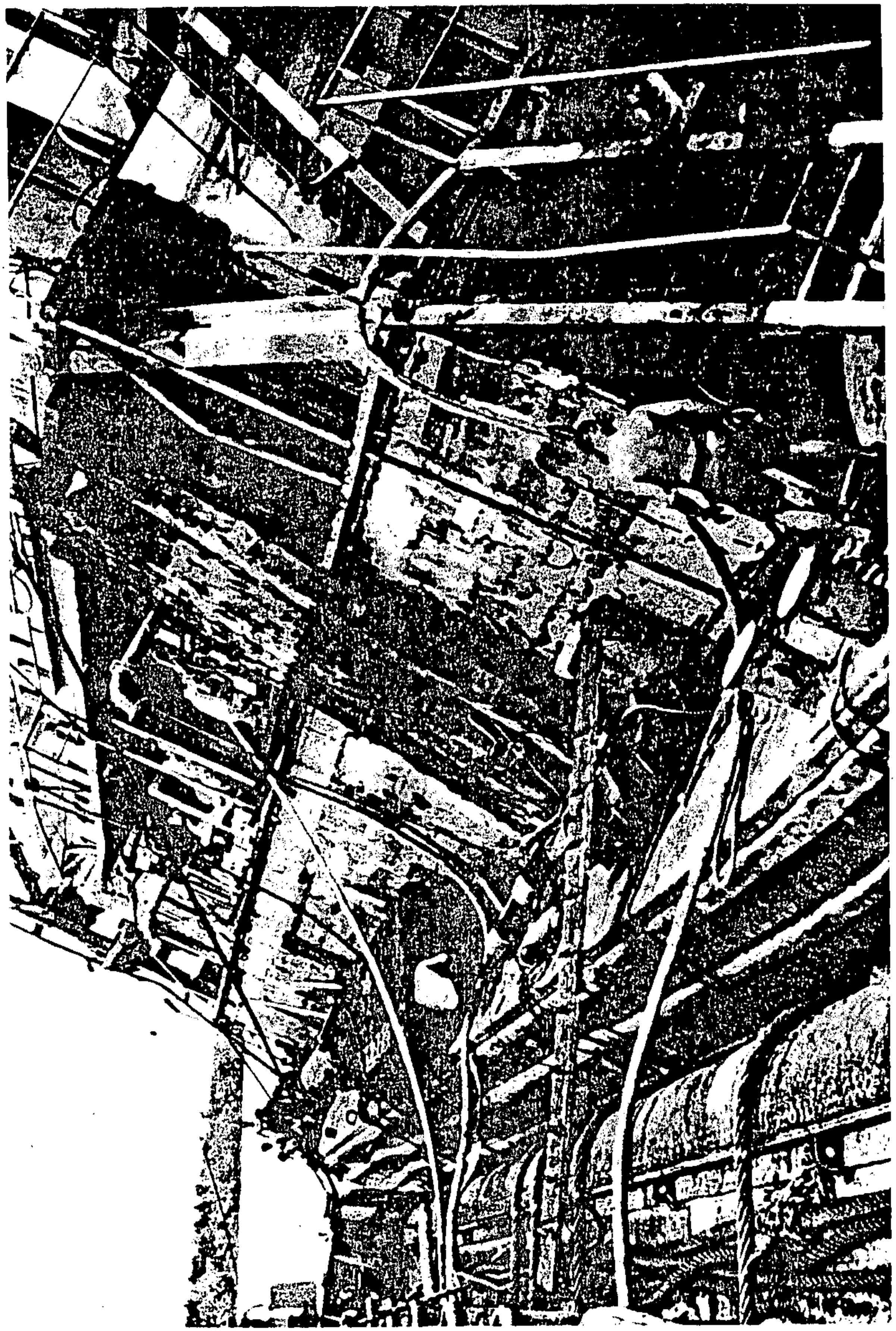
FOUR LIFT CRAFT ARRANGEMENT ON THE JAMAICA BAY DREDGE SALVAGE 19 FEBRUARY 1967

FIG. 14 NO. 2

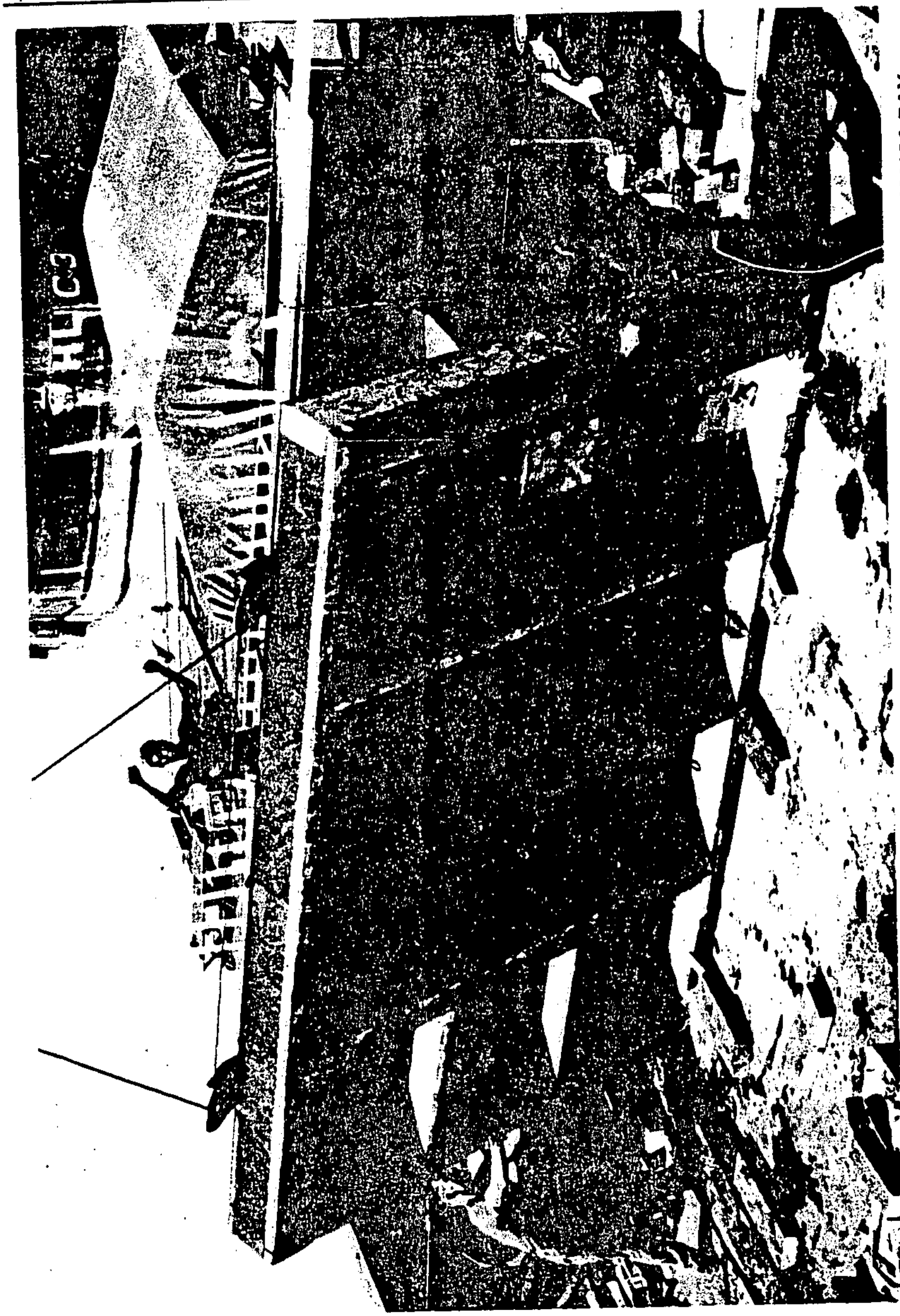
AERIAL VIEW OF THE JAMAICA BAY
SALVAGE OPERATION.
FIG. 14 NO. 3



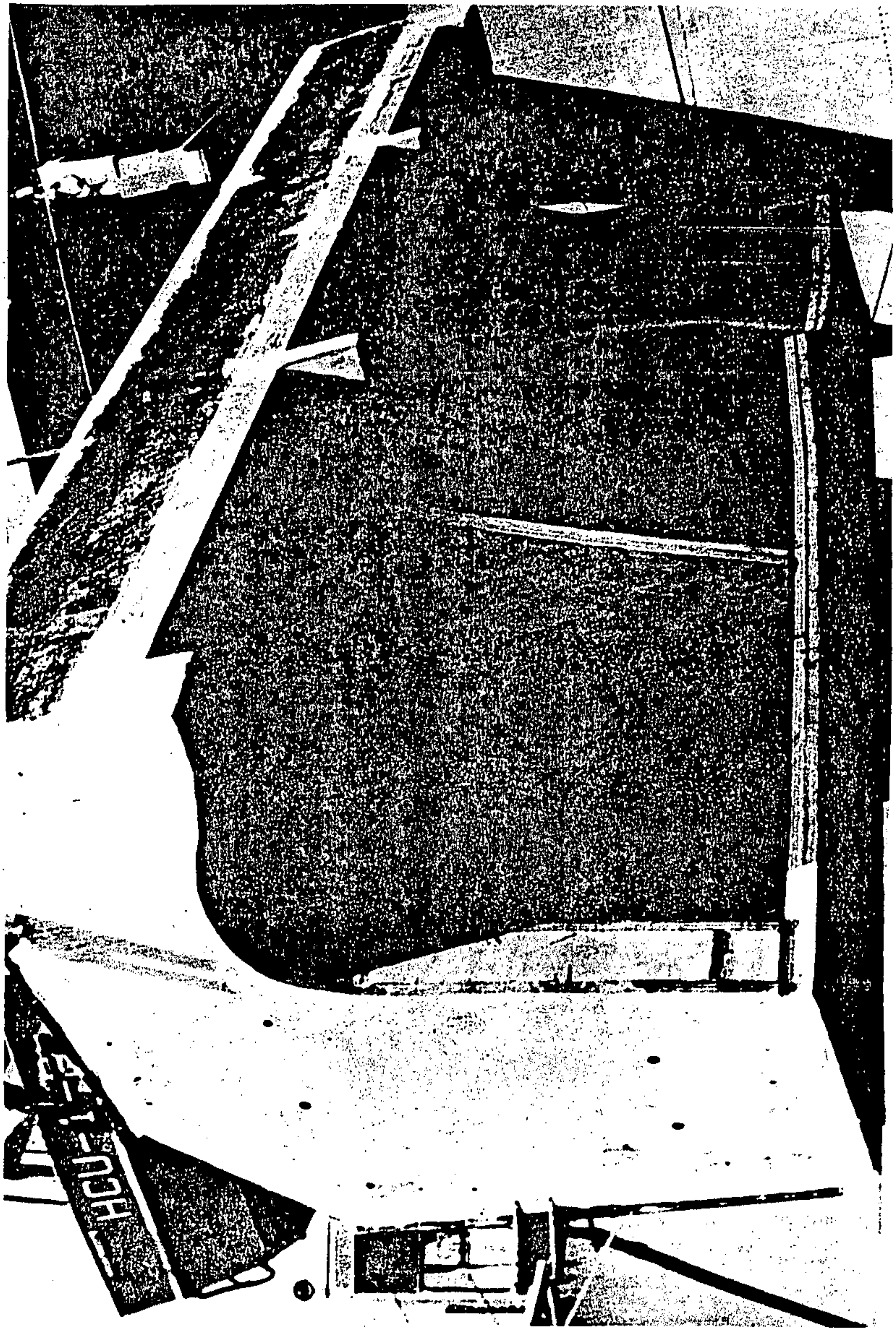
PORT QUARTER VIEW OF THE SUNKEN DREDGE JAMAICA BAY.
FIG. 14 NO. 4



LOOKING AFT ON THE STARBOARD SIDE
OF JAMAICA BAY.
FIG. 14 NO. 5



STARBOARD PATCH FOR THE JAMAICA BAY.
FIG. 14 NO. 6



PORT RADIUS PATCH FABRICATED TO COVER DAMAGE AT THE TURN OF THE BILGE, JAMAICA BAY. FIG. 14 NO. 7

JAMAICA BAY STERN COMPARTMENT FOAM FILLING OPERATION. NOTE AIR MASK USED FOR FRESH AIR AND 55-GALLON DRUMS USED TO REDUCE THE VOLUME.
FIG. 14 NO. 8

14.7. THE SALVAGE OF THE DREDGE SANDPUMPER

Among the many jobs tackled by HCU-One, the salvage of the dredge *SANDPUMPER* was of interest because it required the use of the two heavy lift craft, *CRILLEY* and *CRANDALL*, in a combined lift effort. This was the first time the two lift craft were employed by HCU-One.

Two dredges, the *NEW JERSEY* and the *SANDPUMPER*, were salved from their sunken positions in Dong Tam, RVN, in 1969. A brief summary of each salvage operation is presented in the following sections.

On 22 September 1969 the 27-inch pipeline dredge *SANDPUMPER*, while dredging in the Dong Tam area of Song My Tho, RVN, suffered an explosion in the dredge suction pump. The explosion blew off an inspection port cover on the suction pipe, and the water in the discharge pipe back-flooded into the pump room. Flooding then progressed through open doors and hatches into all other spaces of the dredge, and the *SANDPUMPER* sank in approximately seven minutes.

While sinking, the spuds jammed against the spud gates and held the stern about six feet off the bottom. As she lay the *SANDPUMPBER* had settled in 35 feet of water with no list and a 15 foot trim by the bow.

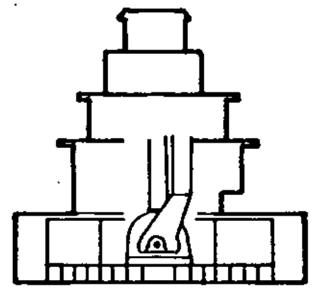
Two methods of salving were investigated. The first was to use local assets and patch and pump the dredge. The second involved the use of the two YHLC's, *CRILLEY* and *CRANDALL*, in a lifting operation that would move the dredge to shallower water for patching and pumping. By dewatering all watertight spaces, the 1945 ton displacement dredge would be 635 tons negative. To obtain this 635 tons, extensive patching and strengthening would be necessary under difficult and hazardous conditions. In view of the time required, and difficulties envisioned for a patching and pumping effort, it was decided to make the *SANDPUMPER* a heavy lift operation.

The heavy lift salvage plan was accomplished in four phases. These were (I) to make preparations for lifting while awaiting the arrival of the lift craft; (II) to remove the dredging ladder and place it on a barge; (III) to lift the dredge itself to shallow water; (IV) to patch and pump the dredge.

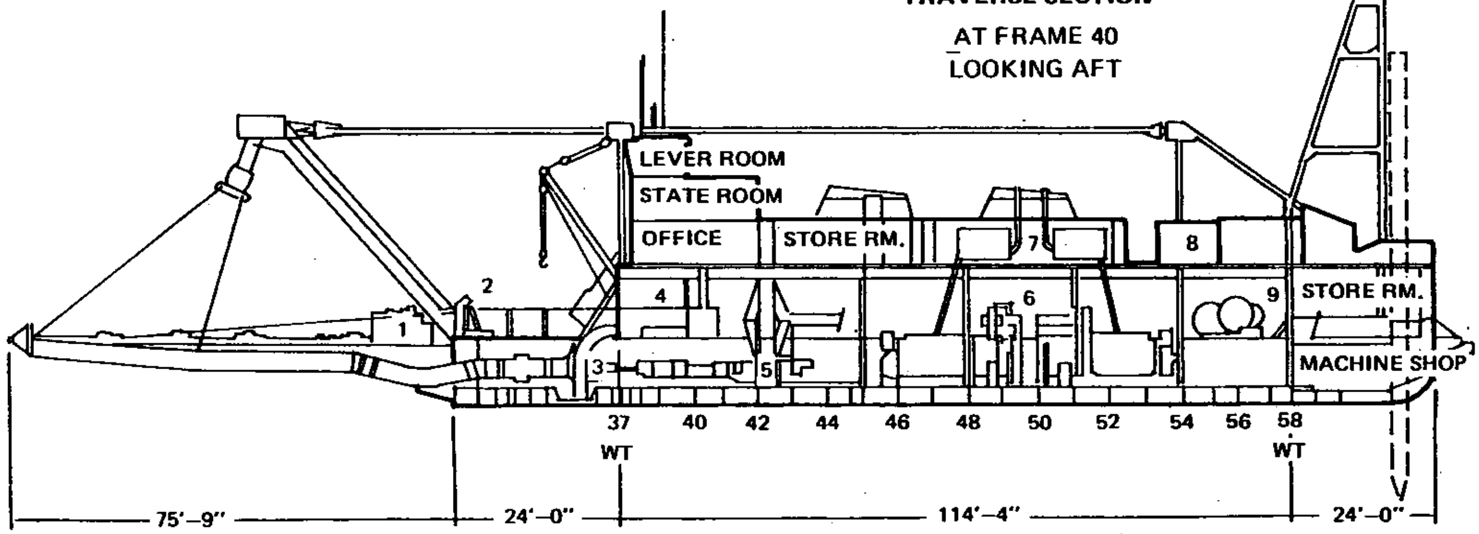
During phase I messenger wires were run under the dredge, the ladder connections were broken, preparations for spud removal were made and moorings were laid out. Throughout this phase of the operations, diving was limited to the two to four hours per day of slack water. This figure was considerably improved when the YHLC's were brought alongside the *SANDPUMPER*.

Phase II commenced on 15 October, and proved to be a major flaw in the salvage plan. The initial attempts to lift the ladder with *CRILLEY's* stern gantries failed, and the ladder had to be dragged clear of the dredge by *CRANDALL*. A week was lost in this effort. The ladder also cost another week's time when the dredge became fouled with the ladder during the first lift. After the dredge had been successfully moved to shallow water, *CRILLEY* lifted the ladder with her gantries and placed it on a barge for removal.

1. CUTTER MOTOR REDUCTION GEARS
2. CUTTER MOTOR
3. MAIN PUMP
4. SWING WIRE WINCHES
5. MAIN PUMP MOTOR
6. DIESEL GENERATORS
7. DIESEL MUFFLERS
8. TRANSFORMER BANK
9. SPUD WINCHES



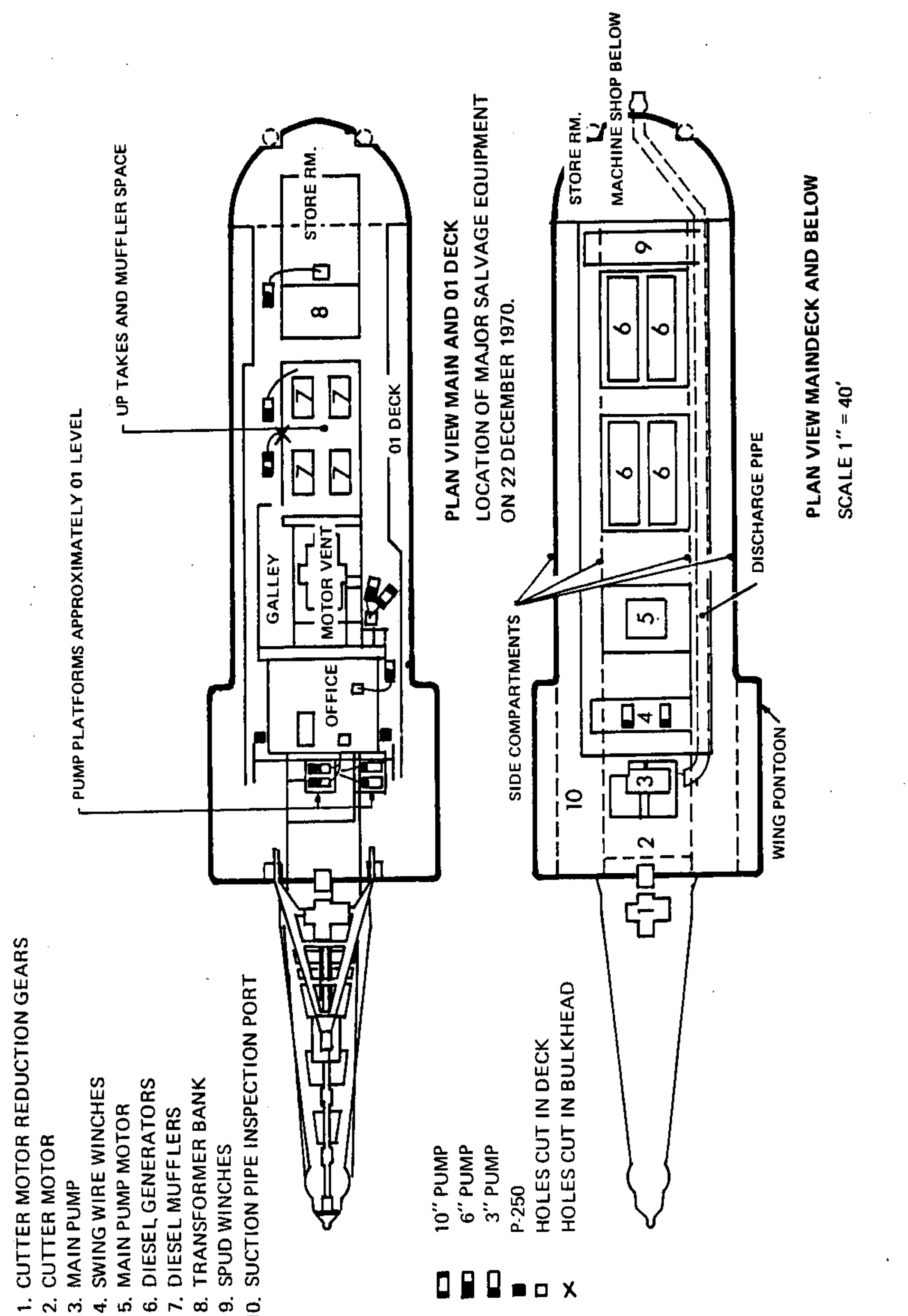
TRAVERSE SECTION
AT FRAME 40
LOOKING AFT



NOTE:
THE BULKHEADS INDICATED BY "WT" ARE THE ONLY INTERNAL TRANSFERSE WATERTIGHT BULKHEADS.

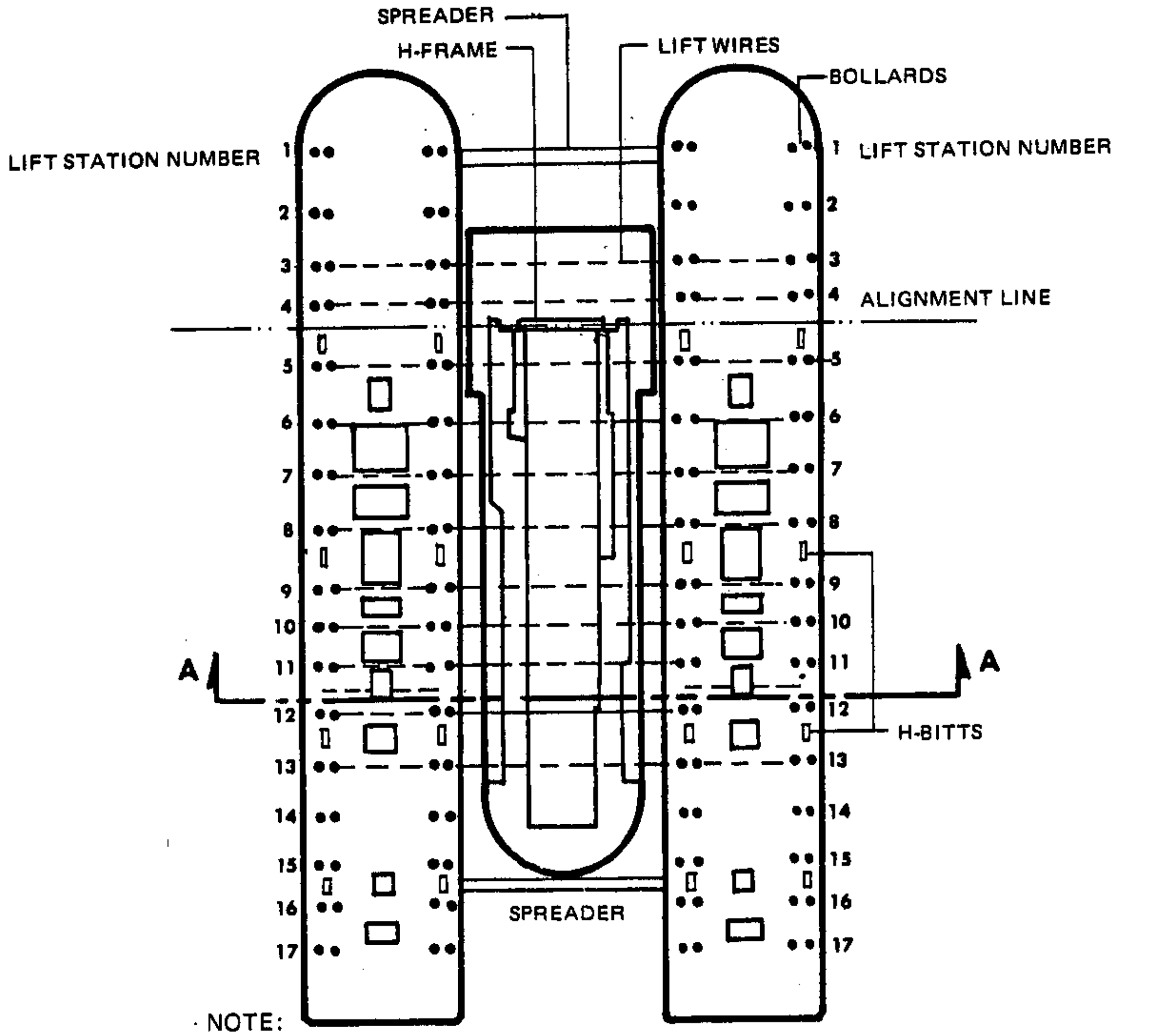
INBOARD PROFILE
LOOKING TO PORT
SCALE 1" = 40'

DREDGE SANDPUMPER
FIG. 14 NO. 9

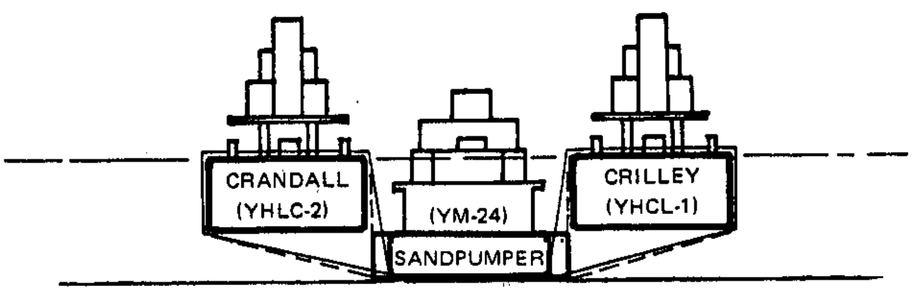


DREDGE SANDPUMPER

FIG. 14 NO. 10



NOTE:
LIFT WIRES PASS FROM THE INBOARD SIDE OF ONE CRAFT TO THE OUTBOARD SIDE OF THE OTHER CRAFT.



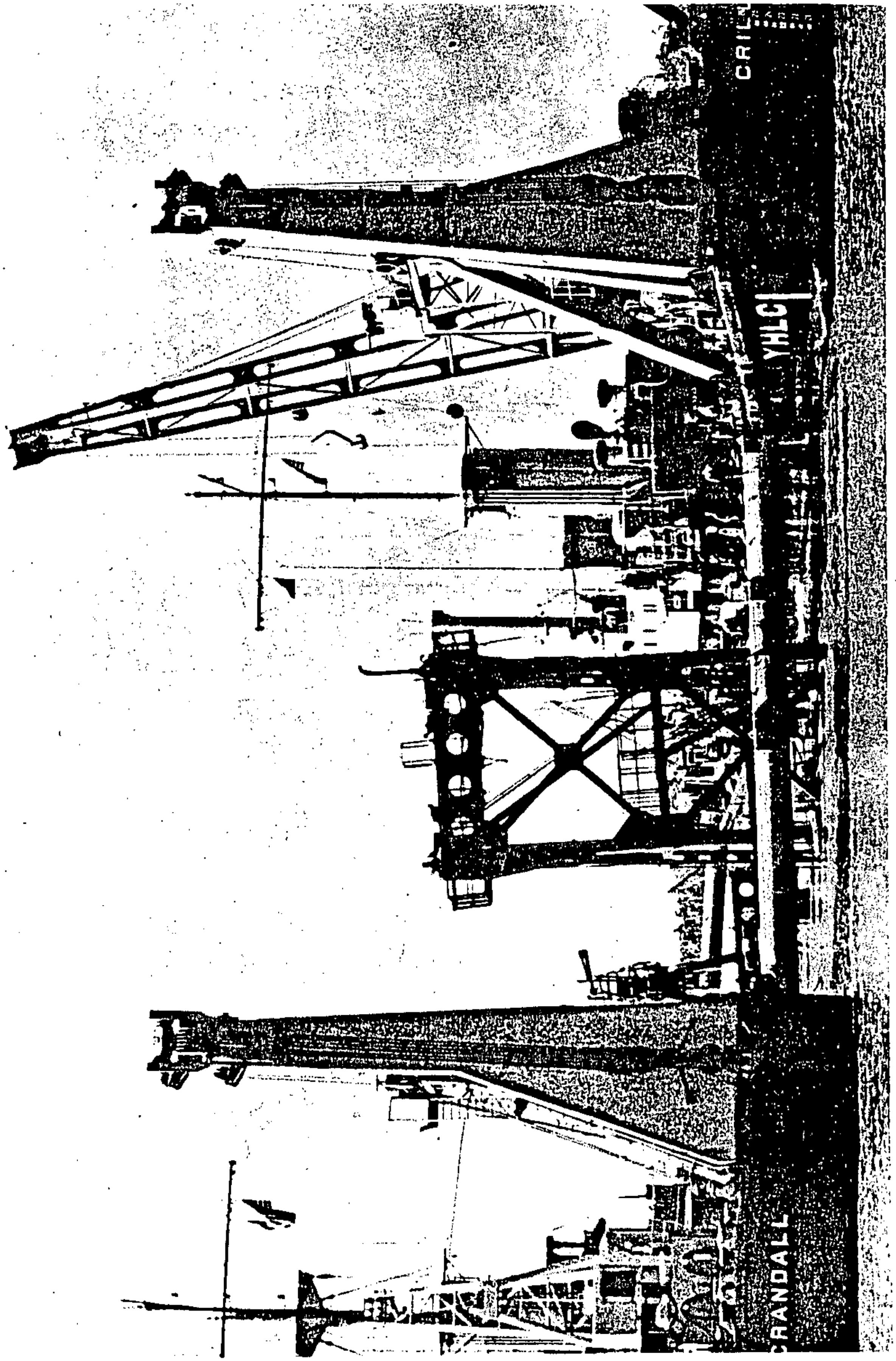
SECTION A–A

- - - - - WIRES AT LIFT STATIONS 3, 4, & 5
——— WIRES AT LIFT STATIONS 6 – 14

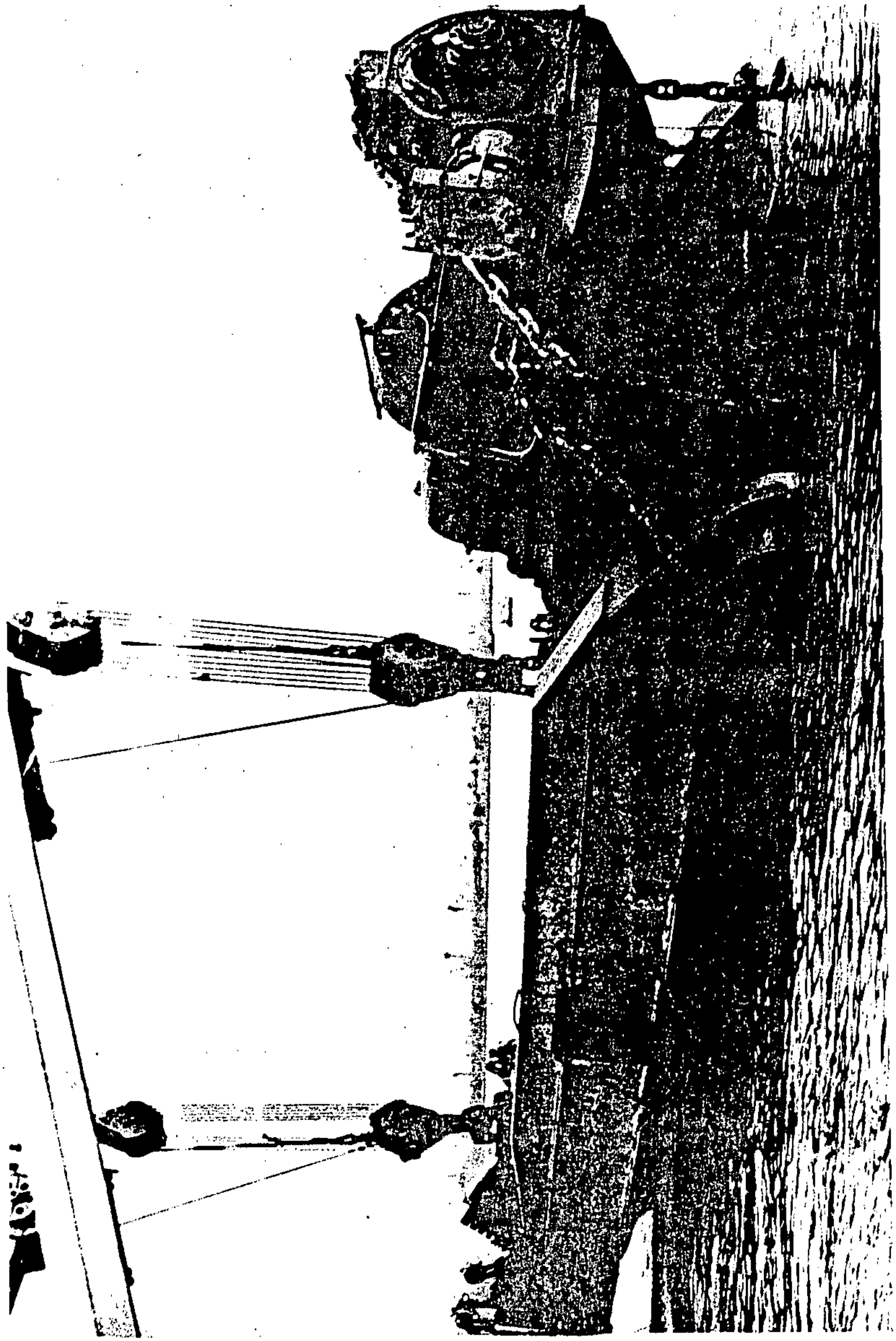
SCALE 1" = 60'

