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MAN OVERBOARD SYSTEM FEASIBILITY STUDY

Robert B. Dayton, et al

Operations Research, Incorporated

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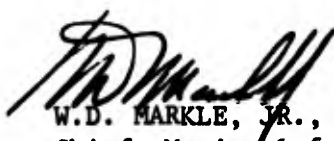
The work reported herein was accomplished for the U.S. Coast Guard's Office of Research and Development, Marine Safety Technology Division, as part of the Great Lakes Winter Season Extension Program.

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policy of the Coast Guard. This report does not constitute a standard, specification, or regulation.

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16. Abstract <p>This report analyzes fall-overboard accidents that occurred on the Great Lakes between 1968 and 1972. None of the victims that fell overboard while the vessel was underway were recovered alive. In many cases it was not known that the victim was missing until many hours later. It is evident that an alarm system of some type is required. The objectives of this report are to investigate various sensor techniques that could be used as a man-overboard alarm, prepare technical descriptions of candidate systems and select the most feasible systems for comparative evaluation. Results indicate that three techniques have possible application. The first is a man-carried transponder; the second is a miniature man-carried RF transmitter; and the third and most promising system is a man-carried sonar pinger.</p>				14. Sponsoring Agency Code	
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## PREFACE

This final report documents work conducted under Task Order 16, Contract No. DOT-CG-31446-A from July 1974 through December 1974. The work was performed by Operations Research, Inc. (ORI) under the direction of Cdr. R. L. Cook, project officer. ORI is grateful to Cdr. J. Deck III, Lcdr. Robert Mason and Ens. J. Vavrek of the Coast Guard 9th District Merchant Marine Technical Branch for their assistance in defining the ship systems and characteristics that are typical of the Great Lakes ore carrier. ORI also wishes to express its gratitude to Mr. Richard A. Feldtz, Hull Superintendent, Oglebay Norton Company for arranging an inspection tour of two ore carriers. ORI's project leader was Mr. R. B. Dayton who was assisted by Mr. J. H. Brown and Dr. M. C. Kim.

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## 1.0 INTRODUCTION

### 1.1 GENERAL BACKGROUND

Coast Guard marine accident statistics show that a significant number of persons are lost overboard from ships each year. Those that fall overboard while the ship is underway are rarely recovered alive. Lack of timely detection of an event is a major cause of failure to recover. Those persons that fall overboard while the ship is at anchor or at a dock have a better chance for survival due to the potential for earlier detection.

Rapid or instantaneous detection of an accident is of paramount importance because the victims are most often ill-equipped for lengthy survival in the water. There are no federal requirements for wearing survival equipment while working on deck or other exposed areas around the ship, and accident statistics indicate that none of the victims were wearing Personal Flotation Devices (PFDs).

This situation indicates that a positive alerting system is required to inform the watch and/or fellow crew members that a fall overboard accident has taken place so immediate action can be taken. A man overboard alarm device coupled with a definitive rescue procedure should be effective in saving the lives of many seamen each year.

Additionally, any such system can only achieve its maximum effectiveness in preventing loss of life if used in conjunction with personal flotation equipment to prevent drowning and some form of thermal protection for cold water situations.

## 1.2 SCOPE

The objective of this study is to provide the Coast Guard with the elements of a Man Overboard System (MOS), prepare technical descriptions of candidate detection systems, and select the most feasible systems for comparative evaluation.

Accident statistics have been reviewed to determine how the details of fall overboard accidents might influence the design and operation of a MOS. Accident locations on the ship and in the vicinity of the ship were reviewed to determine constraints imposed by local area details. A Great Lakes ore carrier has been selected as the type of ship to be used when analyzing ship details such as railings, bulwarks, deck dimensions, depth, draft, etc. These parameters will have some influence on a MOS installation and may affect the type of system selected. Rescue operations are briefly studied so that each candidate MOS can be evaluated within the total accident-detection-location-recovery operation. The most effective MOSs will be those that minimize the time between detection and recovery without abnormal hazard to the rescue team.

The current state-of-the-art in intruder security systems has been reviewed to determine which techniques could be adapted for shipboard use. Specification sheets on each system have been prepared for comparison and evaluation with system elements. The final result will be selection of the most effective systems for more detailed analysis and recommendations.

## 1.3 SYSTEM REQUIREMENTS

The system elements are defined in terms of the accident statistics and data contained in the accident reports, the constraints imposed by the ship configuration, the ship systems, the rescue operation, and the time required to complete each step in the rescue procedure.

## 2.0 SYSTEM REQUIREMENTS

### 2.1 ACCIDENT INFORMATION

Accidents which occurred on the Great Lakes between 1968 and 1972 are reviewed and summarized in Reference 1. <sup>1/</sup> The fall overboard types of accidents have been reviewed by ORI to discover data which is useful to the design of a man-overboard detection system. These data have been compiled on the following pages to discover the areas on and around the ship from which the fall overboards occur so that high risk areas can be identified.

Tables 2.1a, 2.1b, 2.2a and 2.2b are a brief outline of 34 fall overboard accident cases. Column headings represent information that may be useful to a man-overboard total system design. Portions of this data are summarized in Figures 2.1 and 2.2.

Falls from deck locations occurred generally at watch and work locations. They also occurred at relatively unprotected or insecure deck areas.

Falls from gangways and/or boarding ladders were almost evenly split between those boarding the ship (5) and those leaving the ship (4) with two unknowns. In several of the boarding cases the victim had been drinking.

In half of the casualty cases, the fall was witnessed by one or more companions who gave the alarm and initiated rescue operations (at least it is assumed that the witness gave an immediate man-overboard signal).

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<sup>1/</sup>Reference 1, "Assessment of the Requirements for Survival on the Great Lakes, " Coast Guard Report No. CG-D-55-74.

TABLE 2.1a  
PRE-ACCIDENT DETAILS (SHIP UNDERWAY)

Ship No.	Ship	Type	Operation	Accident Location and Observations	Accident Result
1.	Paul H. Townsend	freighter	underway	tell over life line at fwd bits -- suspect suicide	drown
2.	SS Henry H. Rogers	freighter	underway	spar deck -- guard rail consists of 2 wires 36" and 18" above deck - victim tripped & fell between upper and lower wires	drown
3.	Thomas Wilson	freighter	underway	unknown - suspect suicide	missing
4.	William A. Erwin	freighter	underway	went thru stateroom port hole - irrational - suspect suicide	missing
5.	MV Julie Ann	tug	underway	assumed to have slipped on deck ice and slid under safety chain opposite galley entrance from main deck	drown
6.	MV Louisiana	tug	approaching lock	Port fwd corner of lead barge - crushed between lock wall and barge - was wearing a PFD	crushed
7.	J.R. Chambers	fishing vessel	fishing	lost balance and fell overboard at stern - setting gill net	drown
8.	MV Watanna	charter vessel	fishing	lost balance and lurched against port rail, stern observation deck, rail contact slightly below waist line flipped victim over side	drown
9.	Birneo	tug	underway	observed leaning over rail near stern with pail in his hand	drown
10.	C & R	tug	underway	observed leaning over rail near stern to dip bucket of water - he either lost balance or bucket in water pulled him over	drown
11.	Texas	tug	underway	Unknown	drown
12.	FV Pelican	fishing trawler	underway	securing work boat towline on stud stern of trawler - deck rail height in this location is 21" - line snapped and victim knocked overboard	missing
13.	MV Spencer	tug	underway	fell headfirst from forward stbd corner - no safety chains in this area	missing

TABLE 2.1b  
PRE-ACCIDENT DETAILS (SHIP NOT UNDERWAY)