SANDPUMPER/YHLC LIFTING ARRANGEMENT

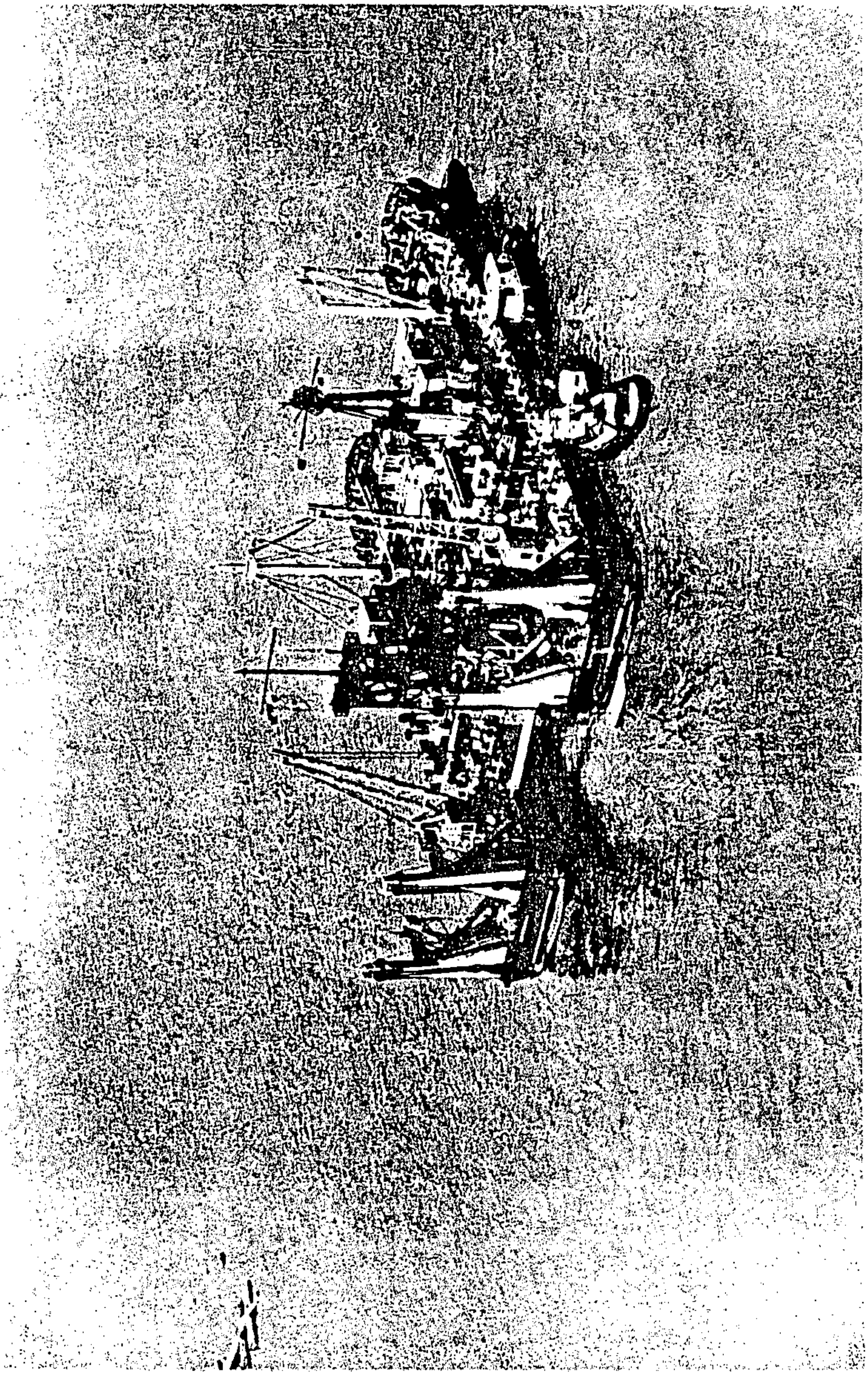
FIG. 14 NO. 11



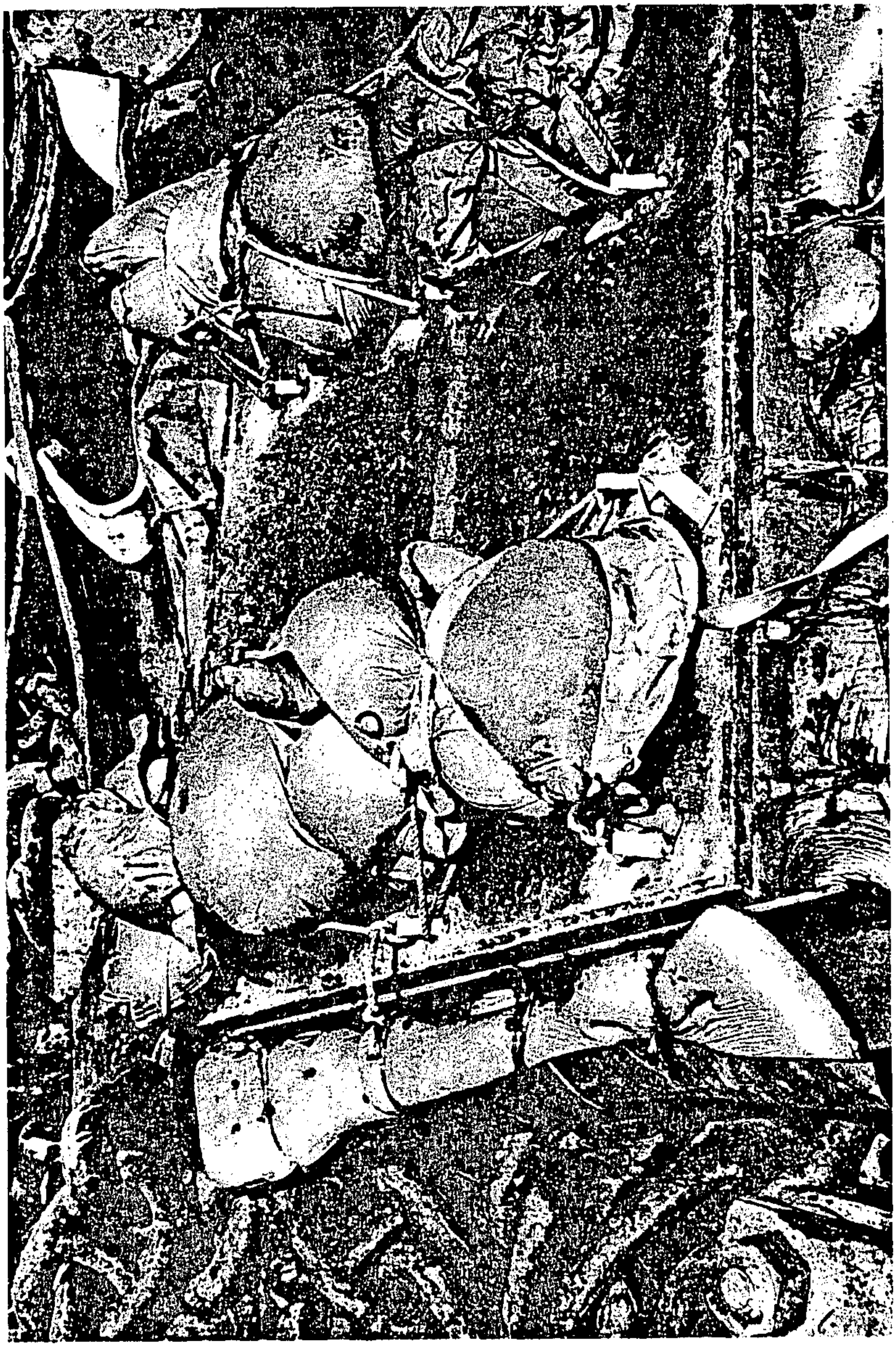
LIFT CRAFT "CRILLEY" AND "CRANDALL"
MOORED ALONGSIDE DREDGE "SANDPUMPER".
FIG. 14 NO. 12



LIFTING SANDPUMPER'S LADDER.
FIG. 14 NO. 13



DREDGE SANDPUMPER SALVAGE OPERATION
AT FINAL GROUNDING SITE.
FIG. 14 NO. 14



STEEL PATCH USED ON SANDPUMPER.
FIG. 14 NO. 15

CONCRETE PATCH. SANDPUMPER
FIG. 14 NO. 16

Phase III saw the heavy lift craft used operationally in a side lift mode for the first time by the U.S. Navy. The performance of these craft in both types of lift, despite numerous material problems, was in all respects, outstanding. The running of the lift wires commenced on 26 October and was completed on 11 November. On 12 November the first lift was made, and on 24 November, after five additional lifts, the *SANDPUMPER* was grounded for the last time in 14 feet of water at mean low tide.

On 25 November, the final phase (IV) of operations commenced. The level of effort applied during the initial ten days of this phase was reduced while the *NEW JERSEY* salvage operation was conducted nearby. On 31 December, after 38 days of continuous patching, pumping, blowing and demudding, the attempt to refloat the *SANDPUMPER* was terminated. On 5 January 1970 the recovery of equipment was completed and HCU-One forces departed for other operations.

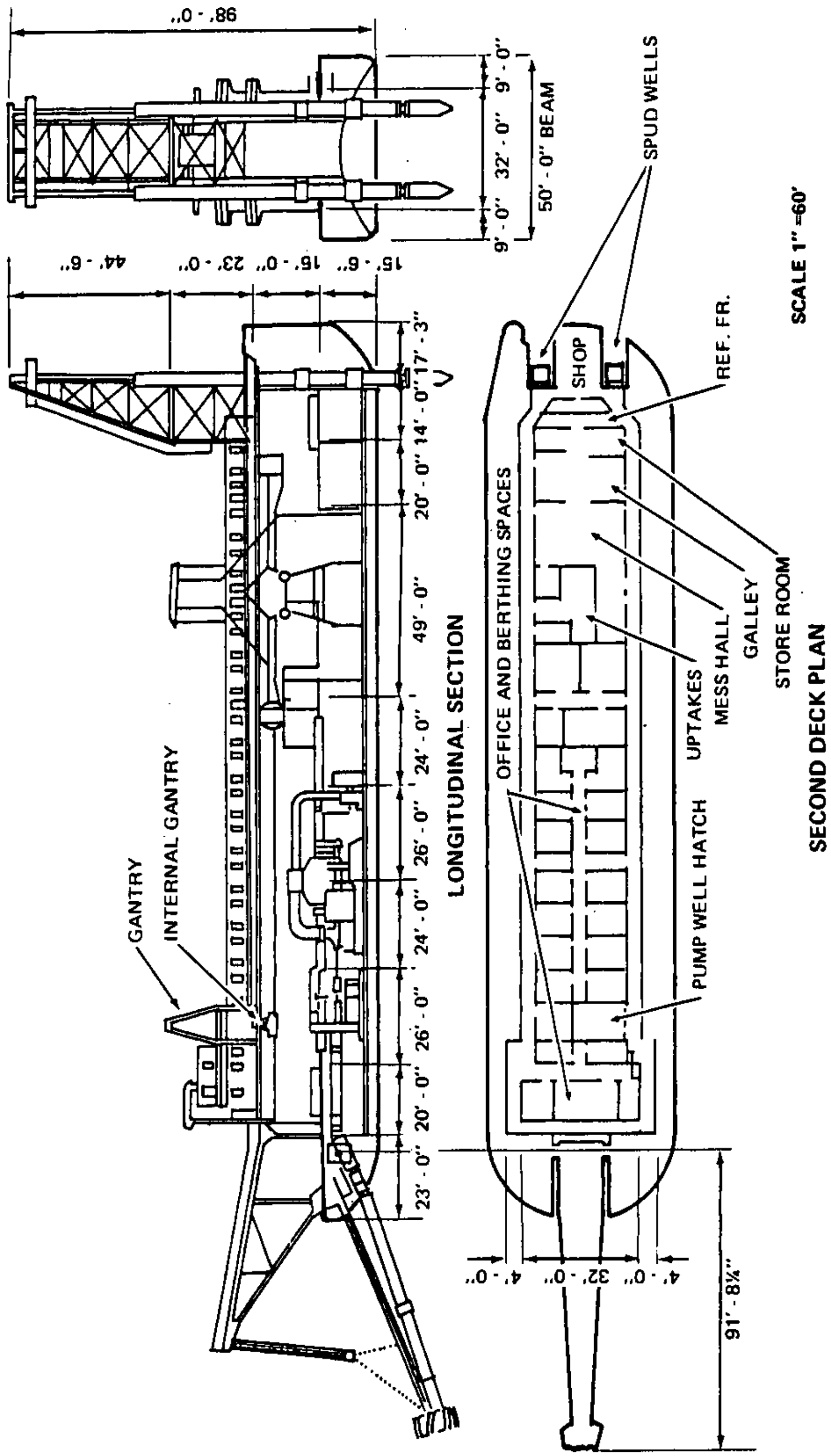
14.8. NEW JERSEY

On 22 November 1969, the 30-inch pipeline dredge *NEW JERSEY*, while dredging in the Dong Tam area of Song My Tho, RVN, suffered an explosion in the area of the starboard spud well and sank. Explosion damage, limited to the structure adjacent to the spud well, caused rapid flooding of all adjacent compartments. This flooding by itself would not have been sufficient to cause the *NEW JERSEY* to sink, as was demonstrated by her being refloated with these same compartments flooded. Progressive flooding through the partially closed watertight doors and the extremely deteriorated bilge area of bulkhead 106, proved to be more than the operating bilge pumps could handle, and all machinery was secured. Flooding then progressed into the remaining engineering spaces and storerooms through large open archways cut in bulkhead 96, which had originally been a watertight bulkhead. With flooding beyond control, the discharge pipe was disconnected and the *NEW JERSEY* was pushed southward to a sandbar by her tugs. Shortly after the explosion the *NEW JERSEY* was resting on the bottom in 24 feet of water and mud with the 01 deck above water.

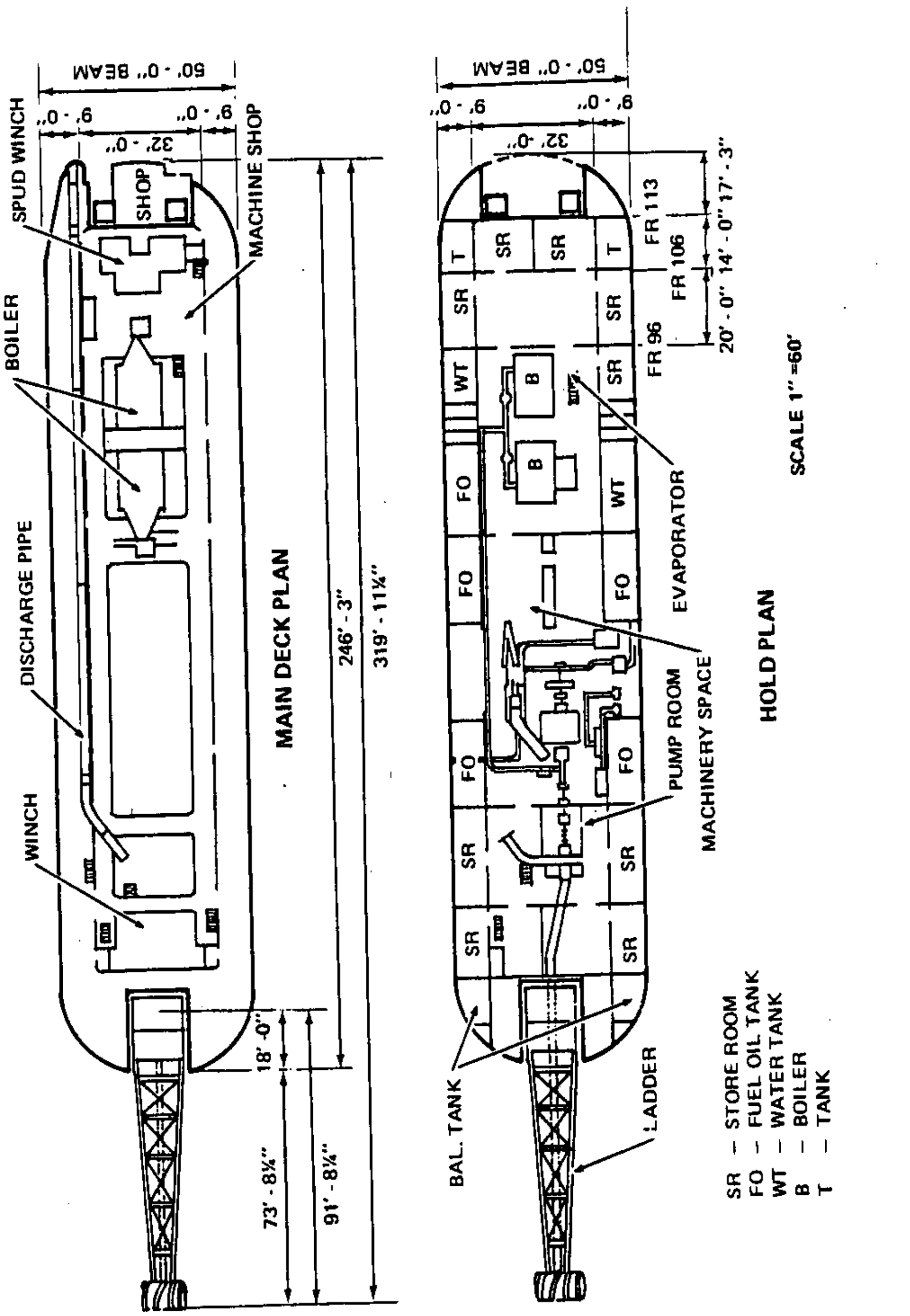
Within minutes after the explosion, Harbor Clearance Unit-One forces, conducting the *SANDPUMPER* salvage 1200 yards away, were notified that *NEW JERSEY* was sinking. Forces were immediately dispatched to the scene in order to assess the situation and render immediate assistance as required. Upon arrival, *NEW JERSEY* was found to be completely flooded to the 24 foot waterline and in need of major salvage to refloat her.

With heavy lift craft already in the Dong Tam area for the *SANDPUMPER* operations, there were two feasible means of salvage available. The first and most expeditious would be to patch and dewater in the present location. The second and more time consuming would be to lift the 3,750 long-ton *NEW JERSEY* with the heavy lift craft, move her to shallow water and then patch and dewater. The latter alternative was rejected because two to three weeks would have been required to prepare for a lift which would have gained at best seven feet less draft and still have left the main deck below water at mid-tide.

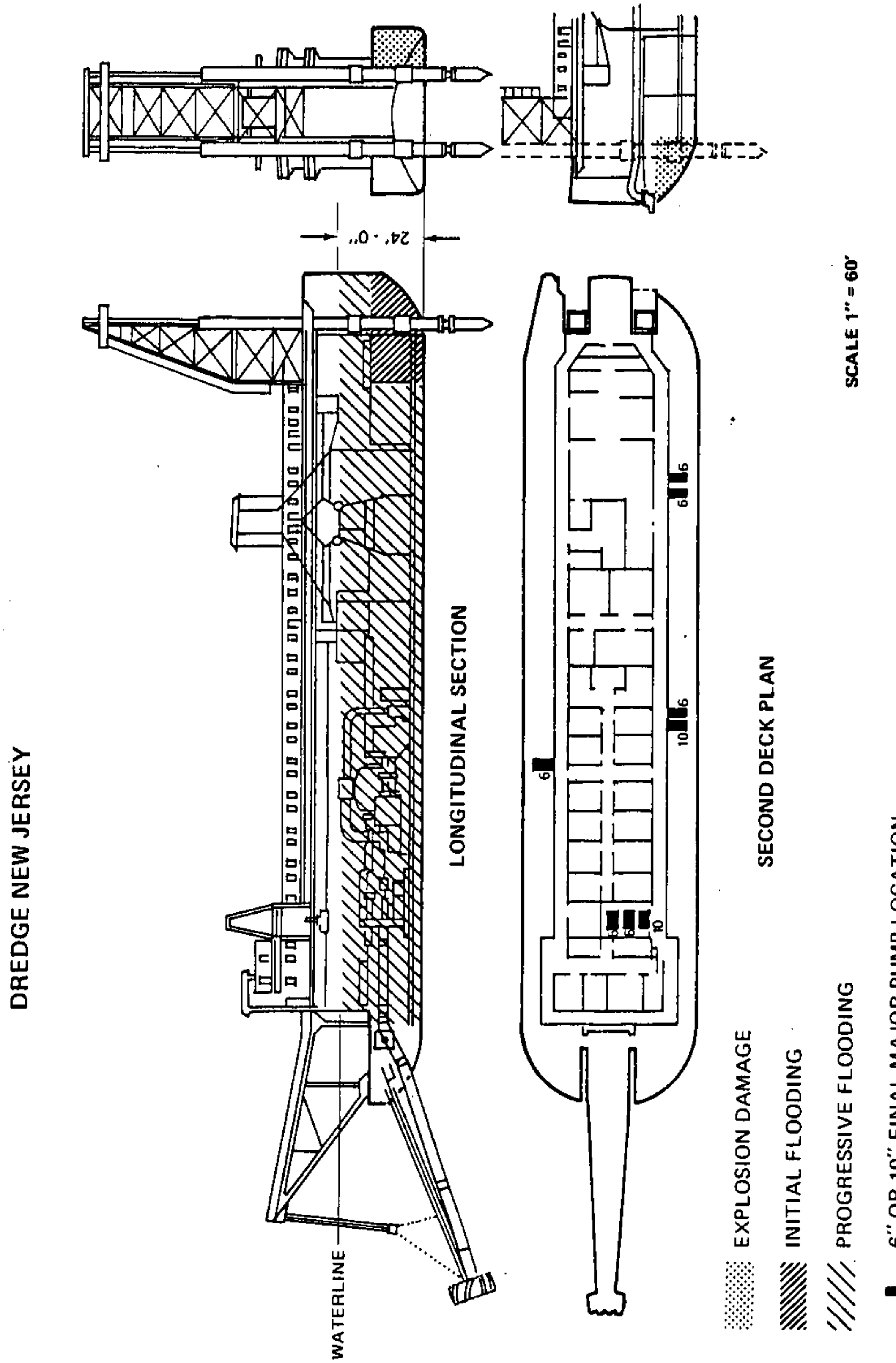
While the decision to patch and pump the *NEW JERSEY* was being made, immediate efforts toward closure of all accesses below high water were commenced in order to limit interior mud build-up as



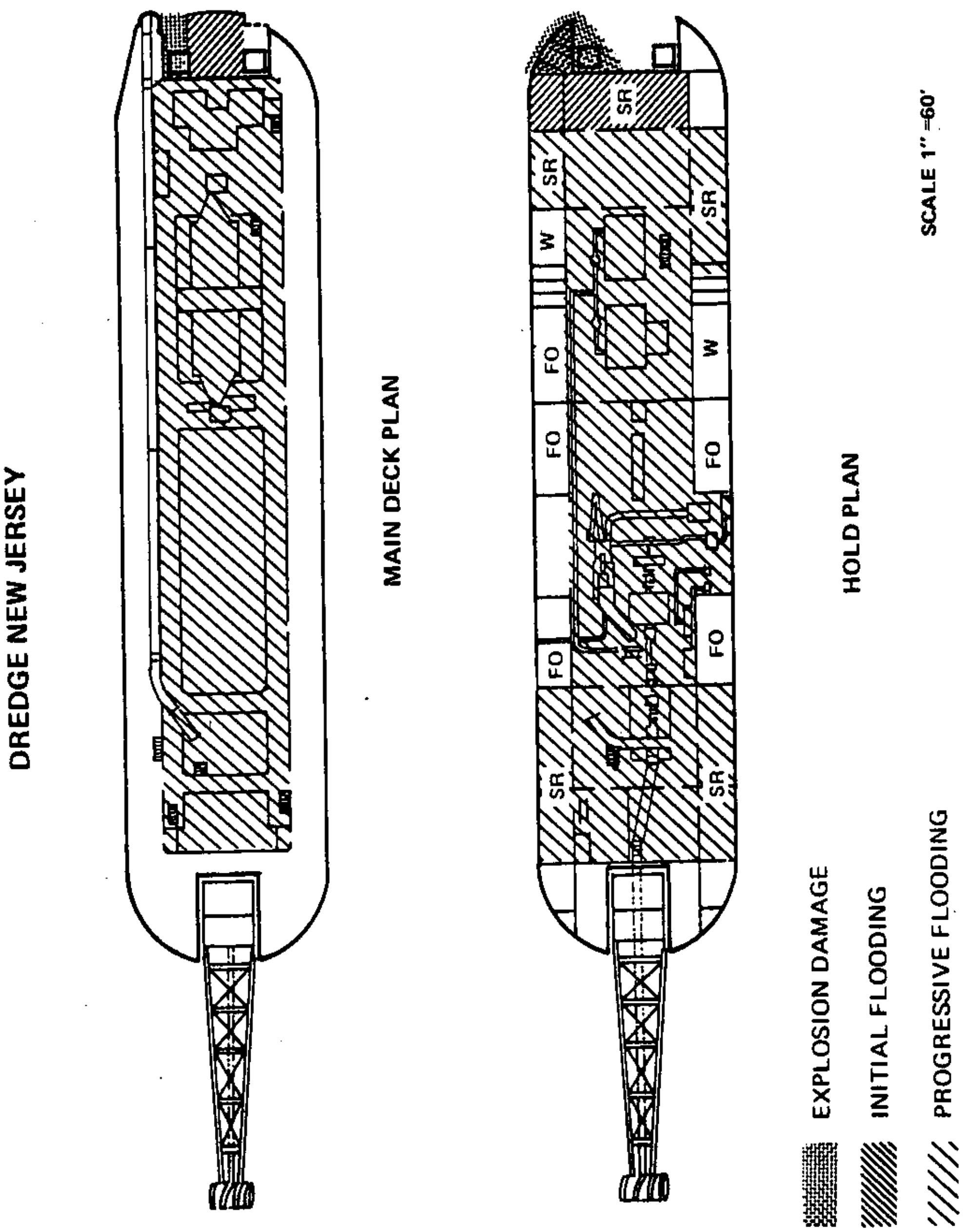
DREDGE "NEW JERSEY".
FIG. 14 NO. 17



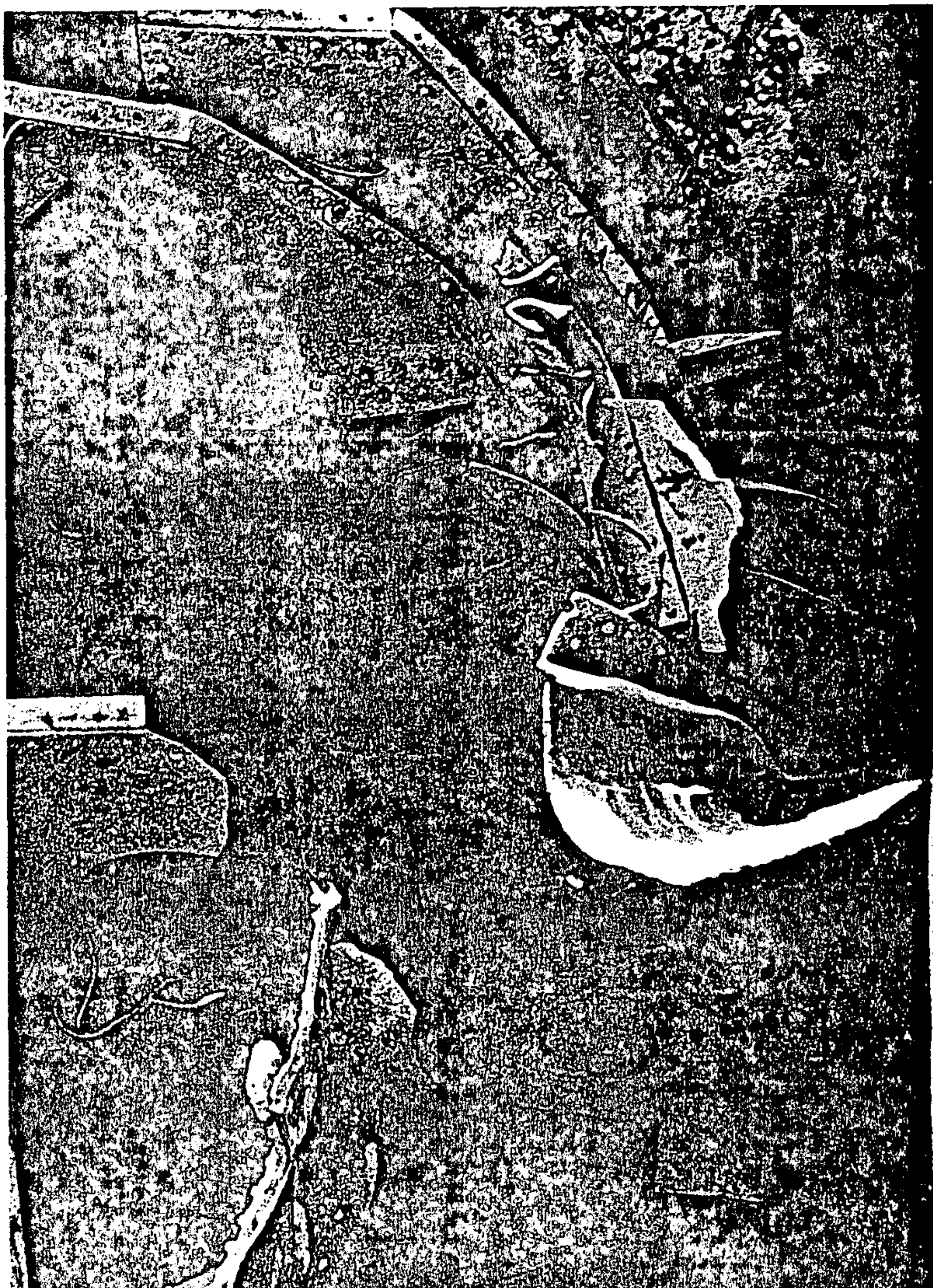
DREDGE "NEW JERSEY".
FIG. 14 NO. 18



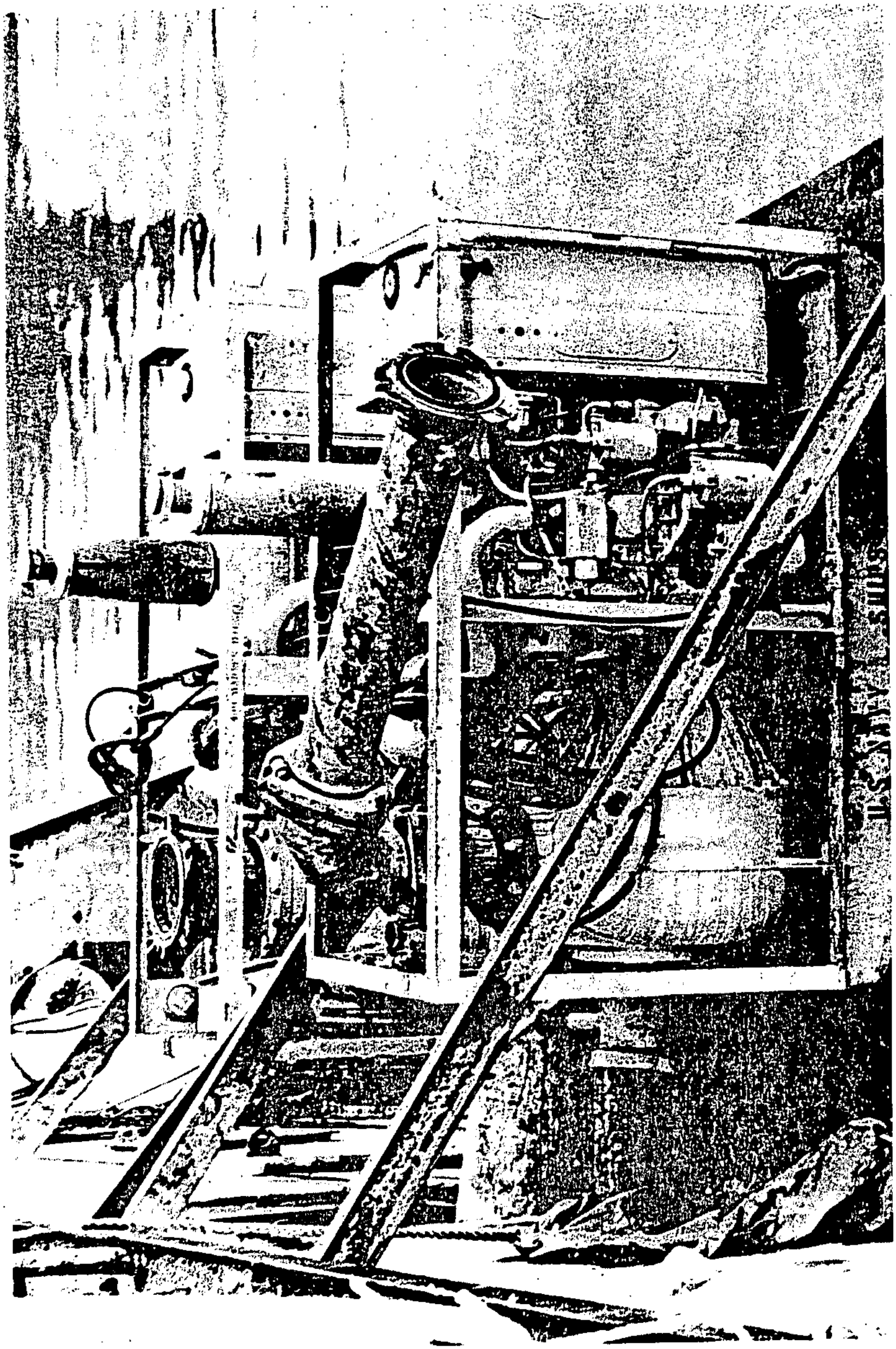
FLOODING PLAN OF THE DREDGE "NEW JERSEY"
FIG. 14 NO. 19