Ship No.	Ship	Type	Operation	Accident Location and Observations	Accident Result
14.	Lackawanna	GL bulk carrier	at dock	discovered hanging on to port anchor line - no other details	recovered alive
15.	Clifford F. Heald	freighter	at dock	fell from ladder while leaving ship	injured
16.	SS Harris N. Snyder	freighter	at dock	lifeboat hoist pierced - dumping 3 men into water - port side	injured
17.	SS Kinsman Independent	freighter	at dock	unknown	drown
18.	Robert Hobson	freighter	at dock	fell off boarding ladder returning from tavern - seen by deck watch and 3 companions	drown
19.	Rocket	tanker	at dock	lost balance at top of gangway returning to ship and fell between ship and dock	injured
20.	SS J.F. Scheellkopf	freighter	at dock	fell from boarding ladder boarding ship	drown
21.	MV Federal St. Laurent	freighter	at dock	climbed down Jacobs ladder at turn to take draft readings - assumed slippery - heavy clothing no PFD or assistance	drown
22.	S.S. Peter Robertson		at dock	fell from dock while shifting mooring lines - seen by crew	unknown
23.	Flo S. Morrow	freighter	at dock	fell from boarding ladder that had been raised off dock - 6-10' - leaving ship	injured
24.	SS C.H. McCullough	freighter	at dock	jumped from gangway to boarding ladder boarding ship - drinking - fell in water - seen by crew	drown
25.	R.C. Norton	freighter	at dock	fell into water attempting to board - no other details	injured
26.	SS E.B. Barber	freighter	at dock	fell from boarding ladder - seen by partner leaving ship	drown
27.	SS Merle McCurdy	freighter	at dock	went ashore to take draft readings - 15 minutes later ship notified of man floating in water near bow	drown
28.	Kinsman Voyager	freighter	at dock	unknown - watchman fired for drunkenness	drown
29.	Grand Rapids	freighter	anchored	hoisting lifeboat when hoist let go - fell in water #2 lifeboat	injured
30.	MV Antonies Demades	freighter	anchored	pilot ladder - port side vicinity	drown
31.	Lady Rea	towboat	at dock	slipped from ladder - going ashore	injured
32.	Florida	towboat	at dock	unknown	drown
33.	SS/John Sherwin	freighter	at dock	unknown - maybe gangway - returning to ship - drinking	drown
34.	Scow # 152	scow	anchored	crane and operator fell overboard	fatal injury

TABLE 2.2a  
POST-ACCIDENT DETAILS (SHIP UNDERWAY)

Ship No.	Time to Alert	Accident Witness	PFD Useful	MOS Useful	Temperature of		Month	Entered Water		Time Betw en Water Contact and Unconsciousness
					Air	Water		Conscious	Unconscious	
1	immediate	lookout	yes	no	--	--	May	x		not seen after fall
2	immediate	companion	yes	no	32	37	April	x		hit water and seen to surfac
3	3.5 hours	none	yes	yes	--	65	August	u*	u*	possible suicide
4	10.45 hours	none	no	yes	--	--	April	u*	u*	possible suicide
5.	20 min.	none	yes	yes	30	38	March	x		u* could have struck head
6.	immediate	crew	no	no	--	--	May	x		crushed in lock
7.	immediate	crewman	yes	no	5	34	February	x		10 sec. - observed struggling on surface
8.	immediate	passenger	yes	no	--	--	August		x	observed face down
9.	few minutes	none	yes	yes	65	10-65	Sept.	x		4 min. - before sinking
10.	immediate	crewman	yes	no	76	--	July	x		5-10 min. before sinking
11.	few minutes	none	yes	yes	30	53	Nov.	x		u* no reason to assume unconscious
12.	immediate	crew member	yes	no	--	--	July	x		estimate 5 min.
13.	immediate	crew member	yes	no	9	32	Jan.	x		zero minute - no reason to assume unconscious

\* unknown

TABLE 2.2b

POST-ACCIDENT DETAILS (SHIP NOT UNDERWAY)

Ship No	Time to Alert	Accident Witness	PFD Useful	NOS Useful	Temperature of		Month	Entered Water		Time Between Water Contact and Unconsciousness
					Air	Water		Conscious	Unconscious	
14.	unknown	none	yes	yes	--	--	Oct.	x		rescued
15.	unknown	unknown	yes	yes	--	--	Oct.	x		rescued
16.	immediate	crewman	yes	no	--	--	April	x		rescued
17.	days	none	yes	yes	--	--	Feb.	u*	u*	u*
18.	immediate	crewman	yes	no	--	--	Oct.		x	zero minutes-struck dock
19.	immediate	watchman	yes	no	--	--	Nov.	x		rescued
20.	immediate	watchman	yes	no	38	32	Dec.	x		zero minutes - did not surface
21.	est. 1 hour	none	yes	yes	--	54	Oct.	x		u*
22.	unknown	crewman	yes	yes	--	--	Oct.	x		- 5 min. - pulled dead from water
23.	unknown	unknown	yes	yes	--	--	Sept.	x		rescued
24.	unknown	assure crew	yes	yes	32	30	Dec.	x		u*- body recovered in 38 min.
25.	unknown	unknown	yes	yes	--	--	May	u*	u*	u*
26.	immediate	companion	yes	yes	75	--	July	x		-1 min. - disappeared - no reason to suspect unconscious
27.	15 min.	unknown	yes	yes	--	50	Nov.	x		- 15 min. - seen struggling
28.	10 min.	unknown	yes	yes	--	--	June	x	possible	seen floating face down - in 10 min - drunk
29.	immediate	crew	yes	yes	--	--	May	x		rescued
30.	unknown	none	yes	yes	--	--	Aug.	x		u*- seen in water - called for help - disappeared
31.	unknown	unknown	yes	yes	--	--	Dec.	x		u*
32.	one day	none	yes	yes	72	--	July	u*	u*	u*
33.	body found next day	none	yes	yes	42	37	April	x		u*- no reason to suspect unconscious - drinking
34.	immediate	fellow worker	no	no	15	--	January	x		zero minutes - did not surface

\* unknown

	Number of Cases*
<b>Ship Operation at Time of Accident</b>	
Underway	13
Anchored or at dock	21
<b>Source of Fall</b>	
Bow area	3
Stern area	5
Midship area	1
Boarding ladder	11
Other location—dock, barge, etc.	7
Unknown	7
<b>Accident by Month</b>	
January	2
February	2
March	1
April	4
May	4
June	1
July	4
August	3
September	2
October	5
November	3
December	3

\* Total number of cases 34.

FIGURE 2.1. SUMMARY OF FALL OVERBOARD ACCIDENTS

	Number of Cases*
<b>Result of Fall</b>	
Deaths	26
Injuries	8
<b>Condition of Victim at Water Entry</b>	
Conscious	27
Unconscious (assumed)	2
Unknown	5
<b>Time to Sink or Apparently to Become Unconscious</b>	
0-5 minutes	7
5-10 minutes	3
10-20 minutes	1
Unknown	23
<b>Fall Observation Categories</b>	
Observed By Others	17
Unobserved	17

\* Total number of cases 34.

FIGURE 2.2. SUMMARY OF VICTIM DETAILS

A MOS would have helped in 17 cases where the fall was not observed. It is assumed that in the 17 cases where a witness was involved a MOS would not have been useful. However, this assumption may not be totally accurate since a well-planned rescue operation keyed to a MOS may reduce rescue time which is of paramount importance.

The majority of those that fell overboard were dressed in working clothes with heavy footwear. There is only one indication that a PFD was worn and this could not be verified. A properly-worn PFD would have been useful in 31 of the 34 cases. Of the three remaining cases, two were fatally injured and the third was a suspected suicide.

Rescue time before unconsciousness or death is extremely limited under these conditions - less than five minutes for 7 of the 11 cases where data was given. This surprisingly short length of time is verified by two Coast Guard reports which analyze small craft accidents entitled, "A Detailed Study of Power and Load Related Boating Accident Data" and "Analysis of Requirements and Methods of Distress Notification for the Recreational Boater." Separate efforts are being pursued to increase this time span.

The Great Lakes casualty data highlights important points.

1. People that fall off ships die very quickly. This situation emphasizes the need for:
  - A man-overboard detection system
  - A quick-response rescue operation
  - Wearing PFDs while on deck or working around the ship.
2. People that fall overboard fall from a variety of locations; the deck, boarding ladders, dock, lifeboats, etc. This dictates the requirement for a detection system which will be responsive under all of these conditions.