FLOODING PLAN OF THE DREDGE "NEW JERSEY".
FIG. 14 NO. 20



NEW JERSEY PORT SIDE EXPLOSION DAMAGE.
FIG. 14 NO. 21



TEN AND SIX INCH PUMPS ON THE PORT SIDE, NEW JERSEY.
FIG. 14 NO. 22

TWENTY-FOUR INCH COFFERDAM, PORT SIDE
ON THE NEW JERSEY.
FIG. 14 NO. 23

much as possible. HCU-One forces, with material and assistance from RMK-BRJ, prepared *NEW JERSEY* for the first dewatering attempt on 27 November. This first attempt, using three six-inch pumps and one ten-inch pump, was essentially a trial effort to determine leakage location. On 2 December, after three additional trials, and with the eventual addition of one more ten-inch pump, four more six-inch pumps and two three-inch pumps, *NEW JERSEY* was refloated. When successful refloating became apparent, most of HCU-One forces were brought on the scene. With personnel working around the clock, the *NEW JERSEY* was prepared for movement and was towed to a grounding site on 4 December. Preparations for the tow to a shipyard were then commenced, and on 13 December *NEW JERSEY* departed Dong Tam for Vung Tau on the first leg of her tow to a repair facility at Singapore.

The most significant problem encountered during the *NEW JERSEY* salvage was the maintenance of stability in the face of extreme free surface on a vessel that was marginally stable when damaged.

14.9. HCU-ONE TODAY

On 1 July, 1971, HCU-One was transferred to its new home port of Pearl Harbor, Hawaii. Because of the Vietnamization Program of 1969 and 1970, and the wind down of U.S. military activities in Viet Nam, HCU-One's assets had been greatly reduced, however, its mission remained basically the same- to provide salvage services to the U.S. Pacific Fleet and to support a variety of fleet operations and surveys requiring the use of HCU-One's highly trained and experienced divers and personnel.

An operation of particular interest in which HCU-One participated was the Navy/Makai Range Cy '71 Dive Project off Makapuu Point, Oahu, Hawaii. Among their support tasks was included the complete overhaul and reoutfitting of the YRST-1 for use as a surface support ship for the project.

Perhaps the most recent and exciting event of interest has been the establishment of HCU-One's "fly-away" salvage concept. Because of the cutbacks of men and equipment and overall monies available in the Navy in recent years, a need emerged for an efficient, professional, mobile salvage organization to assist the overburdened salvage ships of the Pacific Fleet. The "fly-away" concept requires that salvage equipment be prestaged and palletized, ready for immediate deployment by surface or air when the need arises.

The unit itself functions with only four officers and 55 enlisted men. The divers are each assigned to teams, each team sharing duty responsibility for a week, standing by ready to assist on a job on short notice. The "fly-away" concept has been very successful on a number of salvage and diving operations and if the unit is not decommissioned due to lack of funding, it should continue to provide fast, efficient service to the U.S. Pacific Fleet, augmenting COMSERVPAC salvage forces.

15. SALVAGE BRIEFS

Eight briefs are presented in this chapter to further the possible technological application to future harbor clearance and ship salvage operations. Each case is unique and offers excellent lessons learned; some are comprehensively covered in other NAVSHIPS publications and are only briefly stated here.

15.1 NET TENDERS

Net Tenders (AN) are useful and versatile ships for harbor clearance work. These ships are good all around rigging craft; their powerful winches are well placed; their bow horns and throat are excellent for lifting.

Salving damaged or sunken ships and other marine property when specialized heavy lift equipment is not available is a problem frequently faced by salvage officers. Such tasks often demand unique methods that have to be applied with unusual know-how and ingenuity to solve the problem with the equipment on hand.

In World War II combat operations in the Pacific Theater, two noteworthy instances were recorded wherein heavy objects sunk in deep water were speedily salved – despite the absence of heavy hoist equipment – by utilizing the winch power and lifting characteristics of Navy Net Tenders.

The assignments were almost identical. Each involved recovering exceptionally heavy tailgates that had broken off ARD floating drydocks operating at advance bases in the Caroline Islands. One tailgate weighed 68,000 pounds and measured 60 feet 8 inches long, 19 feet 8 inches high, and 5 feet 4 inches wide at the top; the other, slightly smaller, weighed 58,000 pounds.

In both instances, the tailgates broke their hinges and sank while the ARDs were preparing to dock vessels in heavy ground swells. The swells pitched the drydocks, causing the tailgates to surge and part the wire purchase that raised and lowered the gates.

The tailgate mishaps were attributed to the fact that their hinges originally were designed to allow the gate to open only 90 degrees. When the gate's hoisting wires parted as a result of sea surge and the gate swung past 90 degrees, the hinges broke. A later alteration replaced the original hinges with a 180-degree type, enabling the gates to swing into the water vertically.

The first incident occurred in 1944 when the ARD-19 lost its 68,000-pound tailgate in 100 feet of water at Kosol Passage, just north of Babelthaup Island. In 1945, the 58,000-pound tailgate of ARD-11, which like the ARD-19 was capable of docking a destroyer, sank in 150 feet of water in the lagoon at Ulithi Island.

To recover an object as bulky and heavy as these tailgates required equipment capable of lifting the object clear of the side or bow of the hoisting ship and above the surface of the water so that the object could be landed on a barge-like vessel. For recovery operations such as this, the Navy ordinarily would use an A-frame or whirley floating derricks with boom capacities of some 30 tons at an appreciable outreach. However, as is often the case, no equipment of this type was immediately available in the areas where the two tailgates were lost.

When the first tailgate went down in Kosol Passage, the recovery operation was assigned to the Salvage Ship *USS GRAPPLE (ARS-7)*. The *GRAPPLE* had the power to raise the tailgate, but the bow rollers and stern rollers of the ARS were positioned so that it was not possible to lift the bulky tailgate high enough above the water to allow a barge to be floated underneath.

Two Net Tenders (AN) were on duty at the time in the Caroline area, and in the absence of any floating cranes (YD) it was decided to use their combined winch power to recover the tailgate. The Net Tenders, which are often used in salvage work, were of heavy duty construction and had bow horns that extended out sufficiently to permit cables to be dropped directly over the tailgate for a lift clear of the bow above the water's surface. Each AN had two winches of 25-ton line pull capability, operating two cable drums each. This deck rigging was primarily for their designed wartime function – to raise, lower and care for nets at the mouths of harbors and strategic water passages to foil submarines.

The AN's bow rollers were so close together that the huge tailgate could not be slung sufficiently from one set of horns to allow it to be lifted high enough out of the water to float a barge underneath, so a method for doing the job with two ANs was devised.

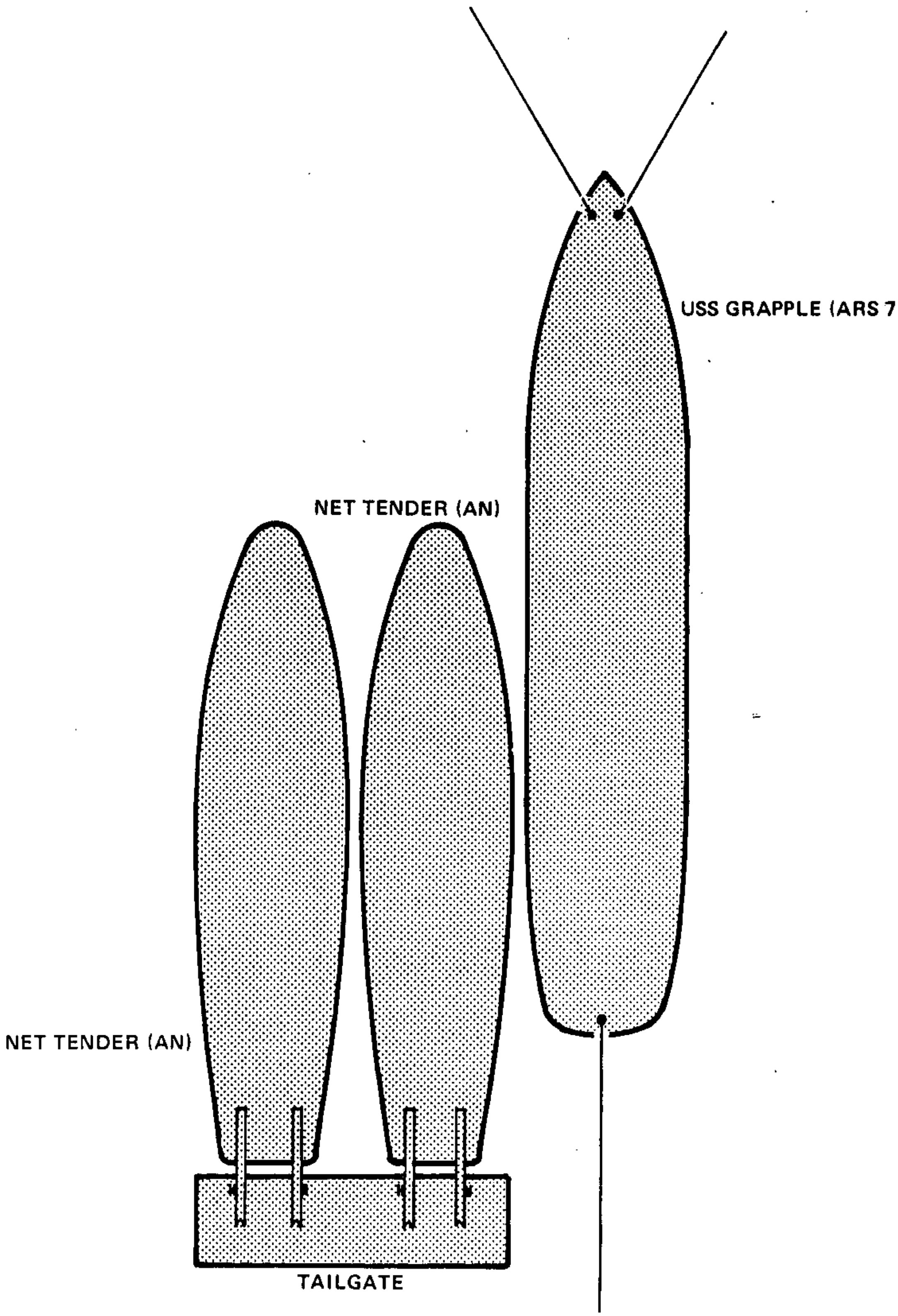
The ANs were placed abreast each other on the port side of the *GRAPPLE* (Fig. 15.1, No. 1.) with their bow horns facing the same direction over the sunken tailgate. Wire slings were run through the gate's steel framing.

The two Net Tenders' eight 1¼-inch cables were then lowered and attached to the slings (Fig. 15.1., No. 4), providing the necessary spread between end hoists.

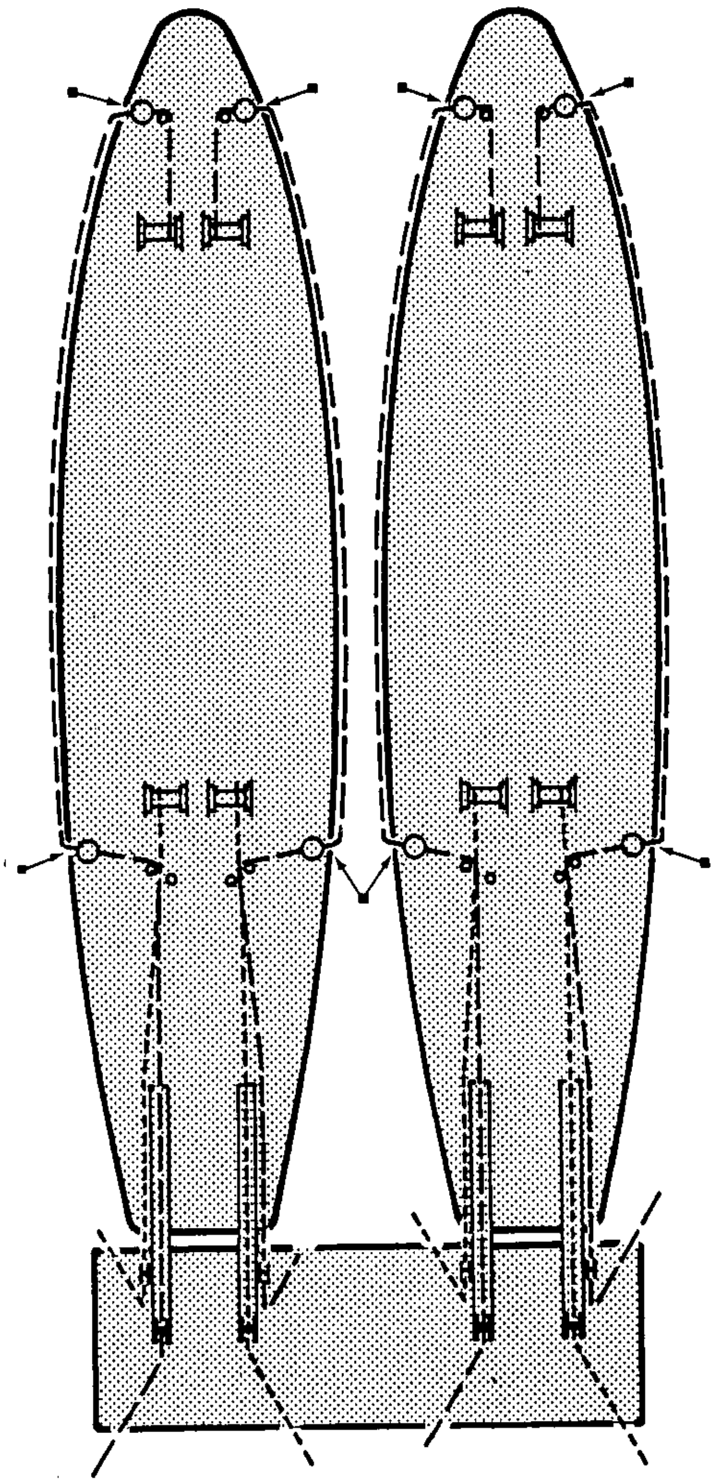
The two winches of one Net Tender by themselves were not capable of lifting the tailgate directly out of the 100-foot depth. The total hoist capacity of the two ships' four winch engines was employed to lift half the gate's weight at a time by constantly operating the winches while alternating hauling on the drums.

One of the major problems was to run eight lines from the four winches of the two ANs to the tailgate so they would not become fouled when the lifting operation commenced. To achieve this, the lines were rigged in the following manner (Fig. 15.1., No. 2 and Fig. 15.1., No. 3) on both ships:

1. From the starboard drum of the after winch, along the starboard side, over the end of the starboard horn, to the top edge of the tailgate.
2. From the port drum of the forward winch, over the end of the port horn, to the top edge of the tailgate.

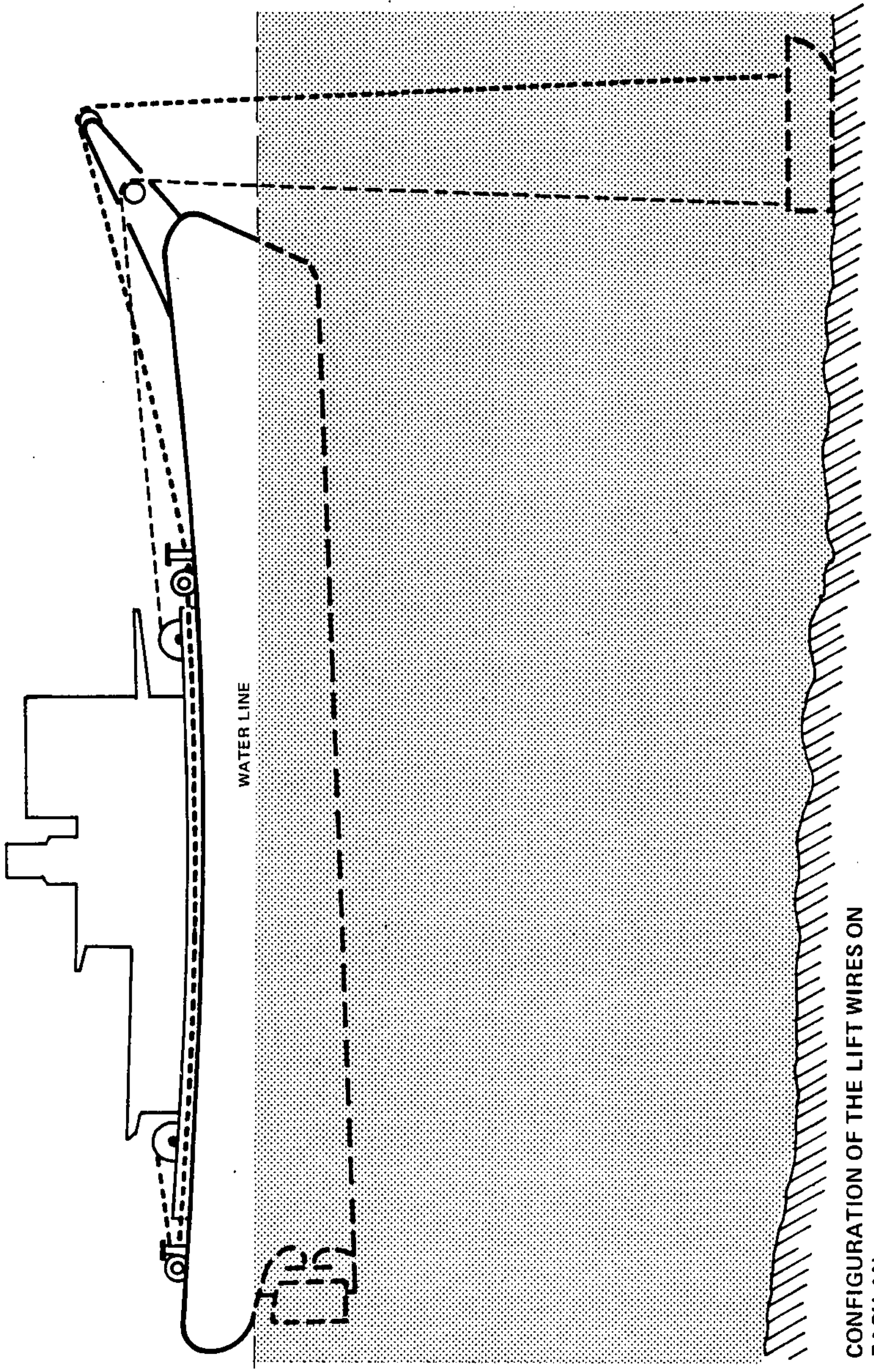


TWO NET TENDERS ALONGSIDE "GRAPPLE".
FIG. 15.1 NO. 1

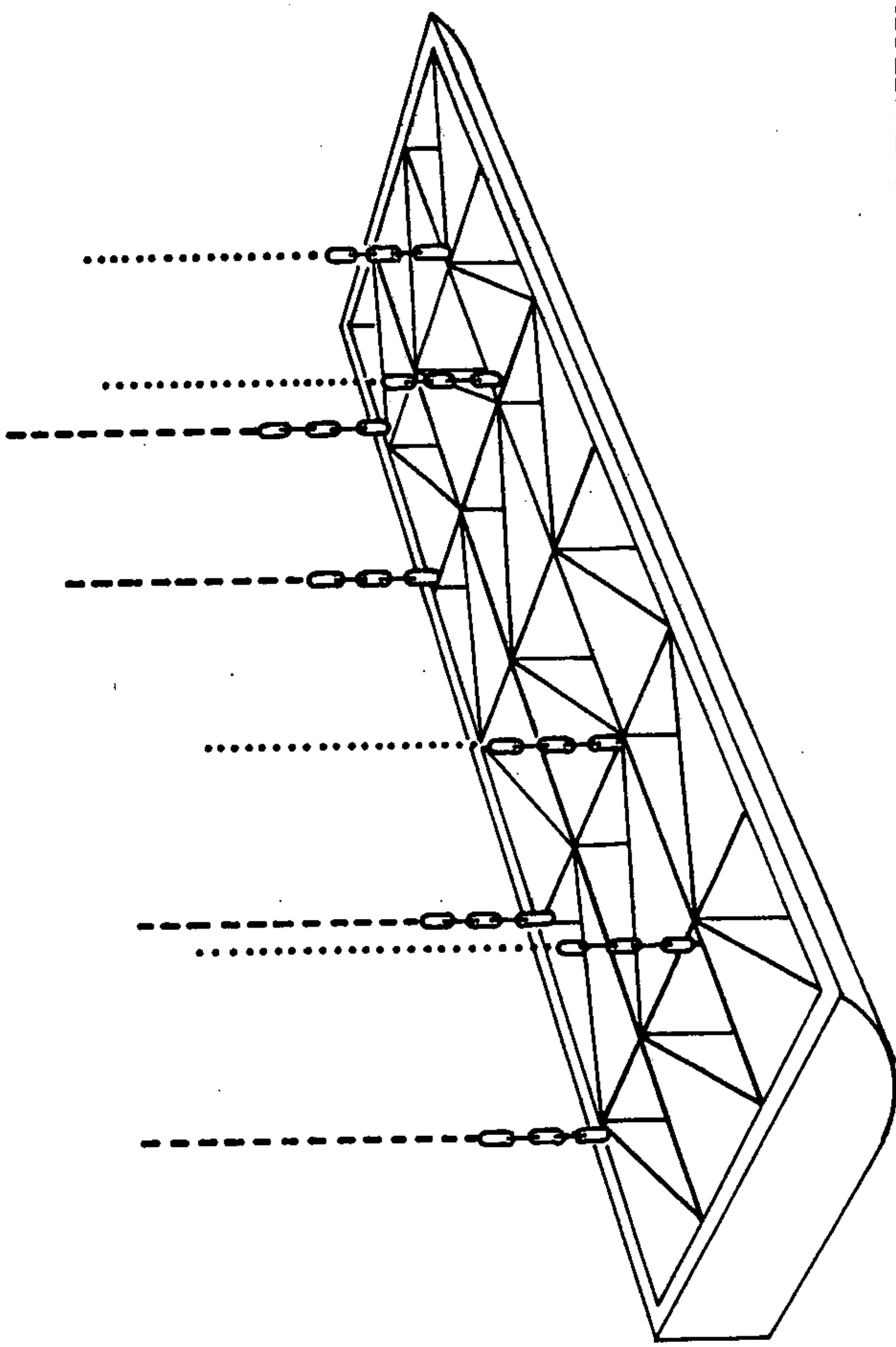


■ INDICATES BERGER SELF ALIGNING FAIRLEADERS

CONNECTING METHOD OF EIGHT WIRES TO EIGHT WINCHES ON THE TWO ANs.
FIG. 15. 1 NO. 2



CONFIGURATION OF THE LIFT WIRES ON EACH AN.
FIG. 15.1 NO. 3



LOCATION OF THE EIGHT LIFT PENDANTS ON THE TAILGATE.
FIG. 15.1 NO. 4

3. From the port drum of the after winch, along the port side, over the port horn sheave, to the bottom edge of the tailgate.

4. From the starboard drum of the forward winch, over the starboard horn sheave, to the bottom edge of the tailgate.

With the same rigging procedure used on both Net Tenders, eight lines were run down to the tailgate — four attached to the top edge and four to the bottom edge.

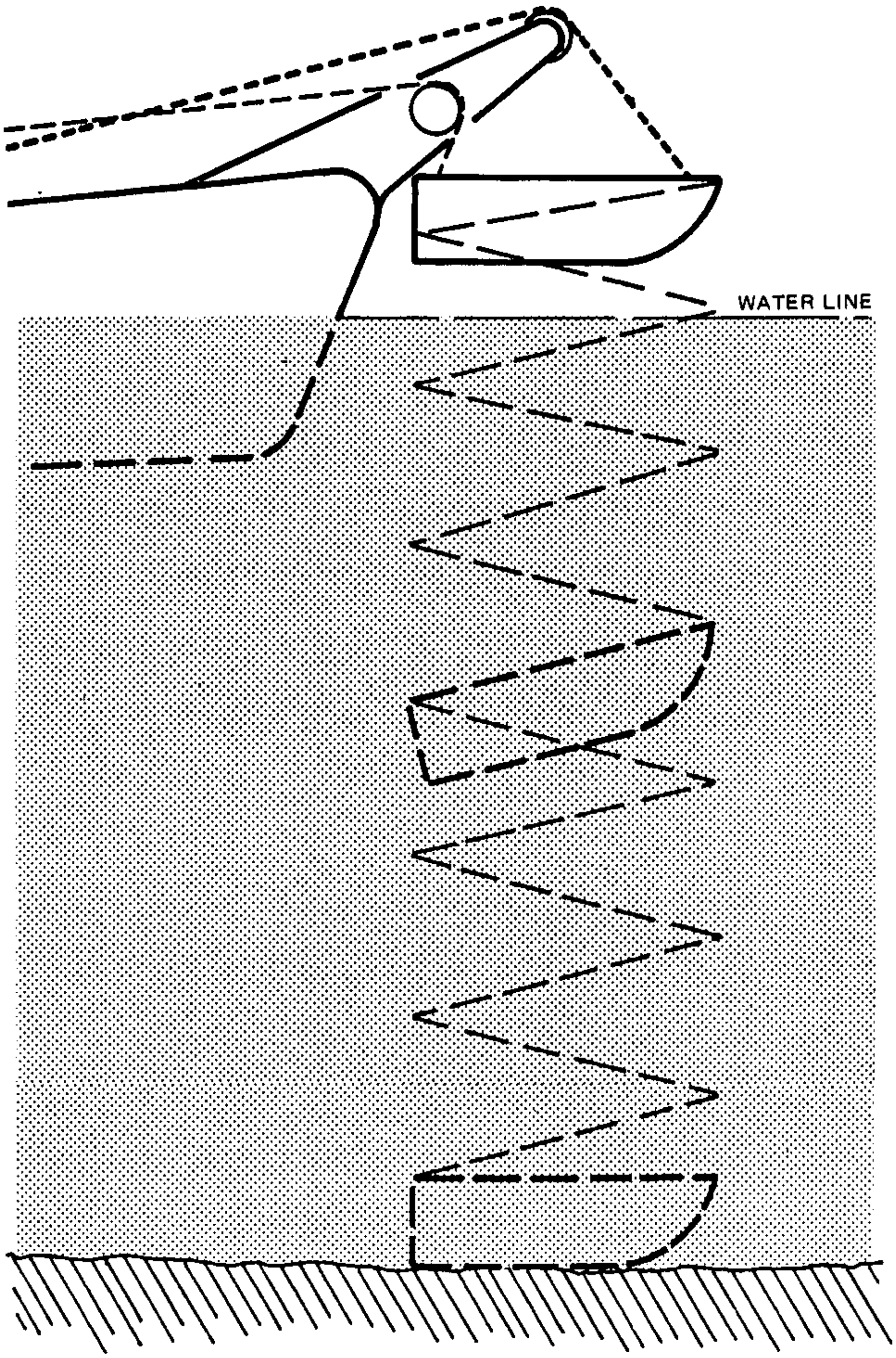
A unique method was employed to allow the four winch engines to pull on half the tailgate's weight at a time. The gate was literally stepped up an edge at a time, with the winches pulling the cables attached to the top edge in unison and then exerting the same amount of pull on the bottom edge (Fig. 15.1., No. 5).

In the process, four drums were alternately dogged off and braked while the other four drums were locked into operation. The edge of the tailgate was raised two to four feet or until the winches stalled. Then those attached to the raised edge were dogged and the other four drums engaged. Thus the gate edge was raised until it was higher than the previously raised edge.