## 2.2 SHIP CONSTRAINTS

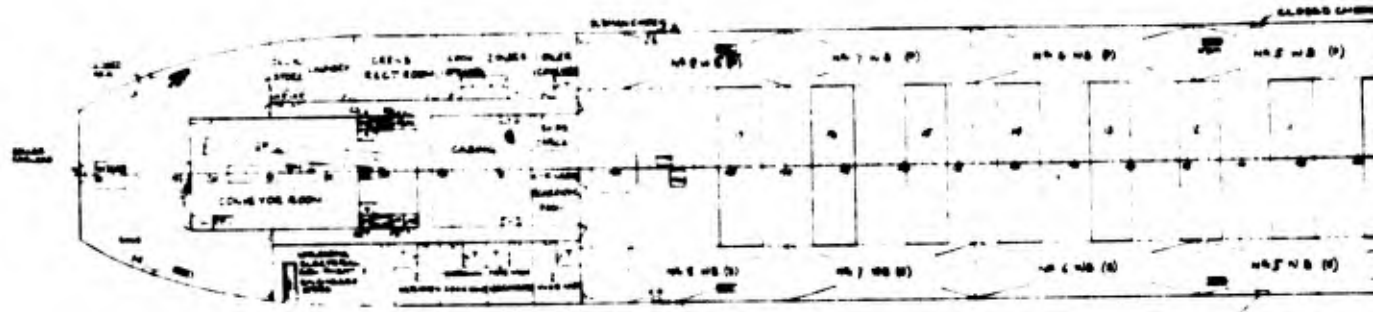
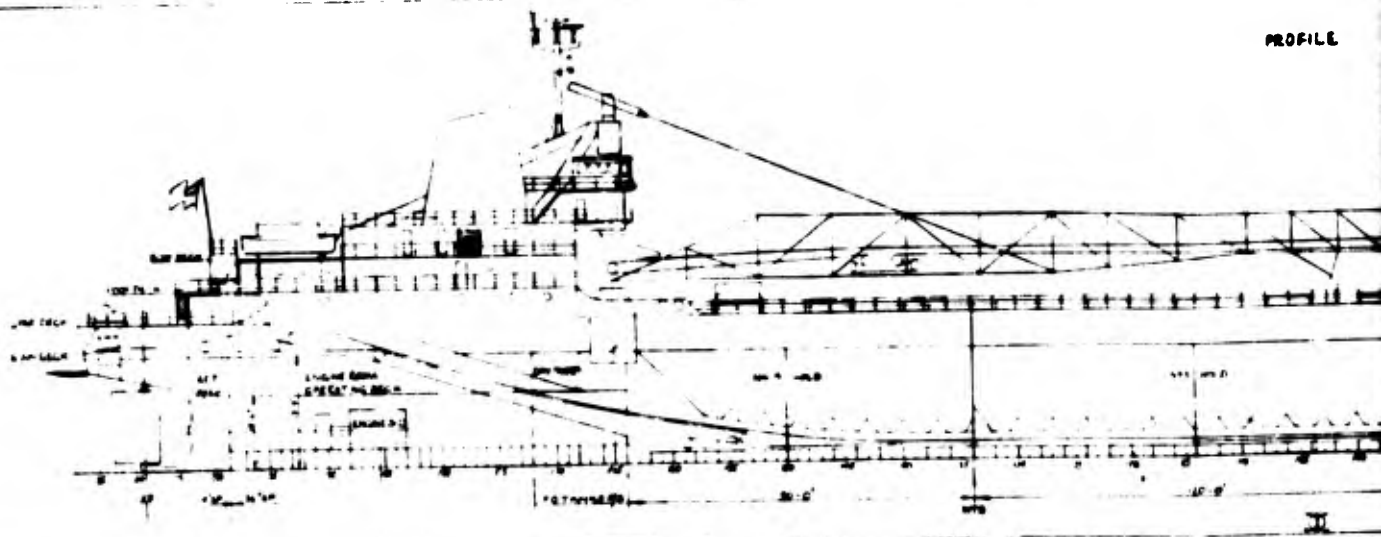
Ship constraints that may conflict with a MOS are items such as, the ship electrical and mechanical systems, the configuration of the ship, and the normal operation of the ship.

A modern Great Lakes self-unloader is shown in Figure 2.3. The figure and system data that follows are taken from Reference 2 and will be used to demonstrate typical systems that may influence the operation, location and installation of a MOS.