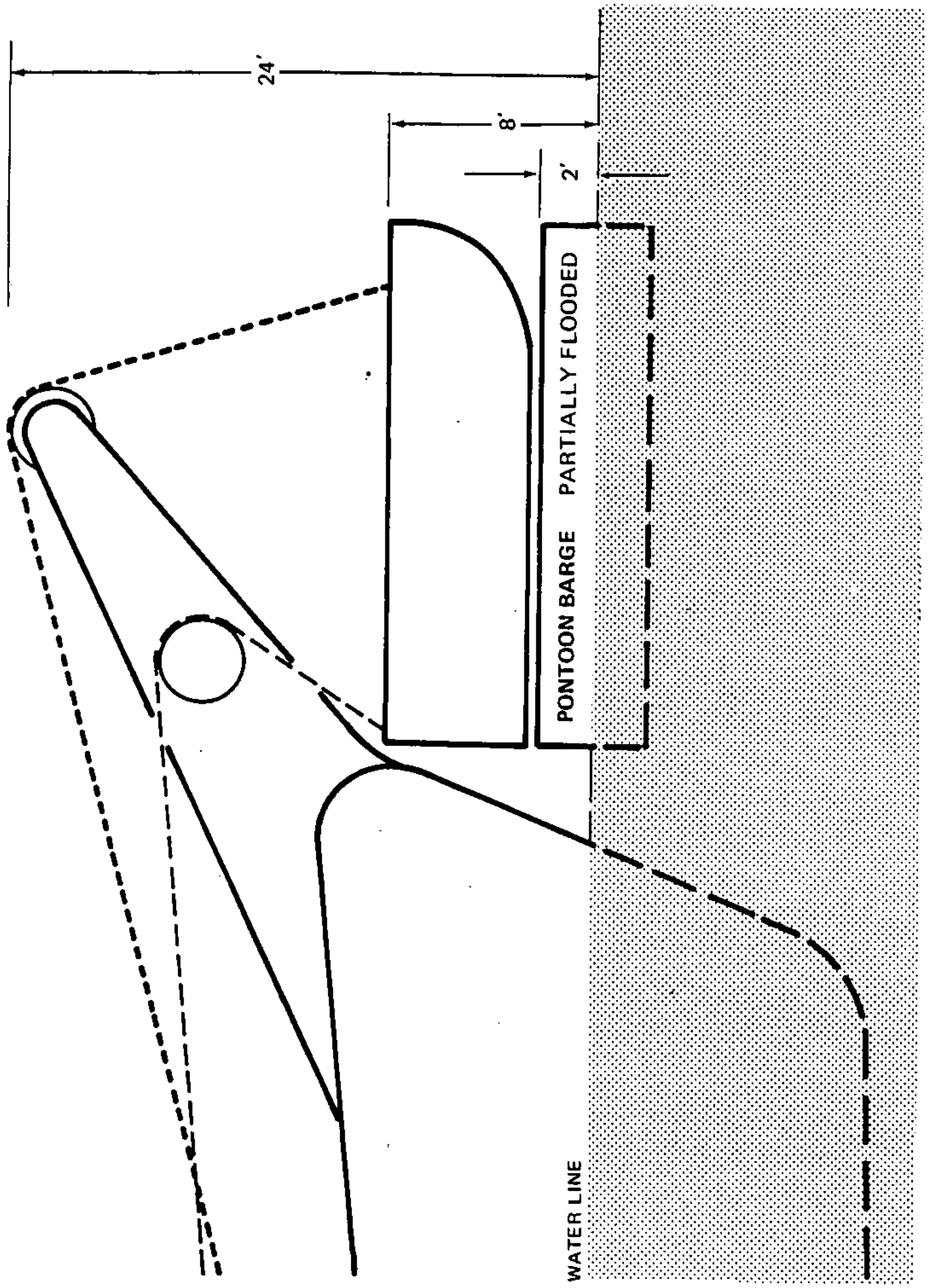
Using this alternating procedure, the tailgate was slowly lifted out of the water to a point about five feet above the surface. A 72-section pontoon barge was floated beneath the hoisted tailgate (Fig. 15.1., No. 6). The gate was then landed on the barge and repaired, after which it was reshipped on the ARD.

The entire recovery operation was accomplished in a matter of hours. If a heavy lift crane (YD) had to be sought out and brought to Kosol Passage to do the job, recovery would have been delayed for days and possibly weeks.

To recover the sunken tailgate of the ARD-11 off the Ulithi staging area in 1945, the same procedure employed at Kosol Passage the year before was utilized. In this case, too, the salvage assignment was undertaken by the *GRAPPLE* (ARS-7), and as before the *GRAPPLE* was assisted by two Net Tenders. The ARD-11's sunken tailgate had to be raised in 150 feet of water — compared to 100 feet for the tailgate sunk at Kosol Passage — but despite the greater depth the assignment was completed within 24 hours.



STEPPING-LIFT METHOD USED TO RECOVER THE TAILGATE.
FIG. 15.1 NO. 5



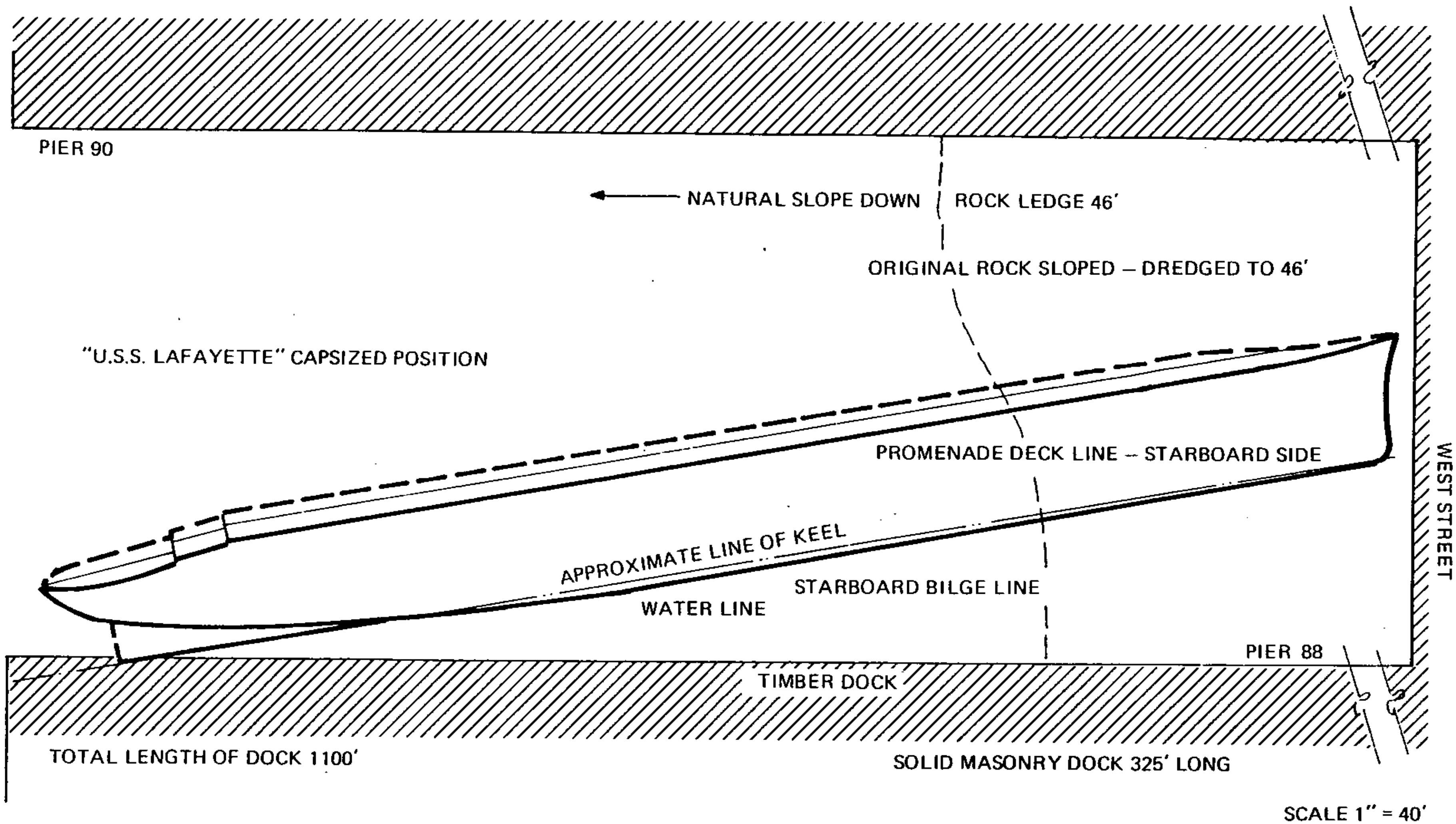
SETTING THE TAILGATE ON A PONTOON BARGE.
FIG. 15.1 NO. 6

15.2. USS LAFAYETTE, (ex-SS NORMANDIE)

The *USS LAFAYETTE (ex-SS NORMANDIE)* undergoing final stages of conversion into a troop carrier at Pier 88 in New York Harbor, caught fire, capsized and sank on 10 February 1942 as a result of the enormous amounts of water used to fight the fire. The ship came to rest on her port side, diagonally in the slip, at an angle of less than 80 degrees, and was flooded throughout up to the outside waterline (Fig. 15.2., No. 1). On 11 June, acting upon recommendations of a special investigation committee appointed by the Secretary of the Navy, salvage operations commenced on the *LAFAYETTE.* She was successfully righted and refloated by extensive patching, shoring and pumping operations.

The salvage of the ship was notable for two reasons. The first was the ship's immense size; she was almost 80,000 gross tons and the magnitude of the righting and pumping operations was proportionally as large. The second reason for the job's importance was that the salvage operation also served as a practical program for the training of new salvage personnel, both Navy and civilian. Realizing the need for a large, well-trained salvage force during the approaching war, the Navy used this opportunity to set up a Diving and Salvage School at Pier 88 and used the ship as a training device for practice in the various skills involved in marine and harbor salvage. The men trained on this operation became the backbone of the Navy's salvage force and were later sent all over the world on salvage missions for the U.S. Navy during and after World War II.

A complete technical report of the massive 16 month salvage task, *Salvage of the USS LAFAYETTE, NAVSHIPS 0994-001-1030,* is available.



U.S.S. LAFAYETTE IN CAPSIZED POSITION BETWEEN PIER 88 AND PIER 90.
FIG. 15.2 NO. 1

15.3. APRA HARBOR

The island of Guam had only four days' warning of the approach of typhoon Karen which struck on 11 November 1962. Apra Harbor, the site of the Naval Ship Repair Facility, Guam, was struck by 150 knot winds with gusts up to 180 knots. Although precautionary measures were taken to secure the harbor before the typhoon, much damage was sustained. Before harbor clearance operations could be completed after Karen, a second typhoon, Olive, arrived, giving little warning of its approach. Emergency precautions were taken, however the harbor once again sustained serious damage. As a result of damage caused by the two typhoons 16 ships or craft had to be raised or refloated. The salvage operations in Apra Harbor and the Guam area in the wake of typhoon Karen were the most extensive performed by the U.S. Navy since World War II in terms of number of ships and craft involved. When the operations stemming from Olive were added to the total, the amount of salvage performed in Guam from November 1962 to July 1963 was astounding.

The individual salvage tasks during this time were not in themselves extraordinary; no new techniques were used, however, the value of the operation aside from the salvage of the ships was that it provided a working-learning experience for all those involved, employing most of the known salvage techniques at one time or another.

The overall operations were outstanding in the following respects. Because of the emphasis placed on safety during the operation no injuries occurred. In the month period from 13 November to 13 December, nine ships and craft were successfully salved — largely because of the efficiency of the planning and coordination of the efforts of those on the job. The development of a bow lift method for the two available ARSs was also a prime determinant in the speedy salvage of ships and craft, as was the salvage and rehabilitation of the sunken YD-120 which was used throughout the operation after it had been raised. The final factor was the existence of excellent working conditions, and the immediate availability of repair facilities.

More information about the individual salvage cases in Guam following typhoons Karen and Olive can be obtained in NAVSHIPS publication 250-638-5, *Harbor Clearance Operations in Guam Following Typhoons Karen and Olive, November 1962 – July 1963.*

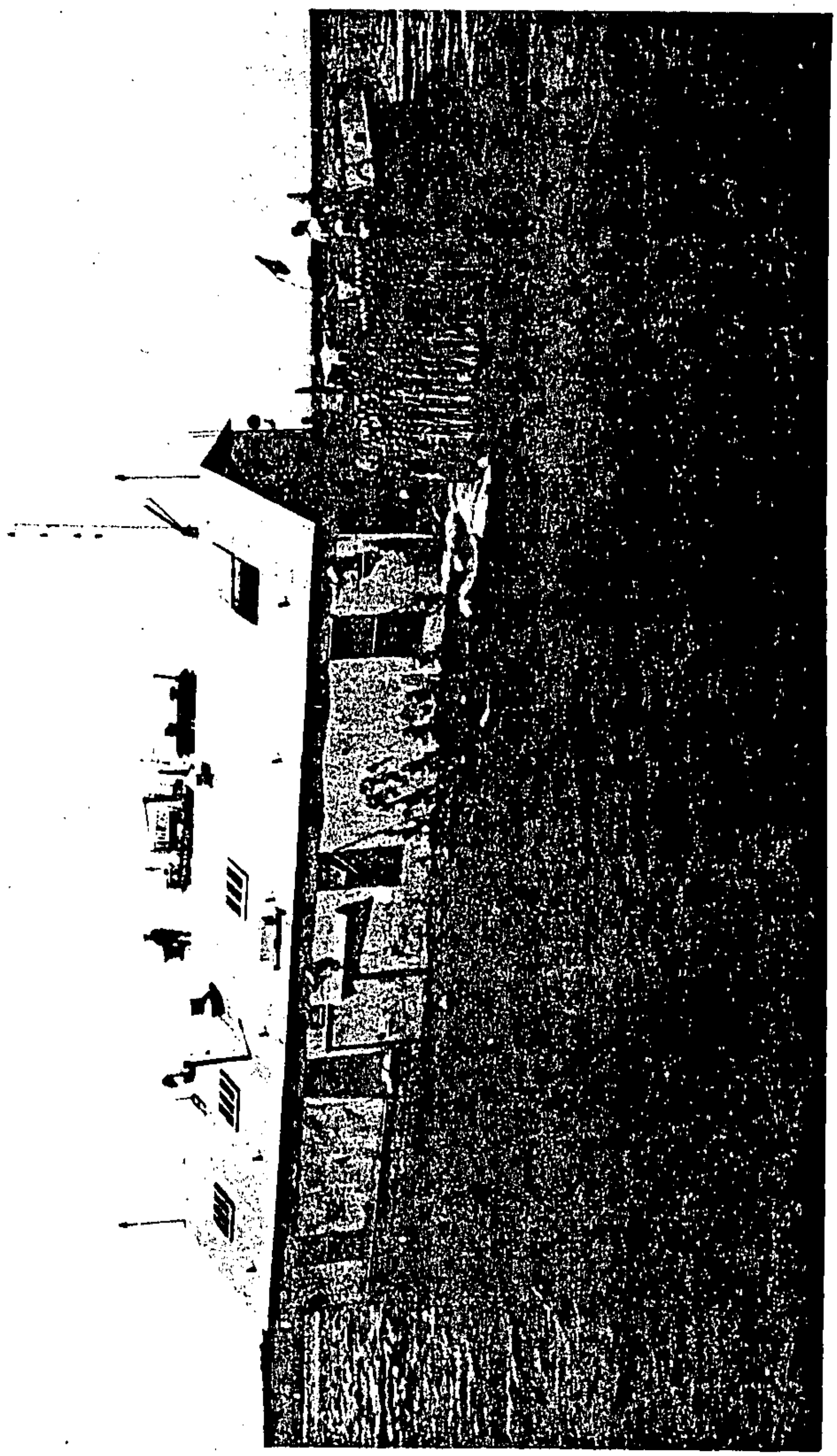
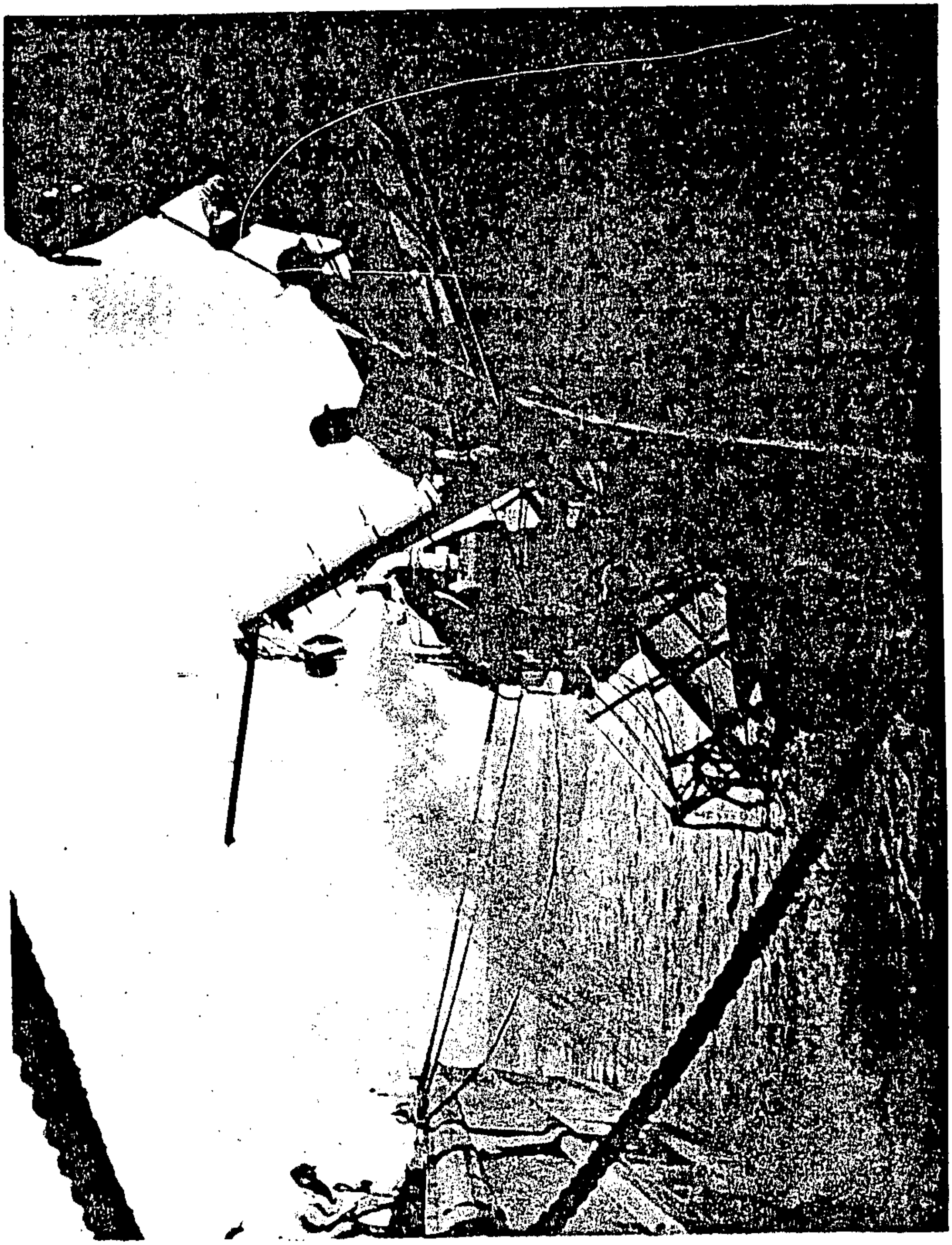
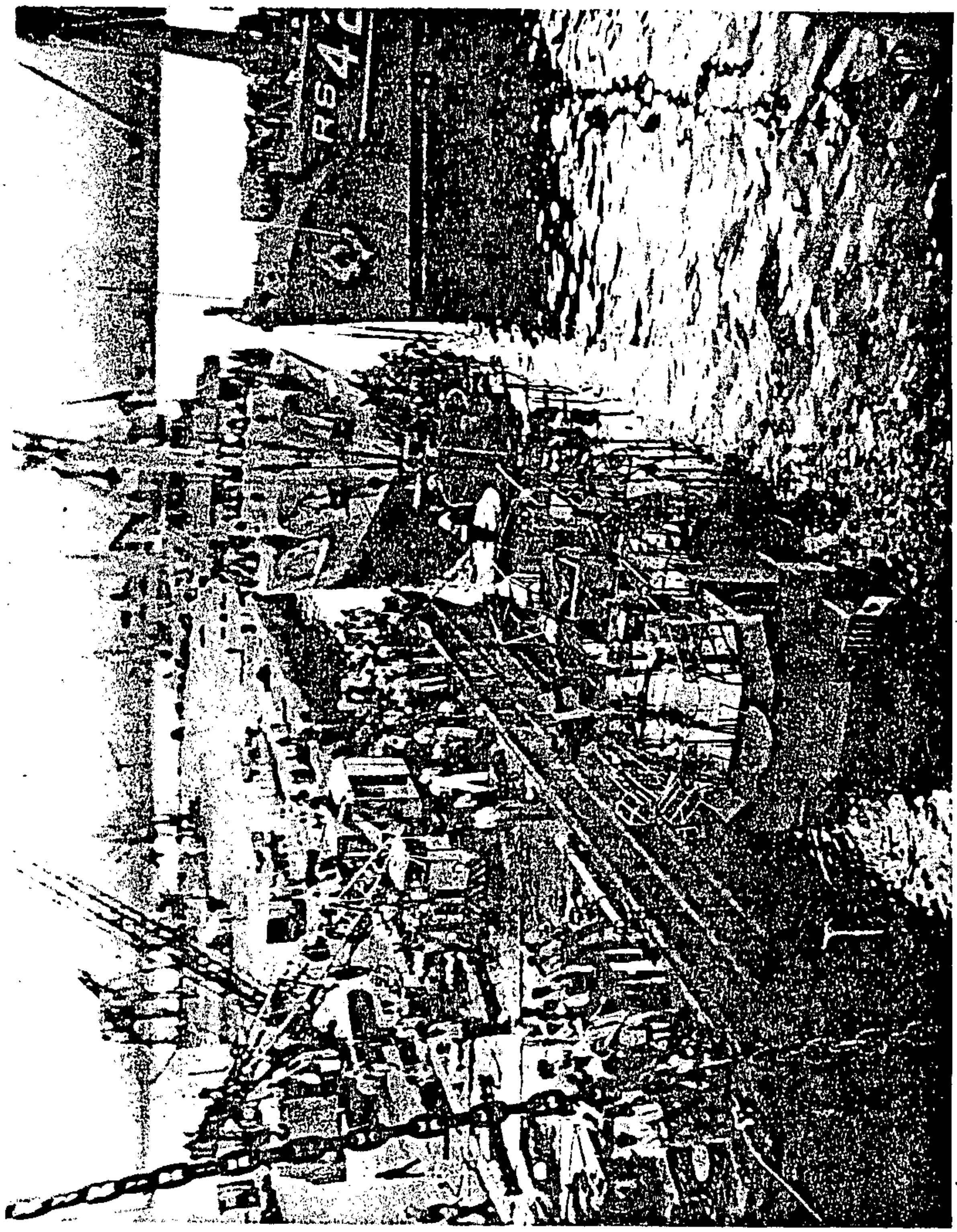


FIG. 15.3 NO. 1
SALVED YSR-19 FLOATING ON AN AIR BUBBLE.



PUMPING OF YTM-521.
FIG. 15.3 NO. 2



PC-705 WITH MAIN DECK ALMOST AWASH
SUBSEQUENT TO LIFTING.
FIG. 15.3 NO. 3

15.4. LUMBERJACK

On 26 October 1963, the sea-going steel barge *LUMBERJACK*, 296 feet long, 75 feet wide, and 21 feet deep, was proceeding through the harbor entrance of Humbolt Bay to the Pacific Ocean with a full cargo of lumber, when an accident occurred leading to the sinking of the barge. High northerly winds and the high cargo forced the barge onto the rocks of the south jetty. Attempts to pull the barge free failed and the barge broke in two. The larger forward section was towed off the jetty and sunk at sea. The stern portion, approximately 108 feet long, 75 feet wide and 21 feet deep, slid off the jetty during a storm and sank in 40 feet of water. The barge section was a hazard to navigation because parts of it were only 15 feet below the surface at low tide. The U.S. Army Corps of Engineers, San Francisco, in whose district the *LUMBERJACK* sank, contracted for the salvage.

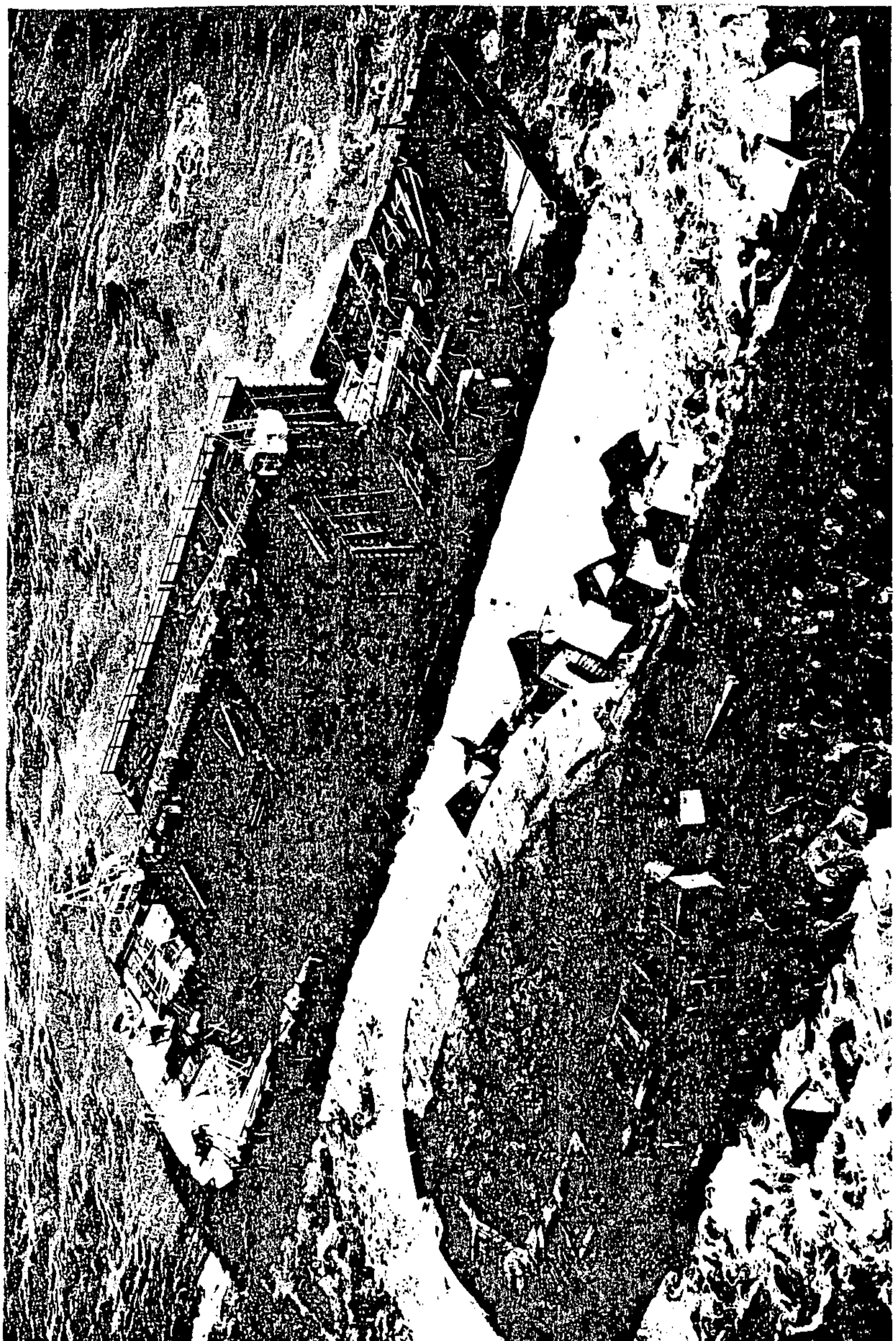
Both external and internal flotation buoyancy were discussed as methods to raise the barge. However, in view of the difficult diving conditions, a decision was made to use inflatable neoprene bags. The water proved rougher than anticipated for use of the bags; the bag attachments wore out and released the bags before the required number could be attached and inflated.

After a restudy of internal flotation alternatives, the original idea was abandoned in favor of an experimental liquid foam. The foam would be placed inside the hull and would harden into a rigid mass providing positive, stable flotation. This method had never been applied in an on-site operation, therefore a test was conducted before the final decision was made to use the foam. The two-component liquid foam was injected into polyethylene bags inside the hull by means of a surface-to-hull hose and a dispensing gun. It took one month to place the required amount of foam, during which time bad weather, extreme swells and toxic gases hampered operations.

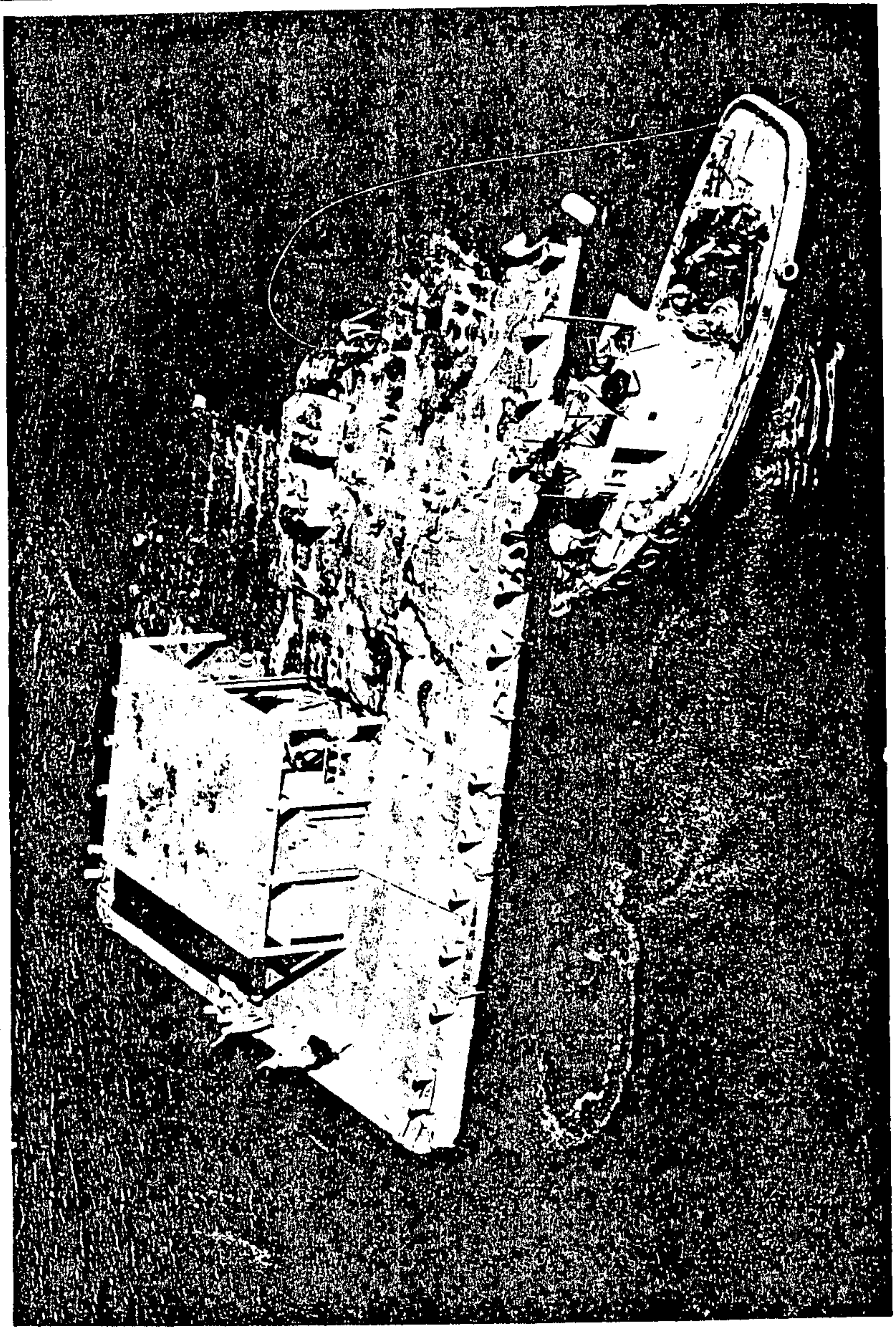
On 31 October one corner of the hull broke the surface as a result of buoyant forces from the foam cast-in-place. The hull appeared impaled and towing by a USCG Cutter failed to free the hulk. On 1 November, the 1500 hp, three-screw tug *QUENETT* was able to tow *LUMBERJACK* to a suitable grounding site where she was cut up and disposed as scrap.