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<sup>2/</sup>O.R. Archer, F. Galquinto and L.A. Dommin, Basic Standard Great Lakes Self-Unloader River Service Type, SNAME, 1974.

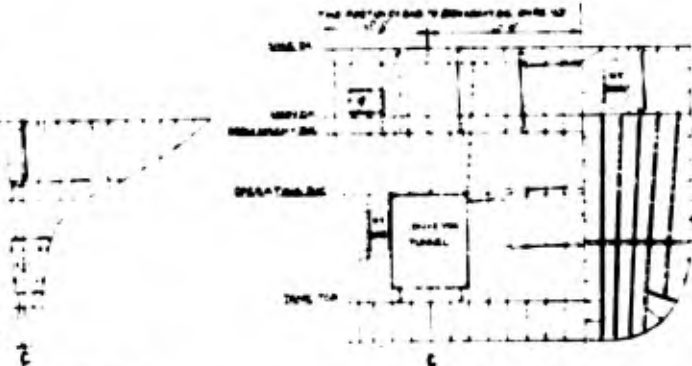
PROFILE



PLAN ON SPARE



SECTION THROUGH BOW



SECTION THROUGH MIDSHIP

SECTION THROUGH STERN



SECTION THROUGH STERN



### 2.2.1 Ship Configuration

The ship depicted in Figure 2.3 has the following characteristics:

#### Principal Characteristics

● Length overall	630'-0"
● Length between perpendiculars	610'-0"
● Beam molded	68'-0"
● Depth molded	36'-11"
● Drafts: Midsummer	26'-0 3/8"
Summer	25'-4 7/8"
Intermediate	25'-2 7/8"
Winter	24'-11 3/8"
● Displacement at summer draft	25,564 L/Tons
● Cargo deadweight at summer draft	19,030 L/Tons
● Cargo deadweight at 22'-6" river draft	15,925 L/Tons
● Lightship weight	5,530 L/Tons
● Cargo cubic	411,905 cu ft
● Tons per inch at summer draft	89.5 L/Tons
● L.C.G. light	42.66 ft AFT midships
● VCG light	32.83 ft above B.L.
● LCB light	15.98 ft Fwd. midships
● LCF light	14.48 ft Fwd.
● KMT	56.92 ft
● GMT (fluid) free surface - 0.02' (loaded)	6.75 ft
● Block coefficient (loaded)	0.8679
● Midship coefficient (loaded)	0.9994
● Prismatic coefficient	0.9321
● Waterplane area coefficient	0.9311
● Wetted surface	64,841 sq ft
● Shaft horsepower	5,400
● Propeller diameter	16 ft
● Propeller R.P.M.	110

- Speed, loaded (designed) 15.4 M.P.H.
- Unloading rate 5,000 L/Tons/Hr
- Accommodations. 23 people

This vessel has over 1,300 feet of deck edge that is protected by either wire railing or bulwarks. A fall from this location to the water surface would represent a distance of 12 feet when the vessel is fully loaded, and up to 30 feet in the light condition. Contact with the water from these heights may stun or injure the crewman and reduce his survival capability. This situation emphasizes the need for a quick detection system.

### 2.2.2 Ship Systems

Electrical and electronic equipment which are typical of shipboard systems are listed below. The detection techniques considered for a MOS must be compatible with these ship systems so that interference and false alarms are minimized.

#### Navigation Equipment

- Radio direction finder
- Fathometer, digital type, with alarm
- Main radar, 3 cm, 12 " display
- Auxiliary radar, 3 cm, 8" display
- Gyro compass, MK227
- Dual electrohydraulic steering control
- Dual main whistle control, with automatic solid state timer
- Three - 1000 watt searchlights.

#### Radiotelephone Equipment

- 10 channel, 150 watt, single sideband M/HF
- 14 channel, 72 watt, VHF-FM.

Systems provide ship-to-ship and ship-to-shore radio communication. All the equipment is of the latest design to meet the current FCC regulations, including emergency operation.