This was an extremely important salvage operation as it was the first successful use of the cast-in-place Urethane foam process. It was valuable especially as an on-site test because it provided much information on the behavior of the foam under pressure in actual use; the information gathered on this operation was used as a guideline for future use of foam salvage methods.

For more information see *A Report on the Removal and Disposal of the Derelict Barge LUMBERJACK by the Cast-in-place Urethane Process*, Murphy Pacific Marine Salvage Company, Emeryville, California.



THE BARGE "LUMBERJACK" AGROUND.
FIG. 15.4 NO. 1



STERN SECTION OF THE "LUMBERJACK"
AFLOAT ON FOAM.
FIG. 15.4 NO. 2

15.5 AFDM-2

On 9 September 1965, Hurricane Betsy hit the Port of New Orleans. Among the hundreds of casualties to shipping inflicted by the hurricane, the Navy's Auxiliary Floating Dock Medium, *AFDM-2*, capsized and sank. The steel drydock was built in three "U" shaped sections bolted together, each section consisting of a rounded pontoon and two fixed wingwalls extending 37 feet above the pontoon deck. The assembled dock totaled 544 feet in length with outriggers at each end extending the overall length to 614 feet. Overall width was 116 feet with a light displacement of 6,360 long tons. At the time of the hurricane, a new ocean going freighter *SS ELIZABETH LYKES* was docked in the drydock.

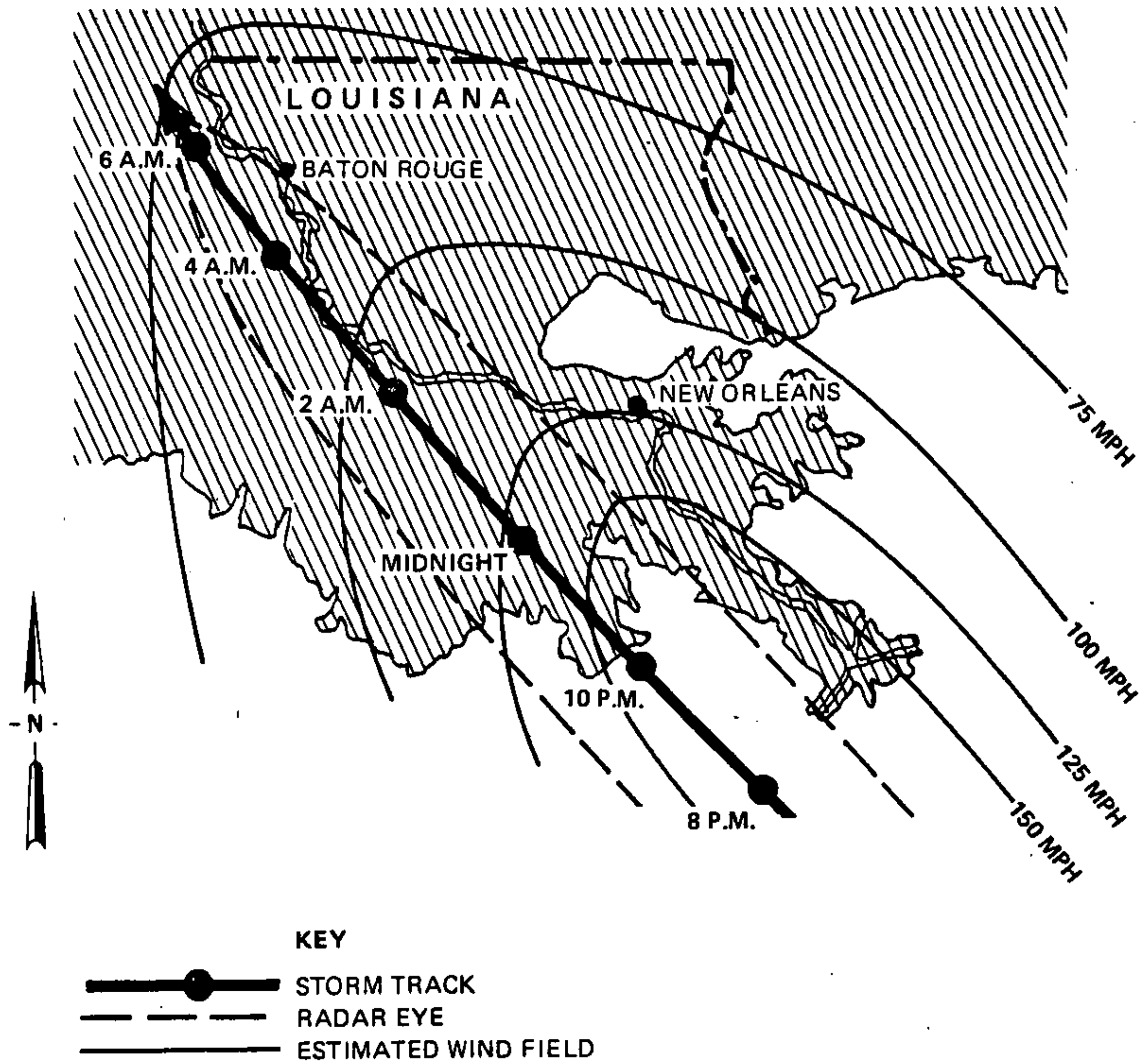
Strong winds and other loose ships tore the dock, with the freighter inside, from the mooring and propelled it across the 1,100 foot wide Mississippi River and upstream about three miles. During this transit the freighter slipped out and grounded, and the dock suffered numerous collisions in the hull and sidewalls. It was holed many times, shipped water, capsized and sank. It was located on 10 September laying 300 feet from shore with the inshore wingwall aground in 80 feet of water and the offshore wingwall afloat in 110 feet of water. Only a small portion of the bottom was visible as 4/5ths of the dock was submerged and it was still taking on water. The dock was very valuable to the Navy and as it lay was a serious navigational hazard to the Mississippi River traffic.

Although the external damage included over a hundred holes and a large gash 20 feet by 15 feet, the internal structural damage appeared minimal upon first inspection. On the basis of this survey, salvage of the *AFDM-2* appeared technically feasible and was later determined to be economically sound; it would cost more than three times what the dock was originally built for in order to replace it. The desirability of salvage was bolstered by the fact that piecemeal removal was both a costly and lengthy procedure.

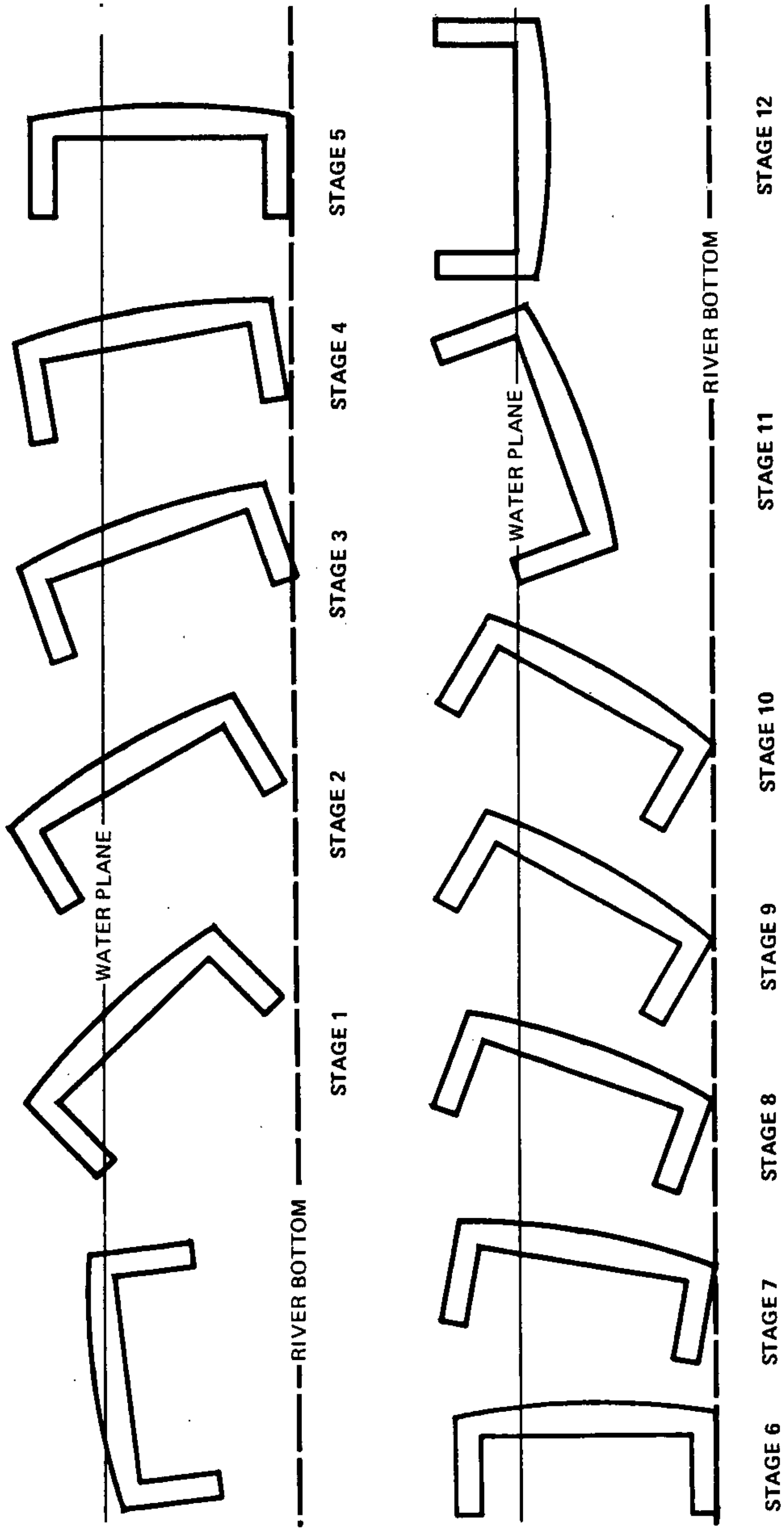
Water had been displaced from the hull in order to prevent further sinkage; more water was pumped out in order to move the dock from its present position blocking the channel, to a site across the river where further investigation would be easier and it would not be a hinderance to navigation. The capsized dock was in the process of being towed when the anchors slipped; it broke free of the mud prematurely and was swept downstream half a mile before the two salvage ships assisting in the tow could halt it, and tow it to its new site.

It remained on the west bank for two months while preparations for the salvage operations were made; a comprehensive survey of the damage and a plan was made for righting the dock.

The final approved plan for righting the dock called for snugging the capsized dock against the river bottom and righting by parbuckling it up and over 180 degrees toward the levee. The parbuckling operation was to be accomplished in twelve stages employing a combination of land-based beach gear, inflatable rubber pontoons for external buoyancy, and the judicious use of water ballast and compressed air. This was the first time all of these techniques were used in one carefully determined effort.



HURRICANE TRACK
ON 9-10 SEPTEMBER 1965
FIG. 15.5 NO. 1



CAPSIZED DRYDOCK TURNS RIGHTSIDE UP IN A 12-STAGE SALVAGE OPERATION AT NEW ORLEANS, LOUISIANA

FIG. 15.5 NO. 2

PROPOSED REFLOATING PLAN

STAGE I – (46½ degrees) Hull is afloat. Flood all ballast tanks on onshore side and blow or pump dry all ballast tanks on offshore side to ground one side of the hull on bottom.

STAGE II – (60 degrees) Exert beach gear force approximately 551 tons to turn of bilge on offshore side of drydock.

STAGE III – (70 degrees) Flood two buoyancy chamber compartments adjacent to midship of center section with 1440 tons of ballast. Exert beach gear force of approximately 332 tons.

STAGE IV – (80 degrees) Increase beach gear force to approximately 451 tons.

STAGE V – (90 degrees) Pump 2950 tons of ballast into two upper compartments adjacent to midships of center section. Increase beach gear force to approximately 500 tons.

STAGE VI – (90 degrees) Add 68 inflatable rubber pontoons to create external source of buoyancy of 600 tons at the intersection of the lower sidewall face. Exert beach gear force of approximately 558 tons. Increase beach gear force until hull begins to rotate.

STAGE VII – (100 degrees) Continue to rotate hull until beach gear force is reduced to approximately 275 tons.

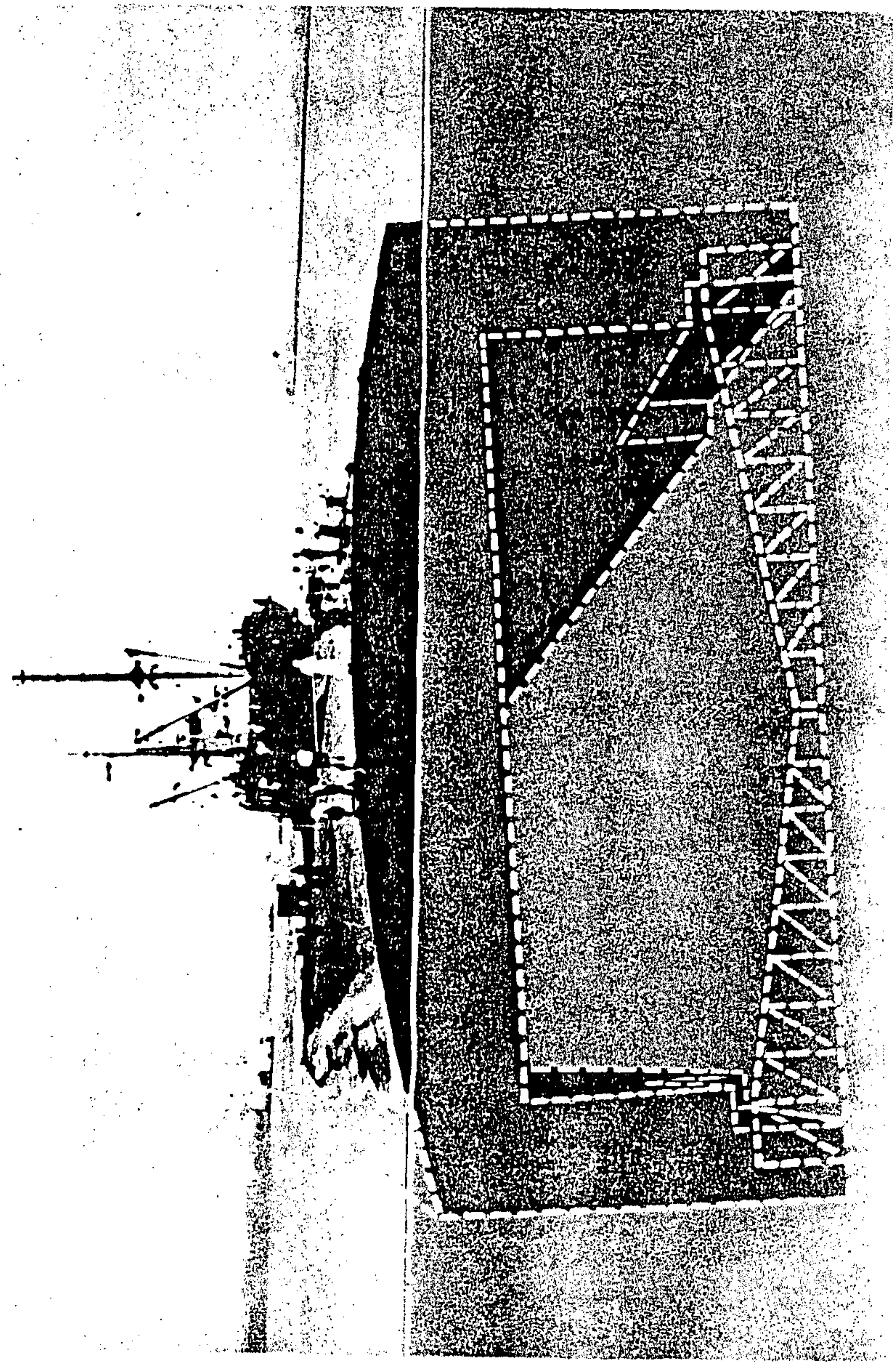
STAGE VIII – (110 degrees) Pump 1000 tons of ballast into two upper compartments at ends of center section. Exert beach gear force of approximately 124 tons.

STAGE IX – (120 degrees) Pump 1950 additional tons of ballast into two compartments at ends of center section of drydock.

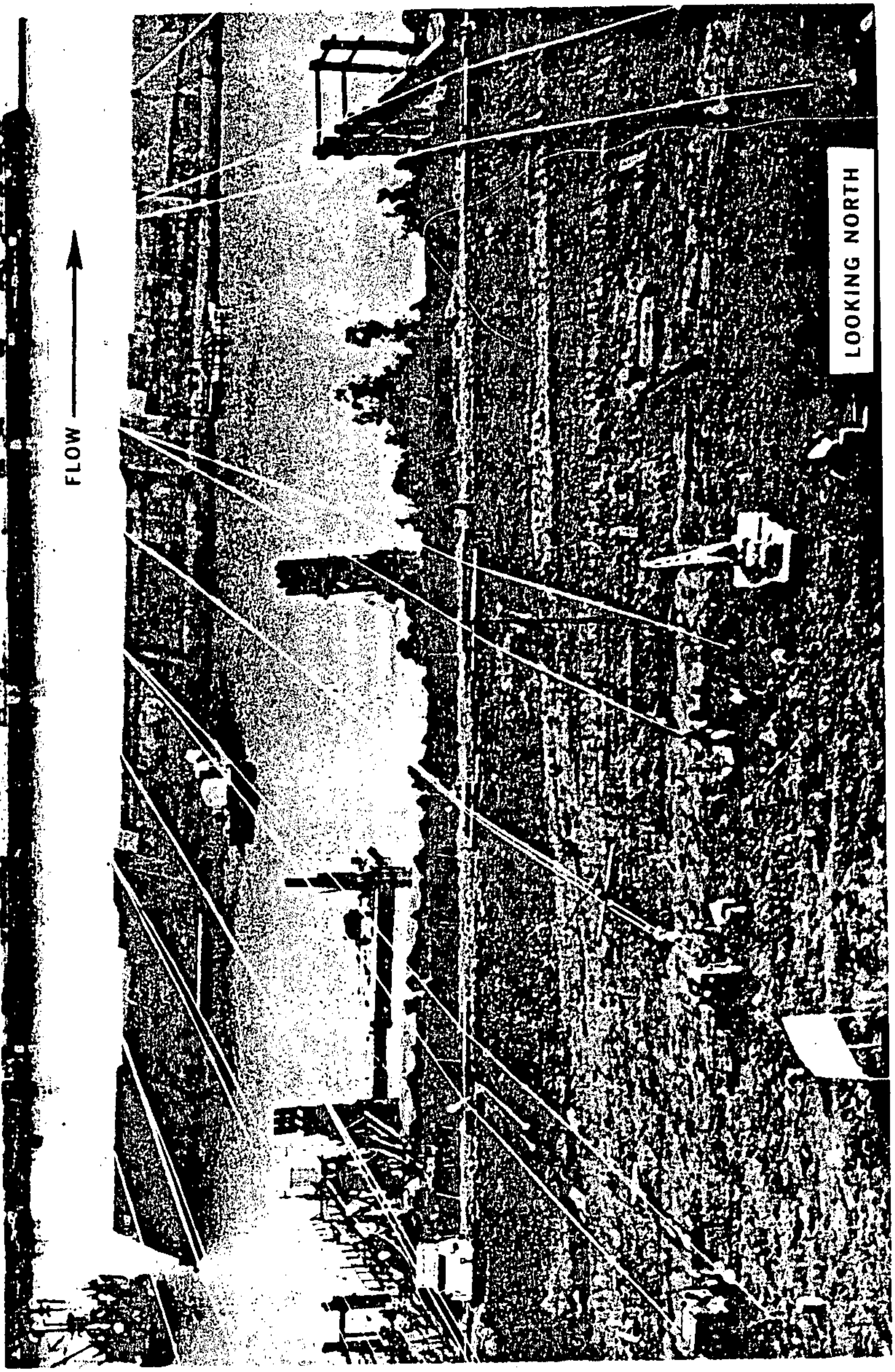
STAGE X – (120 degrees) Discharge 560 tons of ballast from four lower compartments of center section by blowing compressed air to a gauge pressure of 25 pounds per square inch. Pressure is not to exceed 26 pounds per square inch at this stage.

STAGE XI – (160 degrees) Pump 2650 tons of ballast at maximum rate of 250 gpm into four upper compartments of the two end sections. As hull rotates air will expand and discharge approximately 1635 tons of ballast and air pressure will reduce. With deck awash at low tide, gauge pressure should be approximately six pounds per square inch and not exceed 6½ psi. Close all eight discharges in four compartments containing air. Tow hull inshore. Bleed trapped air down to atmospheric pressure.

STAGE XII – (180 degrees) Pump approximately 1100 tons of ballast from between main deck and safety deck. Continue pumping ballast from all compartments on low side of hull until list is zero. Approximately 7100 tons of ballast will be removed. Draft will be approximately 15 feet.



CAPSIZED AFMD-2.
FIG. 15.5 NO. 3



BEACH GEAR RIGGED ASHORE FOR PARBUCKLING
THE AFDM-2.
FIG. 15.5 NO. 4

The preparatory work was two-fold; the repairs to the hull and wingwalls that would be underwater during the righting operation had to be made, and the vents, valves, padeyes, and other fittings that would be used during the operation had to be installed. During this time the dock was jarred loose from her moorings by high water and a surge of debris, and had to be moved across the river again back to the west bank. While the work was being carried out on the dock, another crew was installing beach gear in the area behind the levee, and the salvage site was selected. A suitable site, meeting the requirements needed for the parbuckling operation was found only 1,500 feet downstream.

During the actual operations only two factors seriously hampered the projected plans. The amount of mud accumulated inside the *AFDM-2* had not been compensated for, and a considerable amount of time was spent pumping out this mud to lighten the dock and shift the weight to make parbuckling possible. The second problem occurred before the dock entered Stage V of the parbuckling operation. The level of the bottom was found to be too shallow to allow the dock to rotate into Stage V. Several days' time was lost in dredging a channel in which the wingwall could rest during the final stages of the righting. All other preliminary calculations were found to be very close to the actual forces encountered necessary to successfully complete the operation.

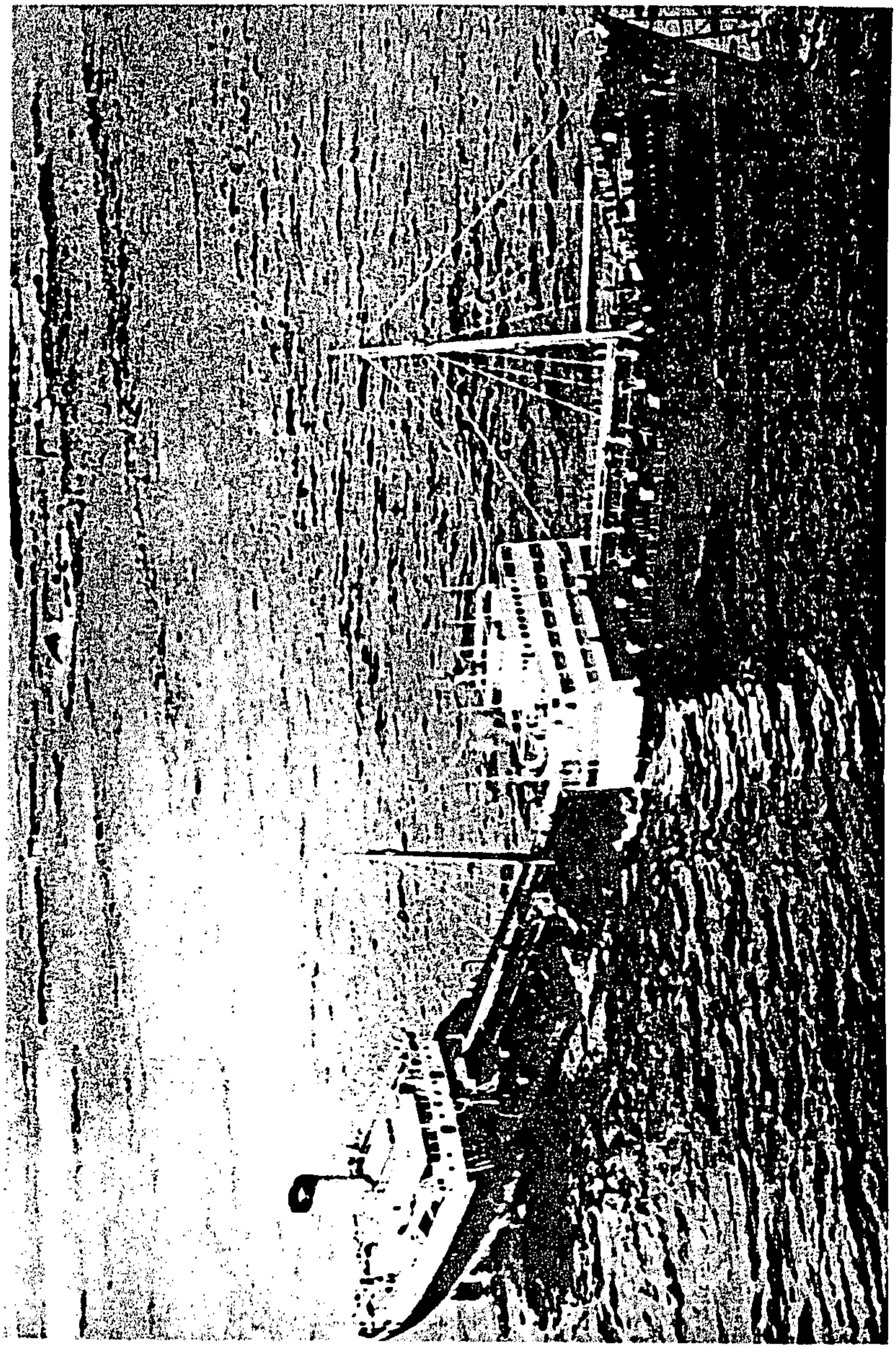
There is a technical report on the salving of the *AFDM-2* (NAVSHIPS publication 0994-001-4010) available for detailed information of the operation.

15.6. S/T OCEAN EAGLE

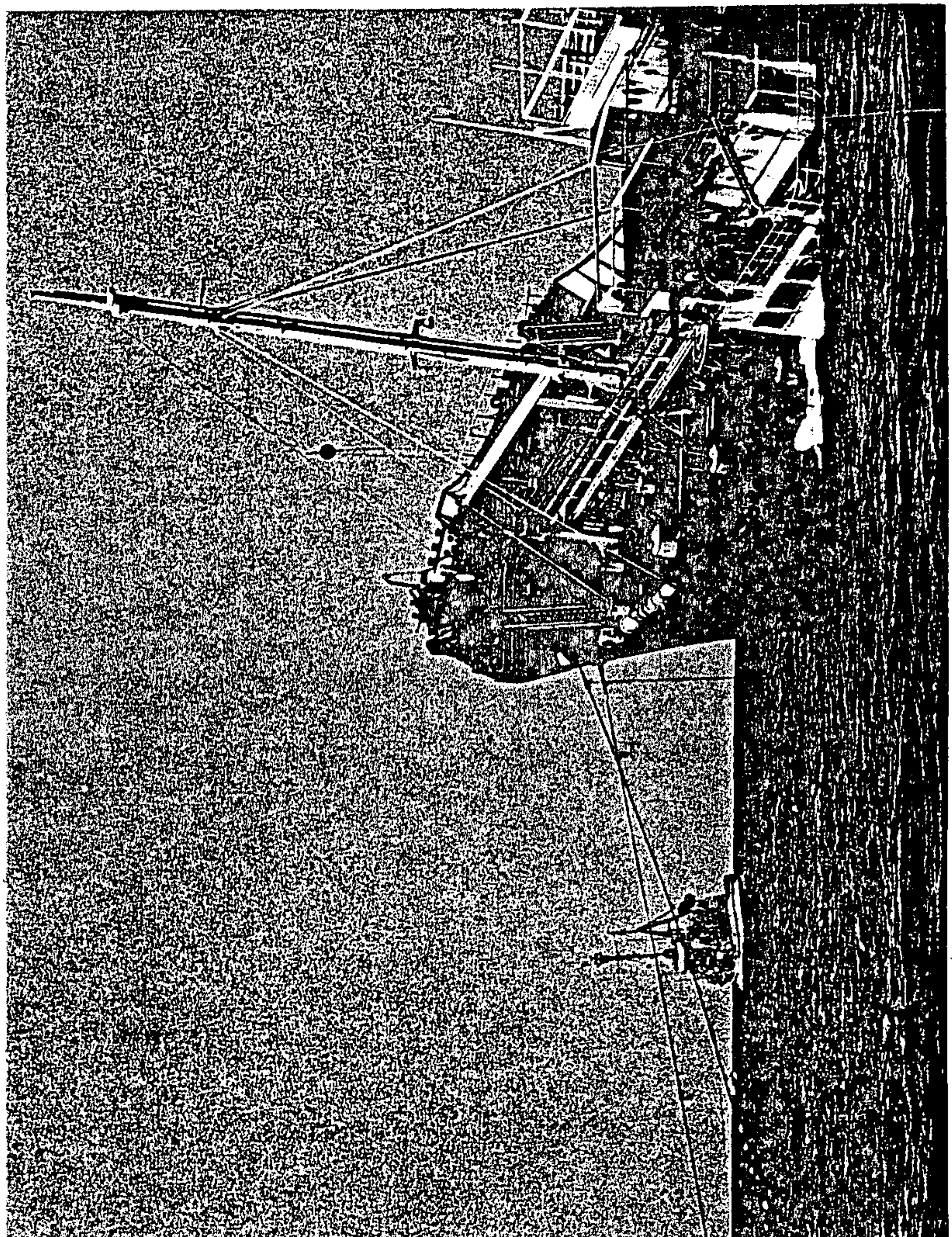
The 25,000 ton steam tanker *OCEAN EAGLE* broke in two at the entrance to San Juan Harbor, Puerto Rico, on 3 March 1968. The bow half of the tanker constituted an immediate threat to safe navigation of the channel entrance; the stern section posed a somewhat lesser threat. Of major concern however, was the immediate threat of oil pollution to the harbor and surrounding resort beaches. Both sections of the *OCEAN EAGLE* began to discharge large quantities of the 5.5 million gallons of crude oil cargo as soon as the ship broke up.

During the period from 5 to 9 March, the *USS PRESERVER (ARS-8), USS UTINA (ATF-163)* and the *USS PAIUTE (ATF-159)* attempted to tow the bow section to sea. On 9 March operations were suspended because heavy swells caused a major change in the condition of the bow. This necessitated the change to a long range salvage program of cargo removal and refloating for eventual disposal of the hulk. From 11 to 21 March essentially all remaining cargo oil was removed – 1,192,487 gallons. On 4 April, after several delays because of rough seas, the hulk was refloated and towed to sea where it was scuttled in 600 fathoms of water approximately eight miles north of San Juan.

The *OCEAN EAGLE* salvage operation provided insight and impetus for governmental reevaluation of resources to meet the serious problems of extensive oil pollution from disabled ships. Attention has focused on the need for an effective response force, and improved equipment and techniques to clean up major open ocean and harbor oil spills.



S/T OCEAN EAGLE BROKEN AMIDSHIPS.
FIG. 15.6 NO. 1



S/T OCEAN EAGLE BOW SECTION UNDER
TOW TO DISPOSAL SITE FOR SINKING.
FIG. 15.6 NO. 2

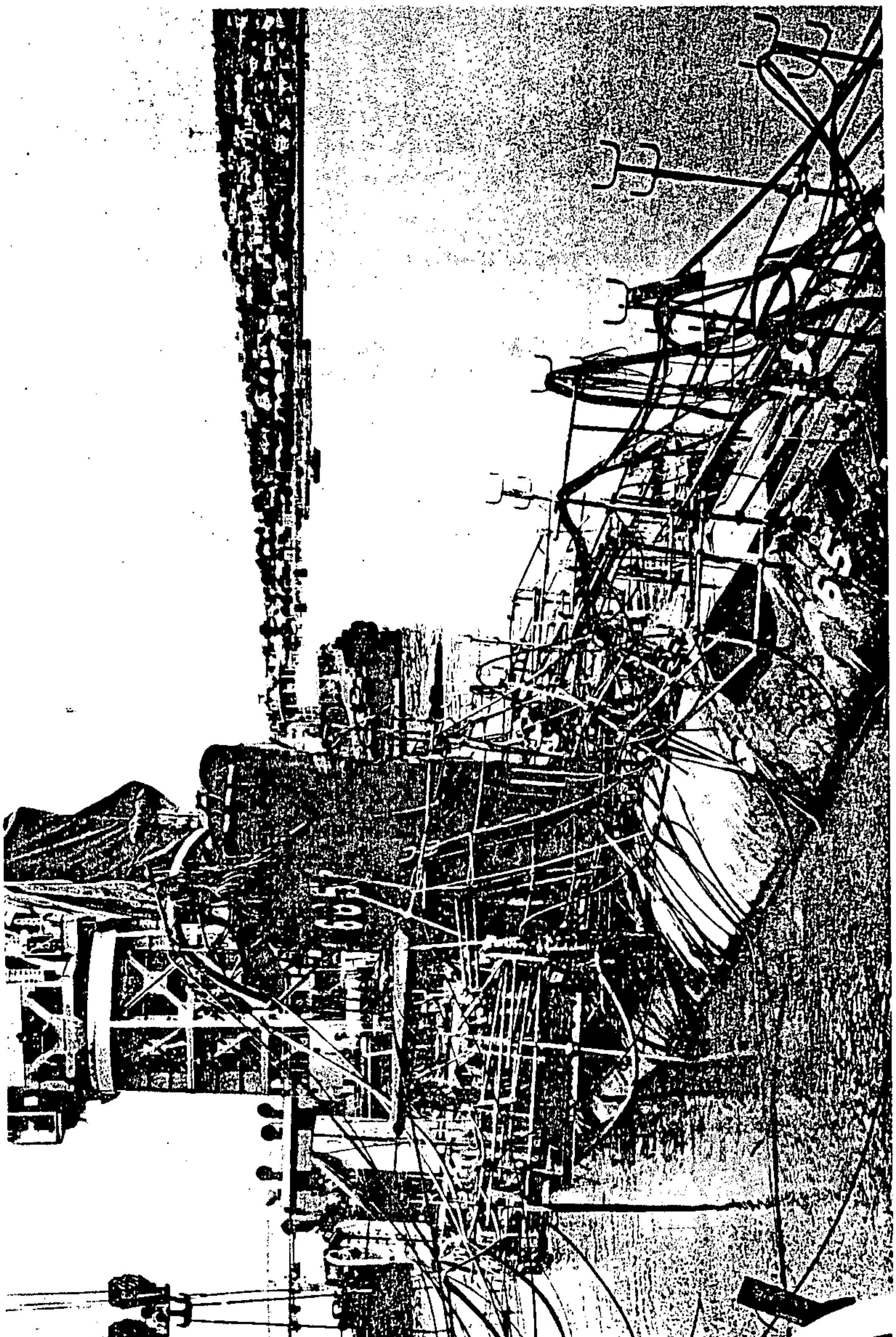
15.7. USS GUITARRO (SSN-665)

On 15 May 1969, the nuclear powered attack submarine *GUITARRO* was in an advanced stage of construction at the San Francisco Naval Shipyard, when she sank as a result of uncontrolled flooding. She came to rest on the bottom in soft mud, approximately 40 feet down, and had a list to port of five degrees.

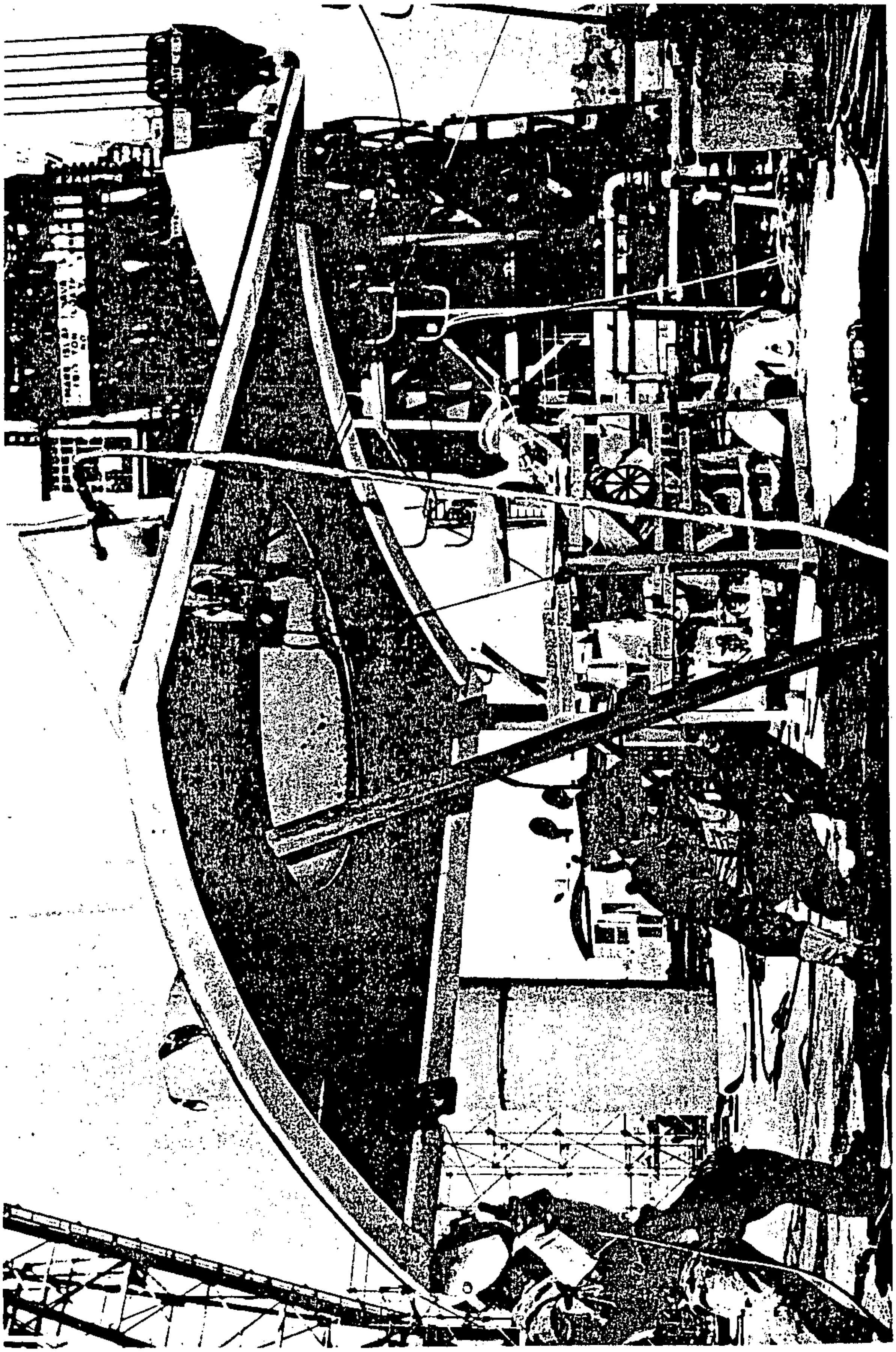
The submarine was refloated on 18 May 1969 by selective dewatering with pumps through cofferdams which had been constructed for that purpose. Though the original salvage plan envisioned expelling water by means of compressed air through the salvage fittings, this plan was abandoned in favor of pumping; it became obvious that pumping would be faster. After the submarine was raised, residual water was removed from the *GUITARRO* until a condition satisfactory for drydocking was reached.

This salvage operation assumes considerable importance as it is the first and only salvage of a nuclear submarine. The shipyard industrial assistance and complete availability of all services, especially cranes, made the salvage of the *GUITARRO* possible in only three days. A similar sinking on the floor of the ocean, even at shallow depths, might present the salvor with a difficult problem.

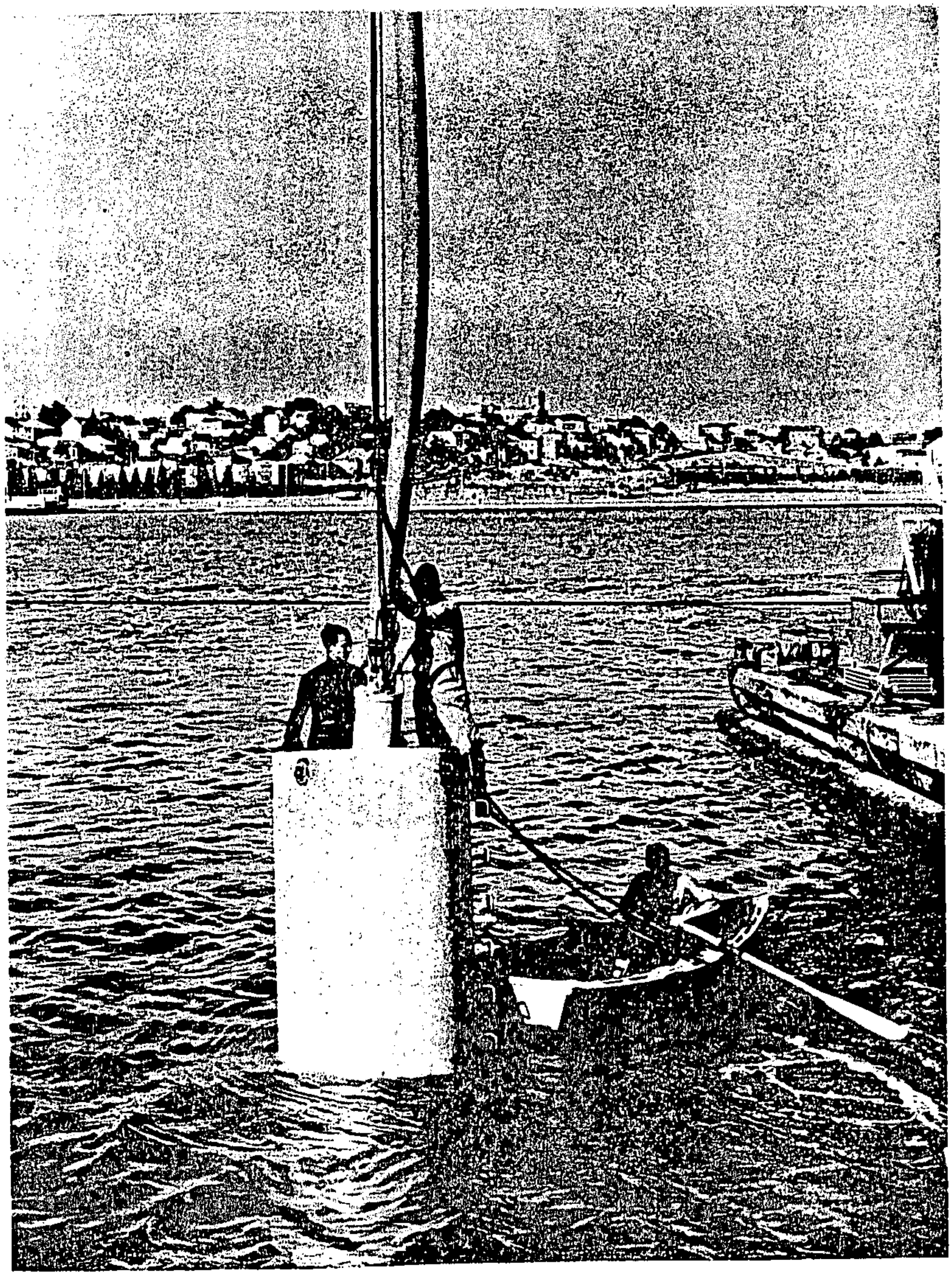
More information on the salvage of the *GUITARRO* can be found in the *US NAVY Ship Salvage Manual, Volume II, Submarine Salvage*, a Naval Ship Systems Command publication.



USS GUITARRO ON THE SURFACE AFTER BEING PUMPED OUT.
FIG. 15.7 NO. 1



FABRICATION OF THE COFFERDAM SEAT.
FIG. 15.7 NO. 2



ELECTRIC PUMP BEING LOWERED INTO COFFERDAM ON THE "GUITARRO".
FIG. 15.7 NO. 3

15.8. S. S. ARROW

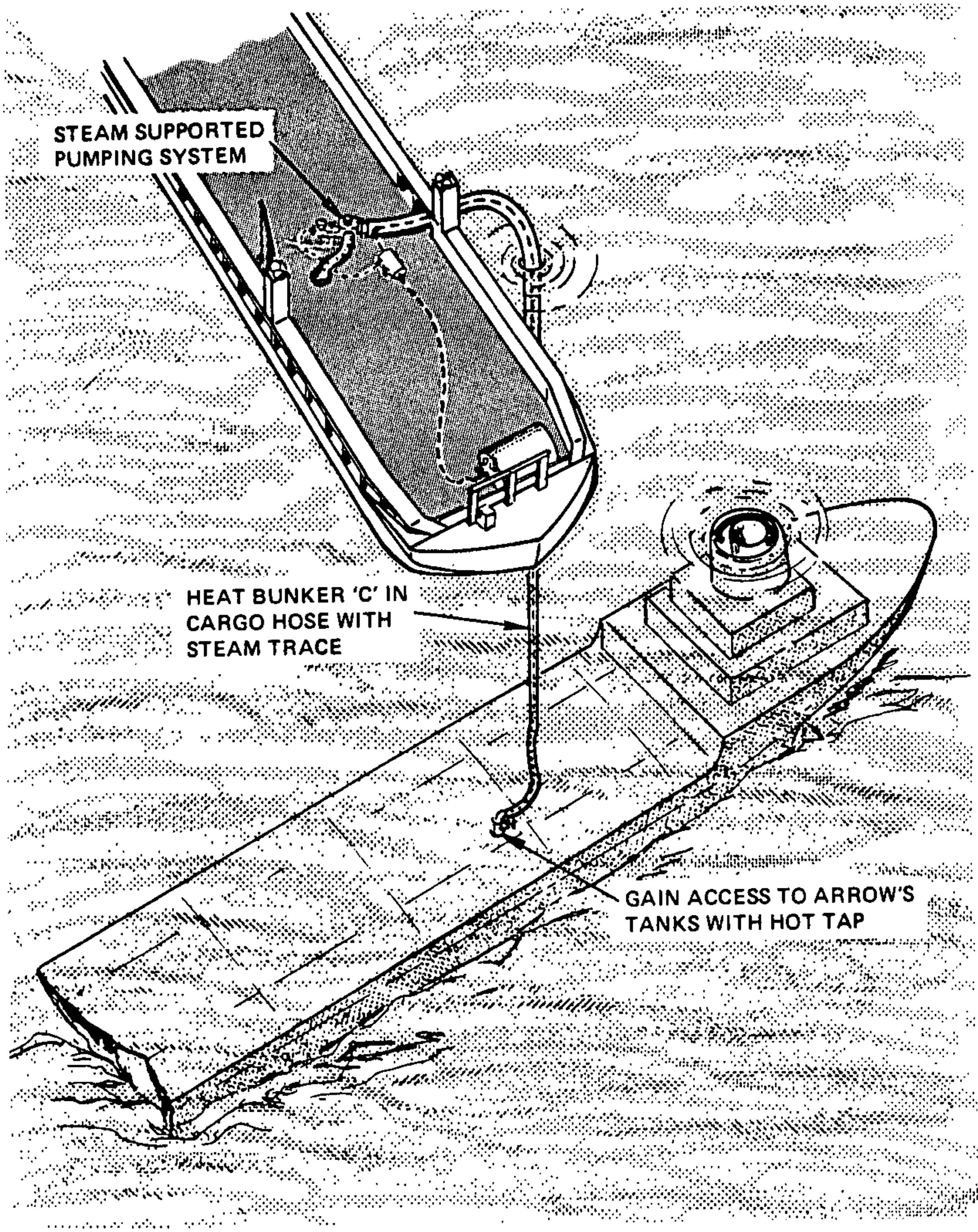
On 4 February 1970, the oil tanker *S. S. ARROW*, grounded in Chedabucto Bay, Nova Scotia, carrying a cargo of almost 17,000 tons of Bunker "C" fuel oil. The *ARROW* subsequently broke in two and sank, releasing approximately 10,000 tons of oil which rapidly contaminated the water and surrounding beaches of the Chedabucto Bay area, an area primarily dependent on its water resources and commercial fishing. Over 6,000 tons of the Bunker "C" fuel oil remained trapped in the cargo tanks of the sunken tanker, threatening further pollution.

In assembling a task force to conduct salvage and recovery operations on the ship and the oil, the Canadian government enlisted the aid of the Supervisor of Salvage of the U. S. Navy, and many other civilian and military personnel from Canada.

The salvage task force developed a steam supported pumping system to recover the oil trapped in the tanker's cargo tanks, using a hot tap method adapted from oil refinery procedures, to penetrate the *ARROW's* cargo tanks and install fittings for the pumping operations. In order to transfer the high viscosity oil from the near freezing tanks to the surface, steam traces were inserted in the salvage hoses to heat the oil to a temperature at which transfer would be possible. The salvage operation was centered around a large oil transfer barge which was moored over the wreck to serve as a lighter and pumping platform.

Both the equipment and the techniques used during the salvage operations were notable in that many of them were devised and used for the first time in this unusual operation, the first attempt to remove oil from a sunken oil tanker in order to avert the possibility of oil pollution and contamination.

A complete report of the salvage operations is available in NAVSHIPS 0994-008-1010, *ARROW, The Recovery of Bunker "C" Fuel Oil from the Sunken Tanker, S.S. ARROW and Concurrent Measures Used to Control Oil Pollution in Chedabucto Bay, Nova Scotia, During the Winter of 1970*, available from Department of the Navy, Naval Ship Systems Command, Washington, D.C.



PRIMARY METHOD FOR HEATING AND LIFTING
THE BUNKER "C". S.S. ARROW SALVAGE
OPERATIONS. 1970.
FIG. 15.8 NO. 1

15.9. USS REGULUS (AF-57)

During the morning of 16 August 1971, the refrigerated stores ship *USS REGULUS*, leaving Hong Kong Harbor, received warning of the approach of typhoon Rose. Transiting the harbor, *REGULUS* made anchor in the port typhoon shelter to weather the storm and remained under steam as the typhoon commenced. At approximately 0200 on 17 August, the ship was driven aground on Kau Yi Chau Island. Extensive surveys revealed significant damage to the ship.

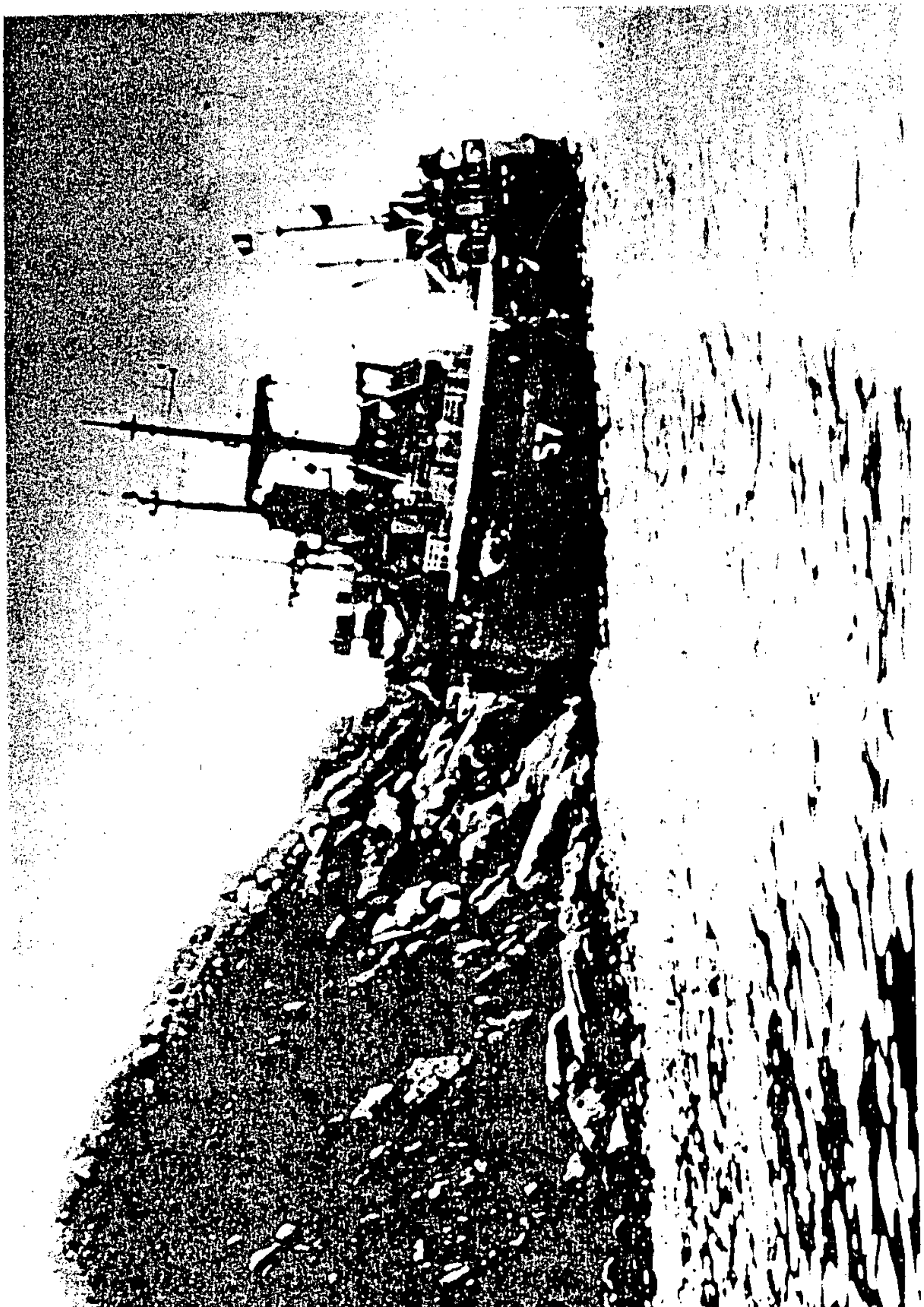
In view of the substantial damage sustained by the *REGULUS* in grounding, it was decided that an investigation should be made as to whether *REGULUS* should be salved and returned to service, or decommissioned and removed as scrap. While the disposition of the ship was being determined, oil pollution abatement procedures were initiated along with the offloading of all salvable equipment, fuel, oil, stores, ammunition and debris.

On 4 September investigation findings indicated that the *REGULUS* was unfit for further service because the material condition of the ship was such that the cost of repairs and alterations required was disproportionate to the value salved. The board recommended that the *REGULUS* be striken from the Naval Register, that all valuable equipment be removed from the ship prior to disposal, and that the hulk be sold on an "as, where is" basis.

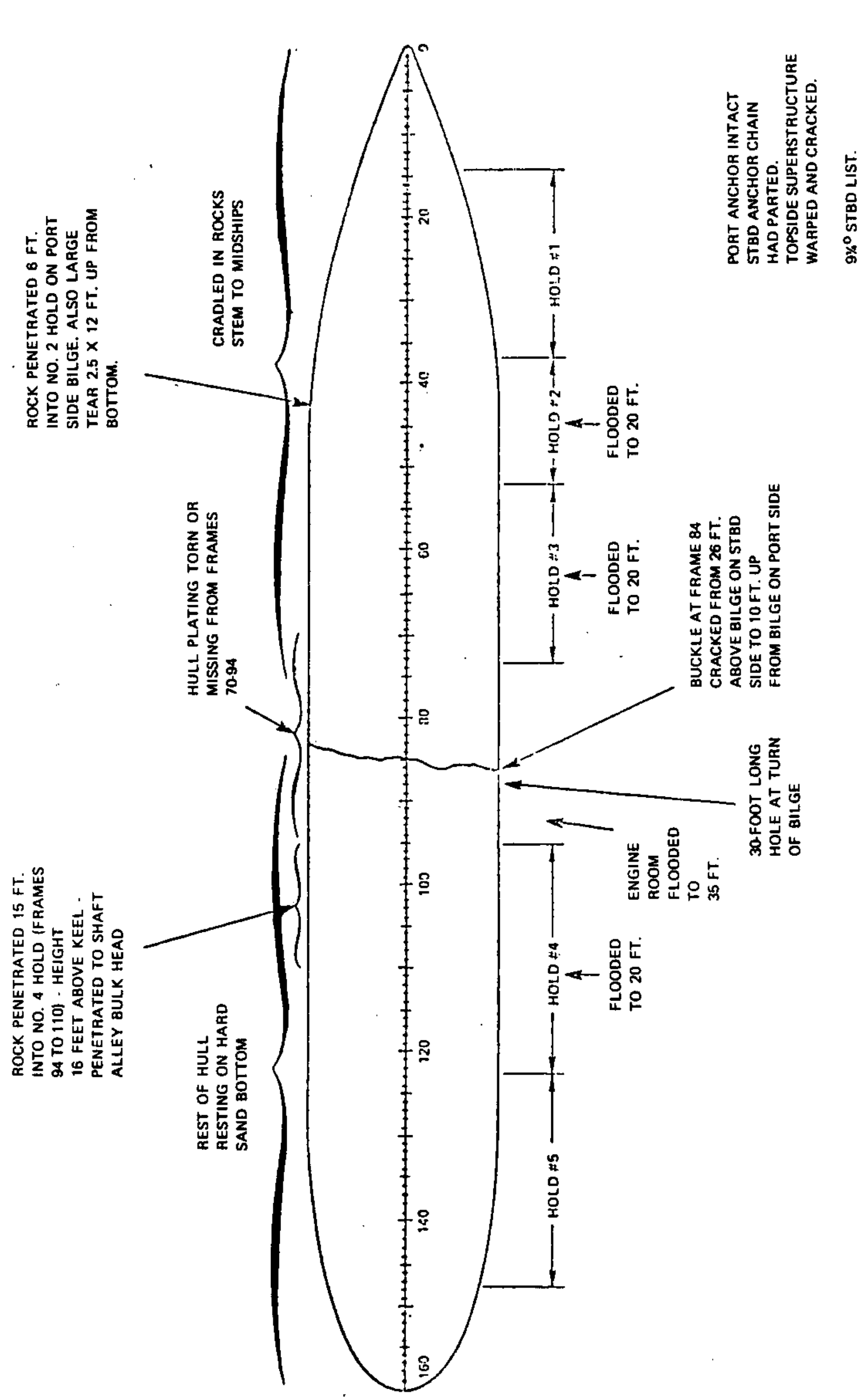
On 10 September the *REGULUS* was decommissioned and the hulk turned over to the Supervisor of Salvage Representative for final disposal. The SUPSALVREP in turn contracted a commercial salvage company, Murphy Pacific Marine Salvage Company to undertake disposal operations.

Disposal operations began on 19 September, and included dismantling and removal of the hulk. The final plan called for removal of upper hull structure and machinery to gain additional buoyancy, severing the hulk into two sections at frame 106.5, and rigging of beach gear, pumps and compressors for refloating and retraction of the sections. Disposal operations continued through five typhoons and a fire on board, casualties which severely hampered operations. However, the bow and stern sections of the ex-*REGULUS* were finally refloated on 24 January and 3 February 1972 respectively, and towed to Junk Bay for scrapping.

A complete report of salvage and disposal operations on the *REGULUS* can be found in the salvage report entitled *USS REGULUS (AF-57)* Salvage and Disposal Operations, published by the Director of Ocean Engineering, Naval Ship Systems Command, Washington, D.C., 20360.

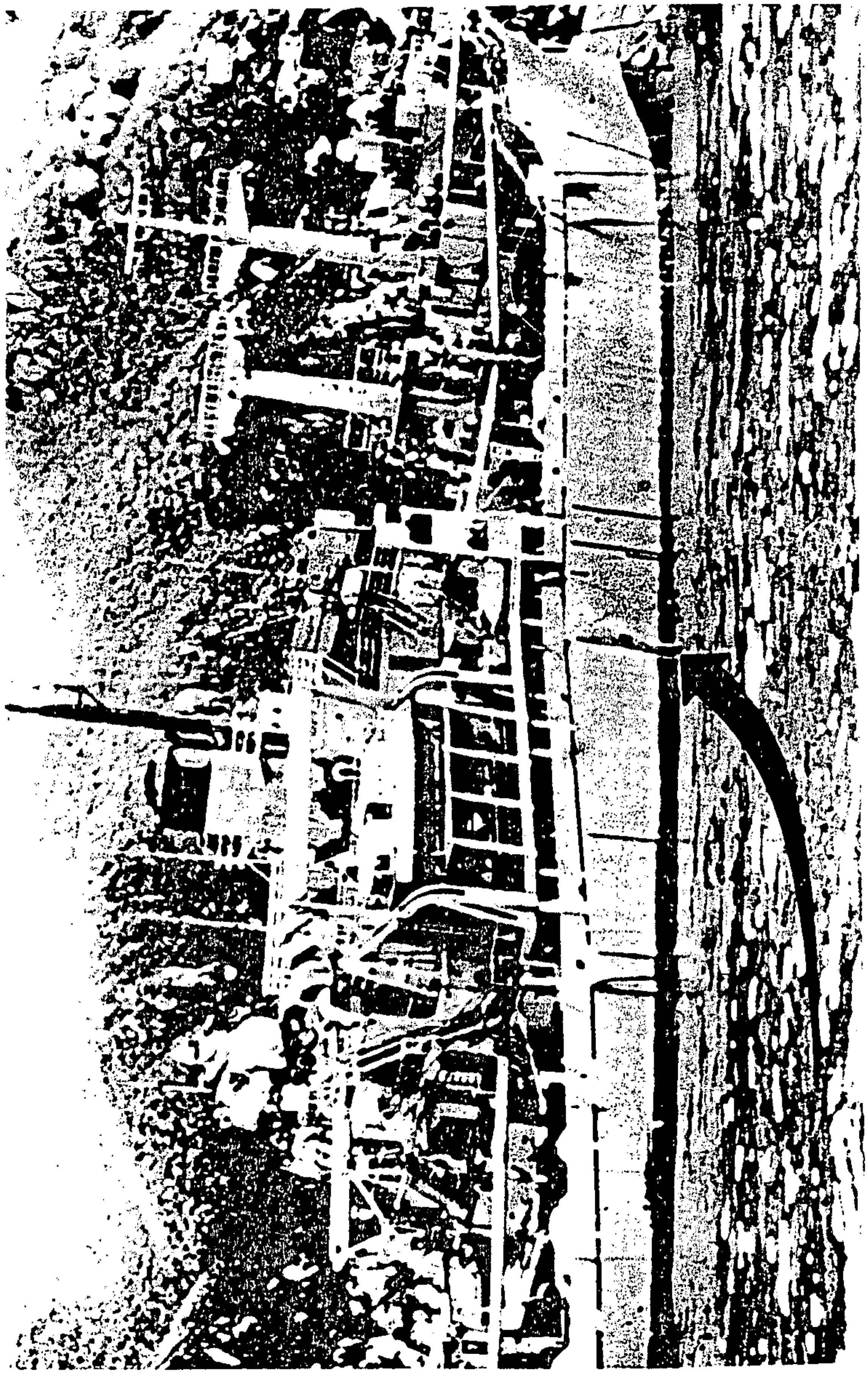


"USS REGULUS" (AF-57) HARD AGROUND PORT SIDE TO KAU YI CHAU ISLAND, HONG KONG HARBOR.
FIG. 15.9 NO. 1



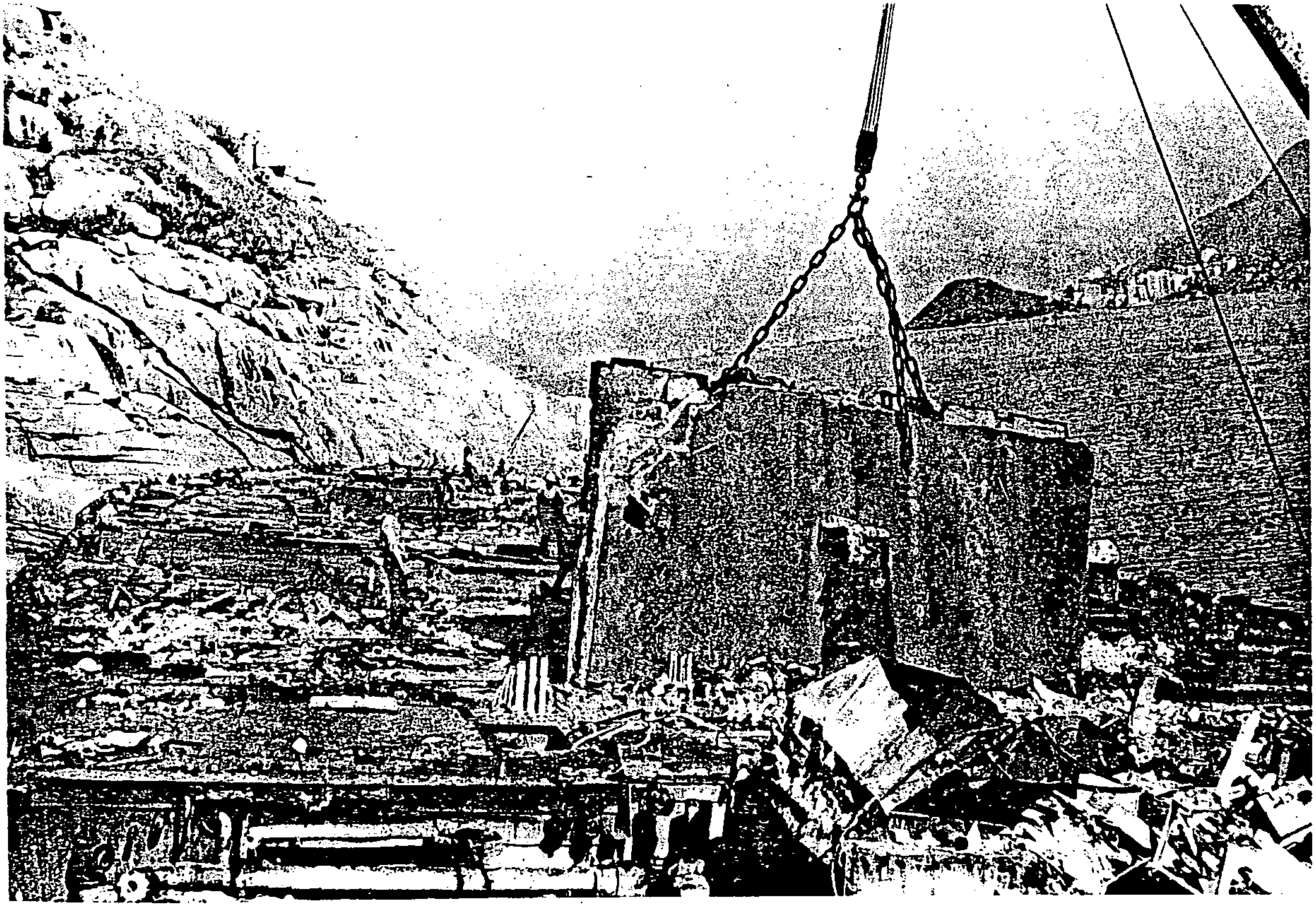
"USS REGULUS" UNDERWATER DAMAGE SURVEY RESULTS

FIG. 15.9 NO. 2



STARBOARD VIEW "USS REGULUS"(AF-57)HARD AGROUND. NOTE DISCONTINUITY OF THE HULL GIRDER.
FIG. 15.9 NO. 3

ROCK DAMAGE ON THE BILGE KEEL SECTION
OF THE SHIP.
FIG. 15.9 NO. 4



REEFER DECK SECTION BEING REMOVED.
FIG. 15.9 NO. 5

15.10. M/V ORIENTAL WARRIOR

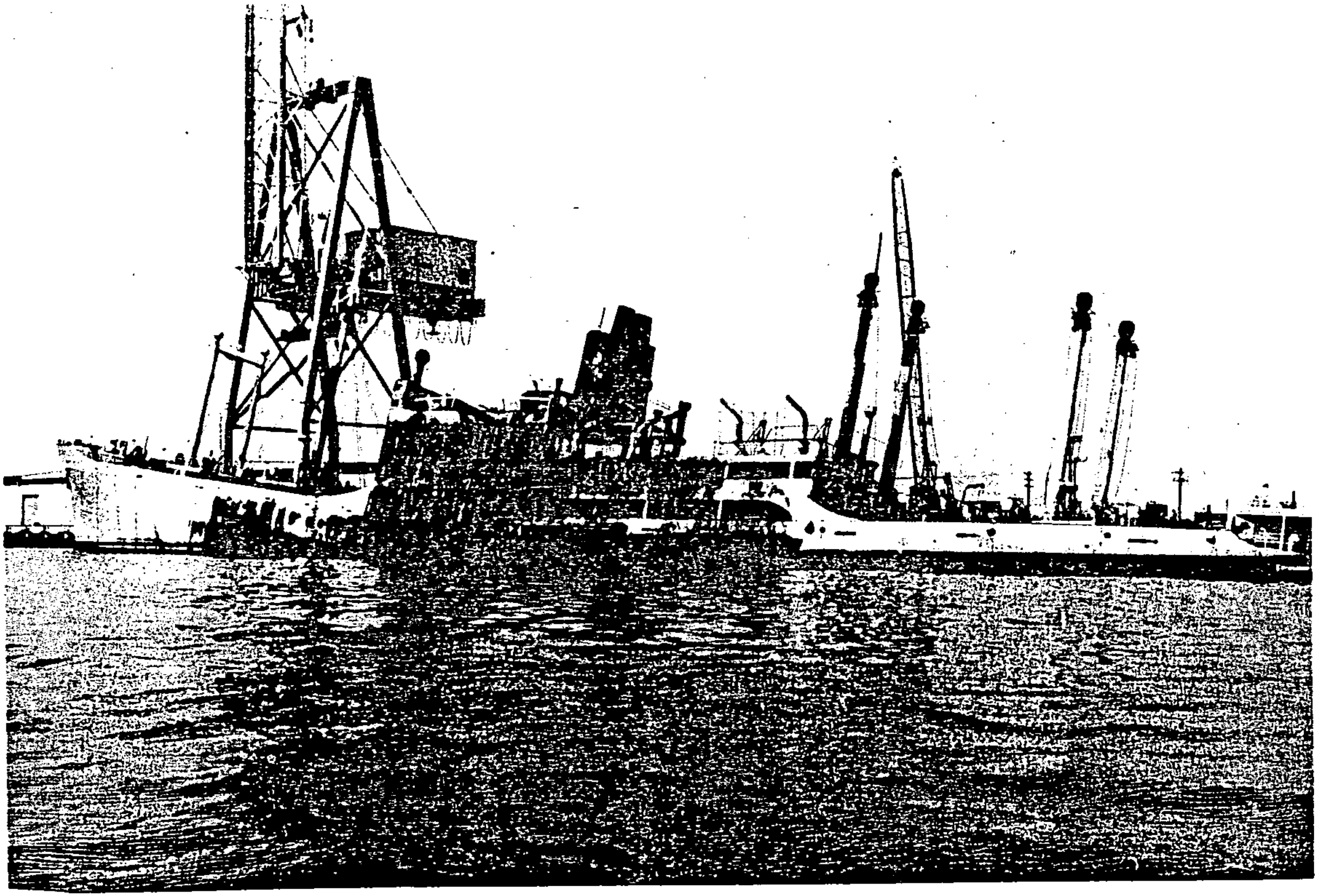
On 27 May,1972, the *M/V ORIENTAL WARRIOR*, a 9,008 gross ton passenger/cargo vessel caught fire at sea and became disabled. Rescue efforts came quickly and the stricken ship was soon alongside the Blount Island Container Facility in Jacksonville, Florida. As the fire still smoldered in the ship's engine-room and after holds, the Jacksonville Fire Department was called into action to extinguish the fire. This was accomplished, however, the large volume of water used in the firefighting operations resulted in flooding of the ship and its subsequent sinking in 35 feet of water.

Immediate concern centered around the threat of oil pollution from the damaged ship. The U.S. Coast Guard contacted the U.S. Navy Supervisor of Salvage in this regard and in a short time a full oil pollution abatement program was underway which included the complete removal of all oil and fuel reserves from inside the sunken ship, some 300,000 gallons in all.

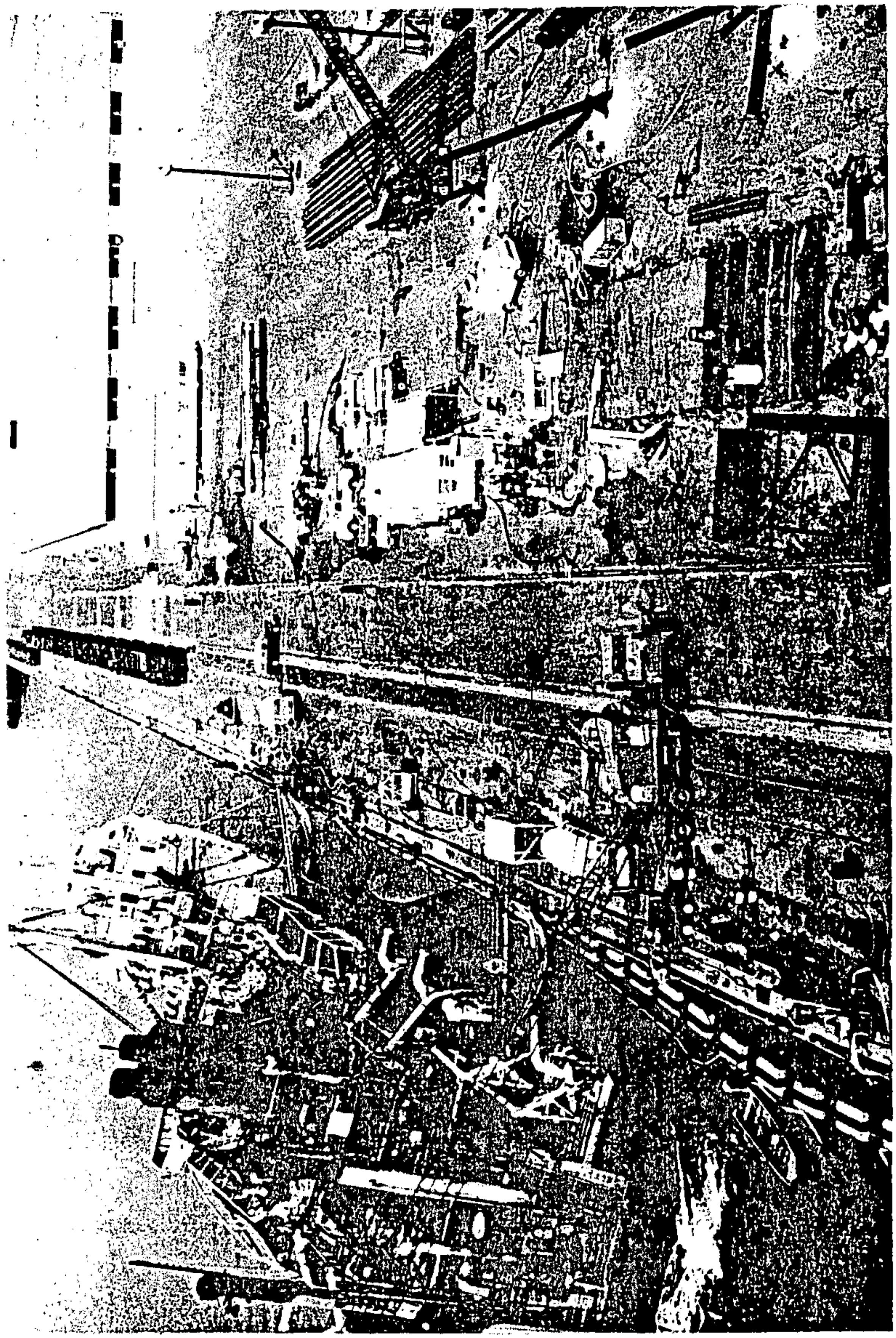
The second phase of operations was the salvage and removal of the *ORIENTAL WARRIOR*, a job which once again reverted to the U.S. Navy Supervisor of Salvage, by way of the U.S. Coast Guard and the U.S. Army Corps of Engineers. The salvage plan which finally evolved was based on information compiled from surveys, cargo manifests, ship's plans, and stability and structure considerations. The plan called for removal of weight, patching, shoring, parbuckling and pumping of the ship. Special care was exercised in the implementation of the salvage plan to ensure that the ship would not capsize or slide into the nearby St. John's River shipping channel - the only transit into the Port of Jacksonville.

Several unique salvage methods and applications were seen in this highly successful operation including the use of hydraulic pullers as well as standard beach gear, the use of almost 2,000 tons of lead ballast to provide additional stability, the extensive use of concrete to seal the *ORIENTAL WARRIOR*'s shaft alley, and the use of the oil industry's "hot tap" method of penetrating tank tops to pump out oil.

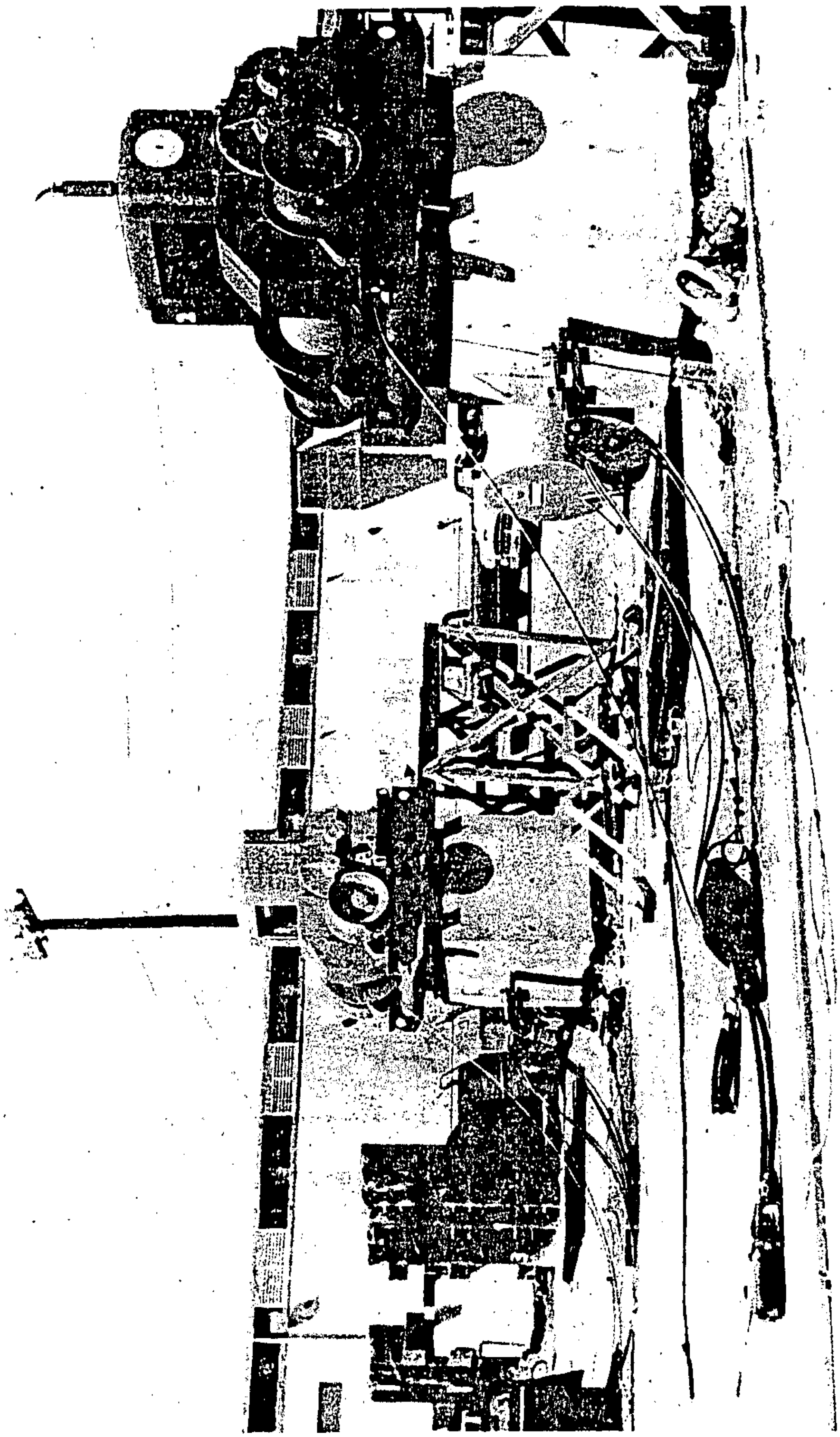
A complete record of the oil pollution abatement, salvage, diving and disposal operations on the *ORIENTAL WARRIOR* can be found in the *M.V. ORIENTAL WARRIOR* Salvage, Jacksonville, Florida, 1972, prepared by the Director of Ocean Engineering, Naval Ship Systems Command, Department of the Navy, Washington, D.C. 20360.



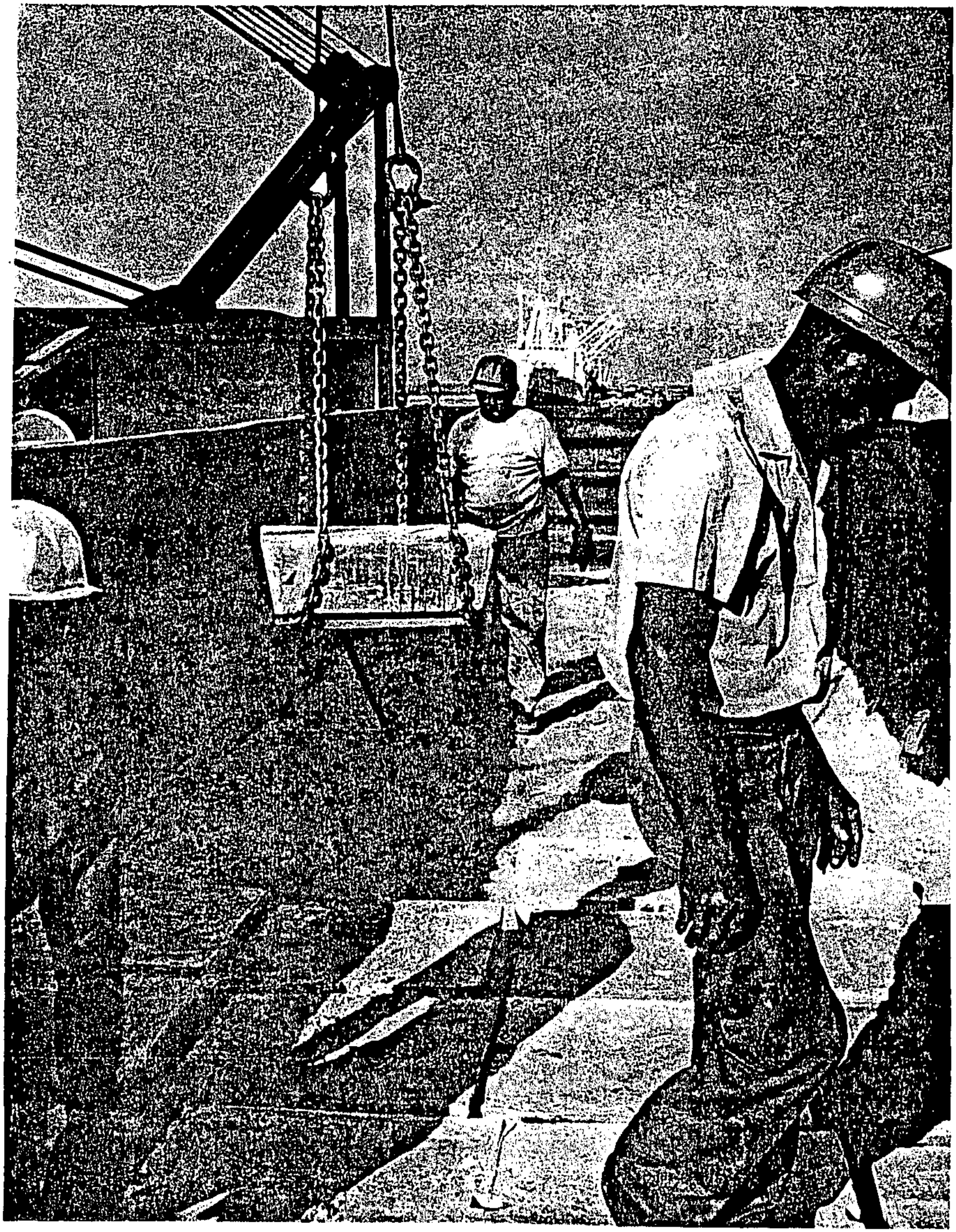
PORT RIVER VIEW OF THE "M/V ORIENTAL WARRIOR".
MIDSHIP DISCOLORATION FROM FIRE DAMAGE CAN BE SEEN
FIG. 15.10 NO. 1



"M/V ORIENTAL WARRIOR" SUNK ALONGSIDE THE DOCK.
NOTE DOCKSIDE PREPARATIONS.
FIG. 15.10 NO. 2



ANCHOR POINTS FOR PARBUCKLING STATIONS.
NOTE PURCHASE GEAR AND WINCHES IN POSITION
FIG. 15.10 NO. 3



LONGSHOREMEN LOADING ONE TON LEAD BALLAST PIGS FROM RAILROAD CAR.
FIG. 15.10 NO. 4

15.11. S.S. SIDNEY E. SMITH

On 5 June, 1972, the 500 foot, 4,200 ton freighter *SIDNEY E. SMITH* was involved in a collision with the *S/S. PARKER EVANS* at Port Huron, Michigan, in the narrow St. Clair channel connecting Lake Huron with St. Clair Lake. Within 30 minutes the *SIDNEY E. SMITH* had sunk closing the down-bound channel; the ship later broke in two with the bow completely submerged and the stern section sinking rapidly.

The U.S. Army Corps of Engineers immediately notified the U.S. Navy Supervisor of Salvage who promptly dispatched a four-man team of salvage experts to the scene. A survey disclosed that the operation was going to be extremely difficult as the current in the area of the wreck varied between 8 and 12 miles per hour at all times. This was not only a severe hinderance to diving operations, but also caused erosion of the river bottom beneath the two sections of the ship at the rate of about one foot per day.

The salvage plan devised envisioned the lightening of both sections so that they could be pulled to shore. It was estimated that the pulling force necessary to accomplish this would have to be about 700 tons to overcome the forces of the current and the ship's weight.

The stern section was tackled first, as it was only partially sunk. Divers working through specially constructed cofferdams installed on the stern section, patched and sealed the section in preparation for the admission of additional buoyancy in the form of polyurethane foam, a two-part chemical which when combined expands to 30 times its original volume as foam, displacing water with positive buoyancy. As soon as the stern section was prepared, operations moved on to the bow section so that both sections could be parbuckled and pulled out of the channel.

The bow section was far more difficult to prepare as it was completely submerged to a depth of about 26 feet. Again divers entered the wreck through specially constructed cofferdams, approximately 100 feet in length. Once inside the ship, divers sealed, patched, and foamed the compartments necessary for refloating.

Parbuckling and pulling operations were executed in August and September. Six 2-1/4 inch chains were placed around the keel of the submerged section by divers, and secured to 2 inch cables leading to shore where 700 tons of pulling force were supplied by 6 hydraulic pullers and 2 large winches. The two sections were to be parbuckled to an upright position and pulled ashore where they would be readied for towing and disposal.

After much preparation, and not without difficulty, the stern section of the *SMITH* was parbuckled into an upright position against a sandbar in the middle of the St. Clair River, and then pulled ashore in this position. Once secured at the shoreline the section was readied for towing by adding additional foam for buoyancy and stability, and removal of some additional weight, by pumping and scrapping.

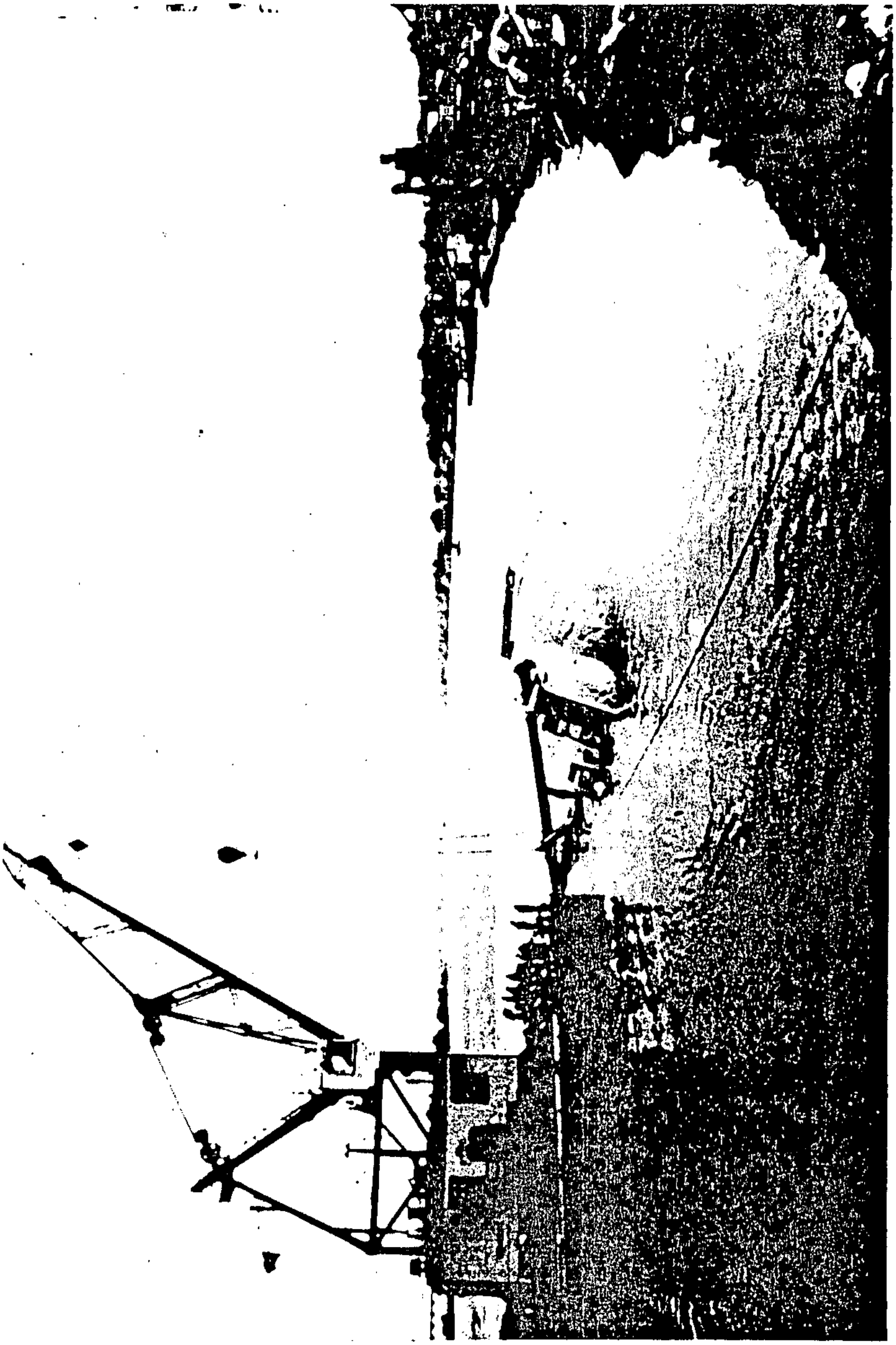
The bow section proved to be even more stubborn. Salvors had to pull the bow section out of the channel and then parbuckle it to an upright position against the shore. This piece was then also readied for towing in much the same manner as the stern section.

When both sections were in condition to tow, they were turned over to the cognizant authority, the U.S. Army Corps of Engineers for disposal. From early June to mid-October the operations continued on one of the most difficult salvage tasks faced by the Supervisor of Salvage for many years. A complete description of the operation can be found in the salvage report of the *S.S. SIDNEY E. SMITH* prepared by the Director of Ocean Engineering, Naval Ship Systems Command, Washington, D.C. 20360.

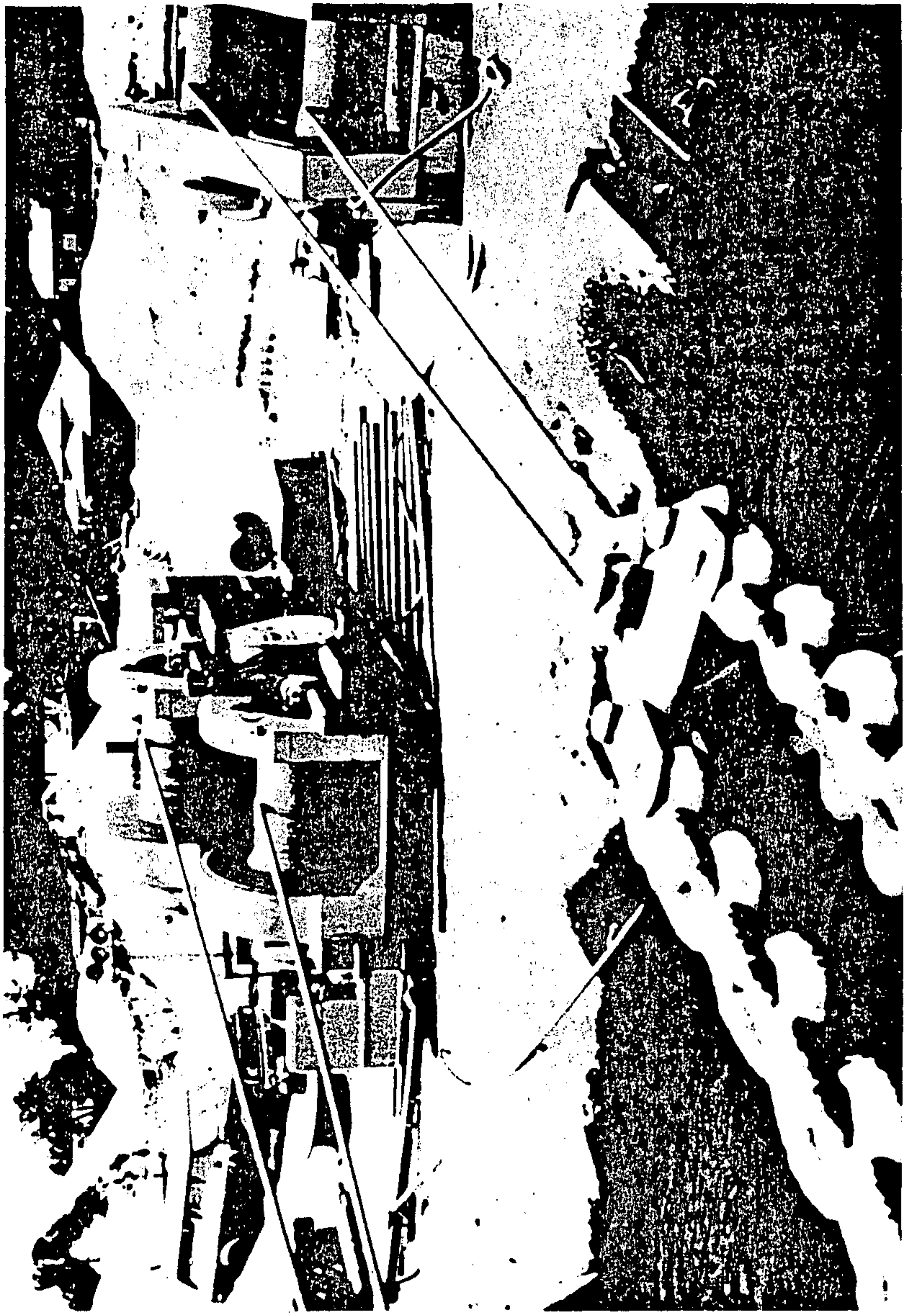
EARLY PHOTOGRAPH OF THE
SS "SIDNEY E. SMITH" CAPSIZED AND SUNK
IN THE ST. CLAIR CHANNEL.
FIG. 15.11 NO. 1

LOCATING MECHANISM POSITIONING DIVERS ACCESS COFFERDAM.
FIG. 15.11 NO. 2

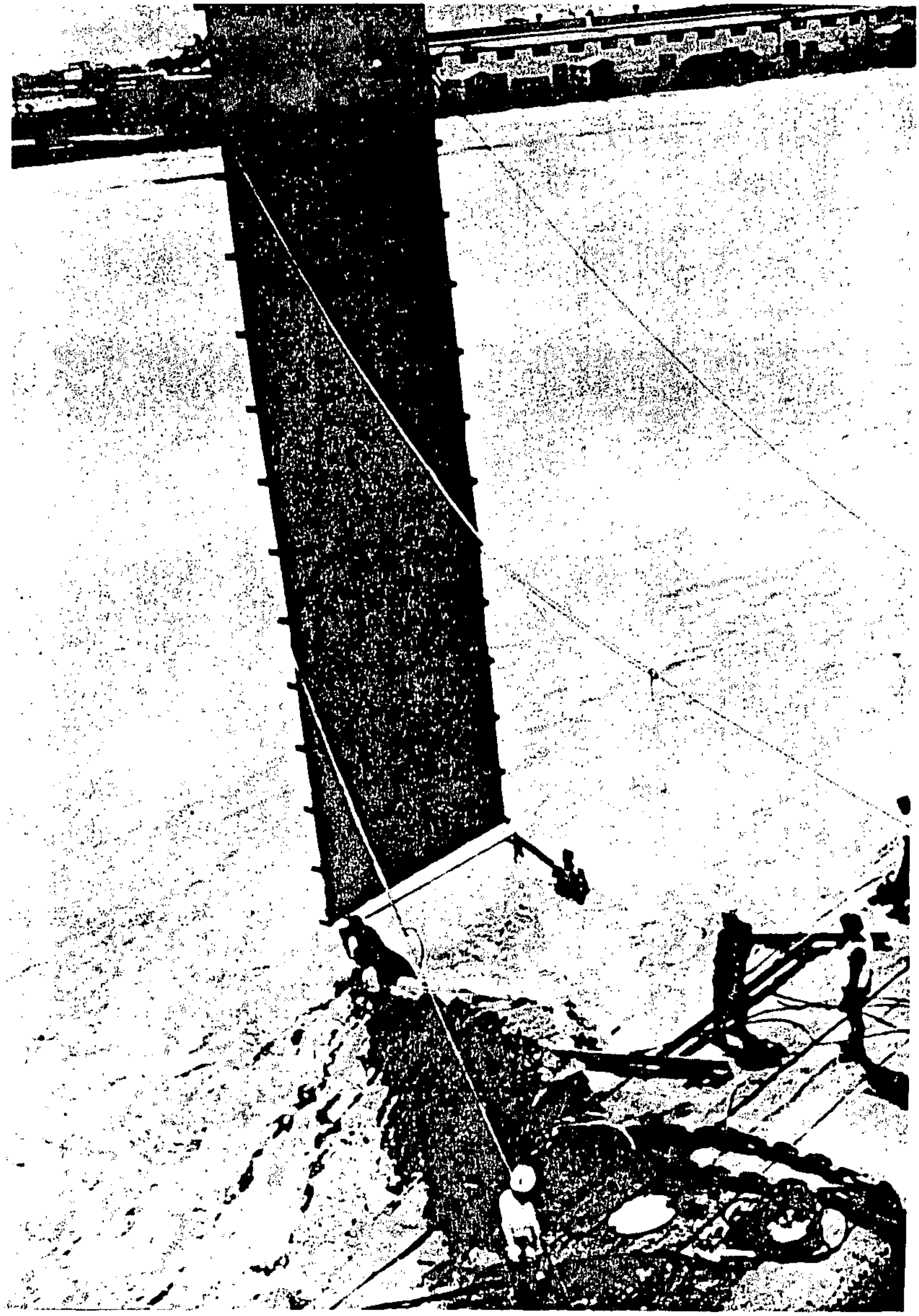
DIVER PREPARING TO ENTER DIVING ACCESS COFFERDAM.
FIG. 15.11 NO. 3



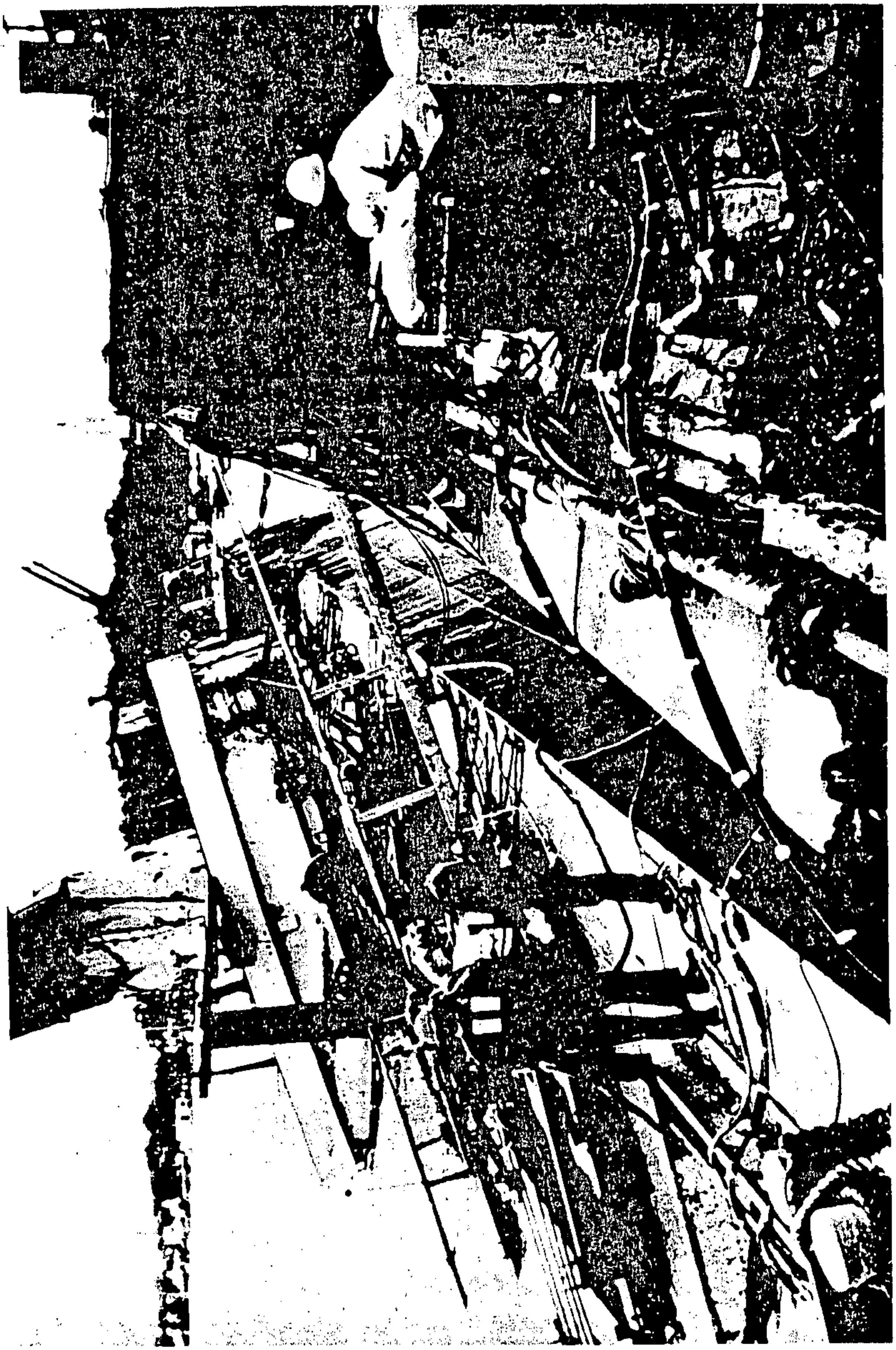
CRANE POSITIONING DECK PATCH.
FIG. 15.11 NO. 4



PARBUCKLING WINCHES STATIONED ASHORE.
FIG. 15.11 NO. 5



DECK PLATE PATCH BEING LOWERED INTO POSITION.
FIG 15.11 NO. 6



ROLLED STERN SECTION ALONGSIDE.
FIG. 15.11 NO. 7

REFERENCES

Of the numerous sources used, certain were made available through the assistance of many people and agencies, both foreign and domestic. The Naval Ship Systems Command would like to acknowledge the permission given by copyright owners to reproduce copyrighted material included in this volume, specifically to the Society of Naval Architects and Marine Engineers for the report by Sherman H. Serre and Frederick E. Krauss, "Salvage of the M/V Montrose"; and to the Foundation Company of Canada, Ltd., and particularly to W.A. Munro of that organization for the use of information on the clearance of the Federal Express. Her Britannic Majesty's Government graciously permitted reproduction of the report on the refloating of the *MAILLE BREZE* and the accompanying figures and photographs; Commodore Edward Clason, Stockholm, contributed material for the story of the *VASA*, Chapter Five. Appreciation is extended to Commodore W.A. Sullivan, USN, (Ret.) for his excellent lecture notes on the World War II harbor clearance carried out under his command. Appreciation is also extended to Captain W.F. Searle, Jr., USN (Ret.) who assisted in the preparation of this volume. A special acknowledgement is due to Lt. General Raymond A. Wheeler, USA, (Ret.) who took time from a crowded schedule to make his collection of photographs of the Suez Canal clearance available for use in this book, and to the Society of American Military Engineers for the use of those Suez clearance photographs that appeared in the MILITARY ENGINEER.

The references which follow are a collection of those references used in the preparation of this volume and those selected to be a guide for further reference in any given area of the book. The references cited are but a few of the many works which cover harbor clearance operations, and are intended as an aid for the reader interested in pursuing this subject further, and therefore are listed by subject, alphabetically, as a matter of convenience.

REFERENCES

AFDM-2

——————, *Technical Report on Salvaging of AFDM-2,* NAVSHIPS 0994-001-4010, Department of the Navy, Washington, D.C.

SS ARROW

Naval Ship Systems Command, *ARROW,* NAVSHIPS 0994-008-1010, Department of the Navy, Washington, D.C.

APRA HARBOR

Bureau of Ships, *Harbor Clearance Operations in Guam Following Typhoons Karen and Olive,* NAVSHIPS 250-638-5, Department of the Navy, Washington, D.C.

EMPRESS OF CANADA

------, "Salving of the *EMPRESS OF CANADA*", *Engineering,* January 25, 1957, (98-101).

Colbeck, W.R., "Salvaging of the *EMPRESS OF CANADA*, Part I", *The Engineer,* January 25, 1957, (128-131).

Colbeck, W.R., "Salvaging of the *EMPRESS OF CANADA*, Part II", *The Engineer,* February 1, 1957, (162-165).

Hart, H.V., "Salving of the *EMPRESS OF CANADA*", *Dock and Harbor Authority,* March 1954, (341-343).

Colbeck, W.R., "Salvaging of Ships with Special Reference to the *EMPRESS OF CANADA*", Institute of Mechanical Engineers publication.

M/V FEDERAL EXPRESS

------, "Salvage Operations in Montreal Harbor", *Dock and Harbor Authority,* January 1962, (303-305).

------, "Montreal Harbor Salvage", *Canadian Shipping and Marine Engineering News,* August 1960, (56).

International Underwater Contractors, "Wreck Busters", Tech-Bulletin #5.

International Underwater Contractors, "Wreck Busters", Film.

HARBOR CLEARANCE UNIT-ONE

------, *Harbor Clearance Unit-One Salvors,* Department of the Navy.

Naval Ship Research and Development Center, *Salvage of the Dredge JAMAICA BAY, January to March 1967,* NSRDC-2956, January 1968, Washington, D.C.

------, "Operations of Harbor Clearance Unit-One", *Faceplate,* Winter 1970, (15).

USS LAFAYETTE

------, "Salvage of the *USS LAFAYETTE*", *Engineer,* August 14, 1942, (126-128); November 19, 1943, (398-400); November 26, 1943, (418-420); December 3, 1943, (440-441).

------, "The Salvage of the *USS LAFAYETTE*", *Engineering,* November 5, 1943, (381).

------, "The Salvage of the *USS LAFAYETTE*", *Journal of the American Proceedings of Naval Engineers,* November 1943, (648-697).

Austin, H.O., "Salvaging of the *USS LAFAYETTE*", *U.S. Naval Institute Proceedings,* August 1951, (810-817).

Hunt, H.W., "Refloating the *SS NORMANDIE*", *Engineering News Record,* August 12, 1943, (264-268).

Bureau of Ships, *Salvage of the USS LAFAYETTE (ex-SS NORMANDIE),* NAVSHIPS 250-880-21, Department of the Navy, Washington, D.C.

LUMBERJACK

Murphy-Pacific Corporation, *A Report on the Removal and Disposal of the Derelict Barge LUMBERJACK by the Cast-in-Place Urethane Process,* 10 March 1964.

MAILLE BREZE

Royal Navy, *Operational Report on Raising the French Destroyer MAILLE BREZE,* OPNAV (OP-922F2), Technical Intelligence Unit.

M/V MONTROSE

Serre & Krauss, "Salvage of the *M/V MONTROSE*", *Society of Naval Architects and Marine Engineers, Transactions,* Great Lakes and Great Rivers Section, October 24, 1963.

M/V ORIENTAL WARRIOR

———, *M/V ORIENTAL WARRIOR* SALVAGE, Department of the Navy, Washington, D.C.

———, "Salvage Operations Show New Skills . . . *ORIENTAL WARRIOR*", *Faceplate,* Winter 1972, (24-25).

PEARL HARBOR

———, "Salvage at PEARL HARBOR, Part II", *The Engineer,* October 29, 1943, (338-339).

———, "Salvage at PEARL HARBOR, Part III", *The Engineer,* November 5, 1943, (358-359).

Alden, J.D., "Up From the Ashes—The Saga of the *CASSIN* and *DOWNES*", *U.S. Naval Institute Proceedings,* January 1961, (32-41).

Wallin, Homer N., "Rejuvenation at PEARL HARBOR", *U.S. Naval Institute Proceedings,* December 1946, (1520-1547).

Whitaker, F.H., "The Salvage of the *USS OKLAHOMA* at Pearl Harbor", *Society of Naval Architects and Marine Engineers, Transaction,* 1944, (133-209).

Wallin, Homer N., *Pearl Harbor: Why, How, Fleet Salvage and Final Appraisal,* Naval History Division, United States Government Printing Office, Washington, D.C., 1968.

USS REGULUS

———, *USS REGULUS (AF-57)* SALVAGE AND DISPOSAL OPERATIONS, Department of the Navy, Washington, D.C.

SCAPA FLOW

Bowman, Gerald, *The Man Who Bought a Navy,* London, 1964.

SS SIDNEY E. SMITH

———, "Salvage Operations Show New Skills . . . *SIDNEY E. SMITH*", *Faceplate,* Winter 1972, (22-23).

SUEZ CANAL

———, "Clearing the SUEZ CANAL; Urgent Salvage by the Anglo-French Forces", *Engineering,* November 23, 1956. (642-644).

———, "Salvage Work (on the Clearance of the SUEZ CANAL)", *Engineering,* November 30, 1956, (680).

Wheeler, Raymond A., "Clearing the SUEZ CANAL", *The Military Engineer,* January-February 1958, (1-8).

VASA

———, "Good Ship *WASA;* Swedish Man-of-War", *Compressed Air Magazine,* June 1961, (26-27).

———, "Salvage of the *WASA*", *The Engineer,* May 5, 1961, (758-759).

Franzen, A., "The Ghost From the Depths: The Warship *VASA*", *National Geographic Magazine,* January 1962, (42-57).

Franzen, A., *The Warship VASA: Deep Diving and Marine Archeology in Stockholm,* 1961.

Ohrelius, Bengt, *VASA, The King's Ship,* New York, 1963.

Widding, L., *The VASA Venture,* 1960.

Wright, H. & Rapport, S., ed., "The Warship *VASA* Returns From the Sea", In: *Great Undersea Adventures,* New York, 1966, (207-226).

Clason, Edward, *Section II, Subject IV,* XXth International Navigation Conference, Stockholm.

WORLD WAR II HARBOR CLEARANCE OPERATIONS

Sullivan, W.A., Commodore, USN, "Harbor Clearance", lecture given for Society of Military Engineers, Cincinnati, Ohio, 1946.

Sullivan, W.A., Commodore, USN, "Harbor Clearance Problems During the War", lecture given to Combined Engineering Societies of New England, 28 April 1947.

Sullivan, W.A., Commodore, USN, Ship Salvage and Harbor Clearance", lecture given at U.S. Naval War College, Newport, Rhode Island, 4 December 1947.

ADDITIONAL REFERENCES

———, "Marine Salvage. Operation of a Port Authority", *Dock and Harbor Authority,* October 1948, (139-143).

———, "*MS CABOT* Salvaged in Montreal Harbor", *Canadian Shipping and Marine Engineering News,* March 1967, (88).

———, "Salvage of a Dutch Dredger", *Dock and Harbor Authority,* September 1963, (161-162).

———, "Salvage at Immingham Dock: Ship Refloated After Recent Flood", *Dock and Harbor Authority,* April 1953, (381).

———, "Salvage Operations in Portugal", *Canadian Shipping and Marine Engineering News,* August 1943, (49).

———, "St. Lawrence Salvage Saga", *Canadian Shipping and Marine Engineering News,* July 1949, (16).

Cleary, E.J., "Chlorine-Barge Salvage Achieves Status of 'National Emergency' ", *Public Works,* January 1963, (60-62).

Colbeck, W.R., "Salvaging of Ships in Ports", *Port and Harbor Authority,* March 1957, (389-392).

de sa Nogueira, "The Salvage of the Dredger *ALCANTARA*. A Portuguese Harbor Problem and Its Solution", *Port and Harbor Authority,* March 1943, (258-262).

Halmos, E.E., "Disaster Underwater", *Undersea Technology,* January 1963, (36-37).

Head, B.C., "The Salvage of the *M. V. WANGANELLA*", *New Zealand Engineer,* January 19, 1948, (68-69).

Hutchinson, P.S. & Mead, C.F., "Salvage of the Dredge *HAPAI*", *Dock and Harbor Authority,* July 1959, (85-90).

Shelford, W.O., "The Work of a Diver in Harbor Waters", *Dock and Harbor Authority,* December 1960, (272-274).

van Dixhoorn, J. & Slagboom, A., "Eliminating an Obstruction in the New Waterway: Burial of Wreck Sunk in Fairway", *Dock and Harbor Authority,* May 1964, (15-18).

Ware, W.F., "Salvage of the Dredger at Port Talbot", *The Engineer,* June 25, 1948, (610-613).

Wright, J.M.P., "Harbor Clearance: Casablanca to Naples", *Journal American Society of Naval Engineers,* May 1957, (319-329).

Bureau of Ships, *Refloating of the USS MISSOURI, (BB-63),* NAVSHIPS 250-694-3, Department of the Navy, Washington, D.C.

Carter, W.R., *Beans, Bullets, and Black Oil,* 1954.

Carter, W.R., *Ships, Salvage, and Sinews of War,* 1954.

Wheeler, G.J., *Ship Salvage,* 1958.

ALPHABETICAL INDEX

	Section
AFDM-2, salvage of	15.5.
Apra Harbor, clearance of	15.3.
Archeological salvage	5.
ARIZONA, salvage of	12.11.
ARROW, salvage of	15.8.
Bizerte Channel, clearance of	11.6.
CALIFORNIA, salvage of	12.7.
CARD, salvage of	9.
CARD, damage control	9.7.
CARD, description of	9.2.
CARD, pumping	9.9.
CARD, pumping	9.10.
CARD, stability calculations	9.6.
CARD, temporary repairs	9.11.
CARD, towing	9.12.
CARD, towing	9.13.
Casablanca, clearance of	11.4.
CASSIN, salvage of	12.10.
Cherbourg, clearance of	11.10.
Diving operations	6.7.
Diving operations	12.13.
DOWNES, salvage of	12.10.
EMPRESS OF CANADA, salvage of	3.
EMPRESS OF CANADA, anchorage blocks, use of	3.6.
EMPRESS OF CANADA, buoyancy pontoons, use of	3.10.
EMPRESS OF CANADA, calcualtions for	3.14.
EMPRESS OF CANADA, compressed air, use of	3.13.
EMPRESS OF CANADA, counterweights, use of	3.11.
EMPRESS OF CANADA, description of	3.2.
EMPRESS OF CANADA, internal buoyancy	3.12.
EMPRESS OF CANADA, purchases and hauling wire	3.8.
EMPRESS OF CANADA, righting moment, sources of	3.5.
EMPRESS OF CANADA, tripods, use of	3.9.
EMPRESS OF CANADA, winches and steam supply	3.7.
Equipment used on *TODARO*	1.10.
Equipment used on *MONTROSE*	2.8.
Equipment used on *RAJAH SOLIMAN*	8.6.

Equipment used at Scapa Flow .... 10.3.
Equipment used at Suez Canal .... 13.7.

FEDERAL EXPRESS, salvage of .... 6.
FEDERAL EXPRESS, deflector wall, use of .... 6.6.
FEDERAL EXPRESS, deflector wall, dismantling of .... 6.10.
FEDERAL EXPRESS, description of .... 6.2.
FEDERAL EXPRESS, air curtain, use of 6.8
Ferryville, clearance of .... 11.7.

GUITARRO, salvage of .... 15.7.

Harbor Clearance Unit-One .... 14.
Harbor Clearance Unit-One, history of .... 14.3.
Harbor Clearance Unit-One, mission of .... 14.2.
Harbor Clearance Unit-One, organization of .... 14.4.
Harbor Clearance Unit-One, salvage craft .... 14.5.
Harbor Clearance Unit-One, today .... 14.9.
Harbor Clearance Unit-One, *JAMAICA BAY* .... 14.6.
Harbor Clearance Unit-One, *NEW JERSEY* .... 14.8.
Harbor Clearance Unit-One, *SANDPUMPER* .... 14.7.
HINDENBURG, salvage of .... 10.7.

JAMAICA BAY, salvage of .... 14.6.

LAFAYETTE, salvage of .... 15.2.
Lifts, on *FEDERAL EXPRESS* .... 6.9.
Lifts, on *MAILLE BREZE* .... 2.10.
Lifts, on *MAILLE BREZE* .... 2.11.
Lifts, on *MAILLE BREZE* .... 2.12.
Lifts, on *MAILLE BREZE* .... 2.13.
Lifts, on *RAJAH SOLIMAN* .... 8.13.
Lifts, on *RAJAH SOLIMAN* .... 8.14.
Lifts, on *RAJAH SOLIMAN* .... 8.15.
Lifts, on *RAJAH SOLIMAN* .... 8.17.
Lifts, on *RAJAH SOLIMAN* .... 8.19.
Lifts, on *VASA* .... 5.9.
LUMBERJACK, salvage of .... 15.4.

MAILLE BREZE, salvage of .... 2.
MAILLE BREZE, description of .... 2.2.
MAILLE BREZE, equipment used .... 2.8.
MAILLE BREZE, lifts .... 2.10.
MAILLE BREZE, lifts .... 2.11.
MAILLE BREZE, lifts .... 2.12.

MAILLE BREZE, lifts . . . . . 2.13.
MAILLE BREZE, major problems . . . . . 2.7.
MAILLE BREZE, method of salvage . . . . . 2.5.
MAILLE BREZE, parbuckling . . . . . 2.9.
MAILLE BREZE, refloating . . . . . 2.14.
MAILLE BREZE, salvage plan . . . . . 2.6.
Manila Bay, clearance of . . . . . 11.11.
MISSION SAN FRANCISCO, salvage of . . . . . 4.
MISSION SAN FRANCISCO, channel clearance . . . . . 4.7.
MISSION SAN FRANCISCO, clearance methods . . . . . 4.5.
MISSION SAN FRANCISCO, demolition methods . . . . . 4.10.
MISSION SAN FRANCISCO, description of . . . . . 4.2.
MISSION SAN FRANCISCO, stern section salvage . . . . . 4.6.
MOLTKE, salvage of . . . . . 10.6.
MONTROSE, salvage of . . . . . 7.
MONTROSE, description of . . . . . 7.2.
MONTROSE, dragging operation . . . . . 7.10.
MONTROSE, final work . . . . . 7.11.
MONTROSE, preliminary righting . . . . . 7.8.
MONTROSE, preliminary work . . . . . 7.7.
MONTROSE, pumping . . . . . 7.9.

Naples, clearance of . . . . . 11.9.
Net Tenders, use of in salvage . . . . . 15.1.
NEVADA, salvage of . . . . . 12.6.
NEW JERSEY, salvage of . . . . . 14.8.

OCEAN EAGLE, salvage of . . . . . 15.6.
OGLALA, salvage of . . . . . 12.9.
Oil pollution control . . . . . 2.
Oil pollution control . . . . . 15.6.
Oil pollution control . . . . . 15.8.
Oil pollution control . . . . . 15.10.
OKLAHOMA, salvage of . . . . . 12.12.
ORIENTAL WARRIOR, salvage of . . . . . 15.10.

Palermo, clearance of . . . . . 11.8.
Parbuckling, on *MAILLE BREZE* . . . . . 2.9.
Parbuckling, on *RAJAH SOLIMAN* . . . . . 8.8.
Parbuckling, on *RAJAH SOLIMAN* . . . . . 8.9.
Parbuckling, on *RAJAH SOLIMAN* . . . . . 8.10.
Parbuckling, on *RAJAH SOLIMAN* . . . . . 8.11.
Parbuckling, on *RAJAH SOLIMAN* . . . . . 8.12.
Pearl Harbor, clearance of . . . . . 12.
Pearl Harbor, *ARIZONA* and *UTAH* . . . . . 12.11.
Pearl Harbor, *CALIFORNIA* . . . . . 12.7.

Pearl Harbor, *CASSIN* and *DOWNES* .... 12.10.
Pearl Harbor, diving operations .... 12.13.
Pearl Harbor, Navy Yard .... 12.14.
Pearl Harbor, *NEVADA* .... 12.6.
Pearl Harbor, *OGLALA* .... 12.9.
Pearl Harbor, *OKLAHOMA* .... 12.12.
Pearl Harbor, salvage schedule .... 12.5.
Pearl Harbor, *WEST VIRGINIA* .... 12.8.
Port Lyautey, clearance of .... 11.5.
Pumping, on *CARD* .... 9.9.
Pumping, on *CARD* .... 9.10.
Pumping, on *MONTROSE* .... 7.9.
Pumping, on *RAJAH SOLIMAN* .... 8.8.
Pumping, on *RAJAH SALIMAN* .... 8.16.
Pumping, on *RAJAH SALIMAN* .... 8.19.
Pumping, on *TODARO* .... 1.7.
Pumping, on *VASA* .... 5.10.

RAJAH SOLIMAN, salvage of .... 8.
RAJAH SOLIMAN, description of .... 8.2.
RAJAH SOLIMAN, equipment used .... 8.6.
RAJAH SOLIMAN, lifts .... 8.13.
RAJAH SOLIMAN, lifts .... 8.14.
RAJAH SOLIMAN, lifts .... 8.15.
RAJAH SOLIMAN, lifts .... 8.17.
RAJAH SOLIMAN, lifts .... 8.19.
RAJAH SOLIMAN, method of salvage .... 8.5.
RAJAH SOLIMAN, parbuckling .... 8.8.
RAJAH SOLIMAN, parbuckling .... 8.9.
RAJAH SOLIMAN, parbuckling .... 8.10.
RAJAH SOLIMAN, parbuckling .... 8.11.
RAJAH SOLIMAN, parbuckling .... 8.12.
RAJAH SOLIMAN, pumping .... 8.16.
RAJAH SOLIMAN, pumping .... 8.18.
RAJAH SOLIMAN, pumping .... 8.19.
REGULUS, salvage of .... 15.9.

Salvage method, on *EMPRESS OF CANADA* .... 3.4.
Salvage method, on *FEDERAL EXPRESS* .... 6.5.
Salvage method, on *MAILLE BREZE* .... 2.5.
Salvage method, on *RAJAH SOLIMAN* .... 8.5.
Salvage method , on *VASA* .... 5.7.
Salvage method, in World War II clearance .... 11.3.
Salvage plan, used on *MAILLE BREZE* .... 2.6.
Salvage plan, used on *MONTROSE* .... 7.5.

Salvage plan, used on *TODARO* .... 1.5.
SANDPUMPER, salvage of .... 14.7.
Scapa Flow, clearance of .... 10.
Scapa Flow, background .... 10.2.
Scapa Flow, *HINDENBURG* .... 10.7.
Scapa Flow, *MOLTKE* .... 10.6.
SIDNEY E. SMITH, salvage of .... 15.11.
Suez Canal, clearance of .... 13.
Suez Canal, contract .... 13.6.
Suez Canal, equipment used .... 13.7.
Suez Canal, Port Said, clearance of .... 13.3.
Suez Canal, UNSCO operations .... 13.8.

TODARO, salvage of .... 1.
TODARO, description of .... 1.2.
TODARO, equipment used .... 1.10.
TODARO, horizontal pivoting .... 1.6.
TODARO, pumping program .... 1.7.
TODARO, refloating .... 1.9.
TODARO, righting the wreck .... 1.8.
TODARO, salvage plan .... 1.5.

UTAH, salvage of .... 12.11.

VASA, salvage of .... 5.
VASA, description of .... 5.2.
VASA, drydocking .... 5.11.
VASA, lifting .... 5.9.
VASA, preliminary investigations .... 5.6.
VASA, pumping phase .... 5.10.
VASA, salvage methods .... 5.7.
VASA, tunneling efforts .... 5.8.

WEST VIRGINIA, salvage of .... 12.8.
World War II Harbor Clearance .... 11.
World War II Clearance, basic methods .... 11.3.
World War II Clearance, Bizerte Channel .... 11.6.
World War II Clearance, Casablanca .... 11.4.
World War II Clearance, Cherbourg .... 11.10.
World War II Clearance, Ferryville .... 11.7.
World War II Clearance, Historical background .... 11.2.
World War II Clearance, Manila .... 11.11.
World War II Clearance, Naples .... 11.9.
World War II Clearance, Palermo .... 11.8.
World War II Clearance, Port Lyautey .... 11.5.

☆U.S. GOVERNMENT PRINTING OFFICE: 1990 - 779-013/20461

Ref: NAVSEAINST 4160.3A NAVSEA S0005-AA-GYD-030/TMMP

NAVSEA/SPAWAR TECHNICAL MANUAL DEFICIENCY/EVALUATION REPORT (TMDER)

INSTRUCTIONS: Continue on 8 ½" x 11" page if additional space is needed.
1. Use this report to indicate deficiencies, problems and recommendations relating to publications.
2. For CLASSIFIED TMDERs see OPNAVINST 5510H for mailing requirements.
3. For TMDERs that affect more than one publication, submit a separate TMDER for each.
4. Submit TMDERs at web site https://nsdsa2.phdnswc.navy.mil or mail to: **COMMANDER, CODE 310 TMDER BLDG 1389, NAVSURFWARCENDIV NSDSA, 4363 MISSILE WAY, PORT HUENEME CA 93043-4307**

1. PUBLICATION NUMBER	2. VOL/PART	3. REV/DATE OR CHG/DATE	4. SYSTEM/EQUIPMENT ID

5. TITLE OF PUBLICATION	6. REPORT CONTROL NUMBER (6 digit UIC-YY-any four: xxxxxx-03-xxxx)

7. RECOMMEND CHANGES TO PUBLICATION

7a. Page #	7b. Para #	7c. RECOMMENDED CHANGES AND REASONS

8. ORIGINATOR'S NAME AND WORK CENTER	9. DATE	10. ORIGINATOR'S E-MAIL ADDRESS	11. TMMA of Manual (NSDSA will complete)

12. SHIP OR ACTIVITY Name and Address (Include UIC/CAGE/HULL)	13. Phone Numbers:
	Commercial (___) ___-____
	DSN ___-____
	FAX (___) ___-____