#### Interior Communications

- Engine order telegraph
- Navigating sound-powered telephone
- Ship's service sound-powered telephone

- Loudspeaker, with talk-back features
- Propeller shaft RPM indicator
- Engineer's indicating and alarm panel
- General alarm, 24V battery powered
- Trim light indicator
- Pyrometer indicator
- Engineer's call and alert alarm
- Mate's call and alert alarm
- Bilge oily water detection and alarm
- Steering gear alarm
- Rudder angle indicator
- Watertight door indicator and alarm
- CO<sup>2</sup> release and alarm.

Electrical Power Generation. The primary ship's service electrical power is provided by three 800 KW, 450 volt, 3-phase, 60 Hz diesel driven generators. Any two of the three generators may be operated in parallel to provide sufficient peak power requirements while the ship is unloading.

A 100 KW, 450 volt, 3-phase, 60 Hz diesel driven generator is installed to provide emergency electric power.

The ship's service generators and distribution switchboard are located in the engineer's control room which serves as the control center of the ship's propulsion and auxiliaries.

Except for a few 115 volt AC fractional horsepower motors, all electric motor driven auxiliaries are rated at 440 volt, 3-phase, 60 Hz. There are over 80 motor driven auxiliaries utilized in the auxiliary system.

One bank of three-25 KVA transformers aft and one bank of three-5 KVA transformers forward are utilized to transform 440 volts to 115 volts AC for ship's lighting and miscellaneous 115 volt power.

Bow Thruster. The bow thruster is powered by a marine vertical motor of 1,000 horsepower, 440 volts, 3-phase and 60 Hz.

Unloading System. The unloading system (conveyors, booms, etc.), is powered by an assortment of motors totaling over 1,540 horsepower. The completely automatic control system includes two remote control stations for controlling the unloading operation from either the port or starboard side of the ship. A third control station is included at the end of the unloading boom conveyor.

### 2.2.3 Rail and Ladder Details

Railings. Railing details were studied from the plans of a modern self-unloader and inspected on two ships built about 1930. Prior to 1968, the height of portable rails on the spar deck was required to be a minimum of 36 inches and consisted of two strands of 3/8 " wire rope supported at 15 foot intervals by stanchions.

A three wire rail on an older vessel is shown in the photograph, Figure 2.4. The stanchions consist of flat bars with three holes through which the wire rails are threaded. Turnbuckles are attached at the ends of the portable wire rails at bulwarks. The turnbuckles, Figure 2.6, are used to apply tension to the wires. The wires on the inspected ships were slack as evidenced by the sag in the top wire of Figure 2.4 due to the weight of several life jackets.

The latest standards for railings require three strands of 1/2" wire rope, the top strand being one meter high. The newer rails are supported on six-foot centers. Both of the older boats met or exceeded the latest requirements. One of the vessels had four wires as shown in Figure 2.5. The left foreground shows the flat bar stanchion and deck fitting at the lower end. Note, the coaming at the deck edge in Figure 2.6. This coaming is 8" high and typical of the older riveted ships. The newer welded ships do not have a coaming.

Railings above the spar deck and around the deckhouse are pipe rails instead of wire. These are permanent railings and are welded to stanchions and to the deck. A good example of this type railing on an older vessel is shown in Figure 2.7. Modern pipe rails consist of three horizontal members. The top rail is 1-1/4" schedule 40 pipe and the lower ones are 1" schedule 40 pipe. The rails are separated from each other by 15 inches and from the deck by 9-1/2".

Boarding Ladder. According to the Great Lakes accident statistics, half of the falls occurred from the boarding ladder. It is similar to a standard stepladder with hand rails. Both hands are required to negotiate the ladder and it is an easy matter to fall off either side. Packages and supplies are hoisted aboard so that both hands are free for clutching the ladder. This rule is spelled out on the sign posted near the top of the ladder, see Figure 2.8. The metal grating or landing platform just above the sign is used to board the ship. The crewman, upon reaching that level, must step off the ladder onto the grating and then over the bulwark and down three steps to the deck. Figure 2.9 shows the intersection of the deck, ladder and landing platform.

After a review of available man overboard alarm systems, it was decided that a prevention device would be more practical for the boarding ladder than a detection system. Figure 2.10 shows the proper use of the ladder by a crewman. A simple wire hood could be attached to the sides of the ladder allowing ample room for access and egress and protecting the user.

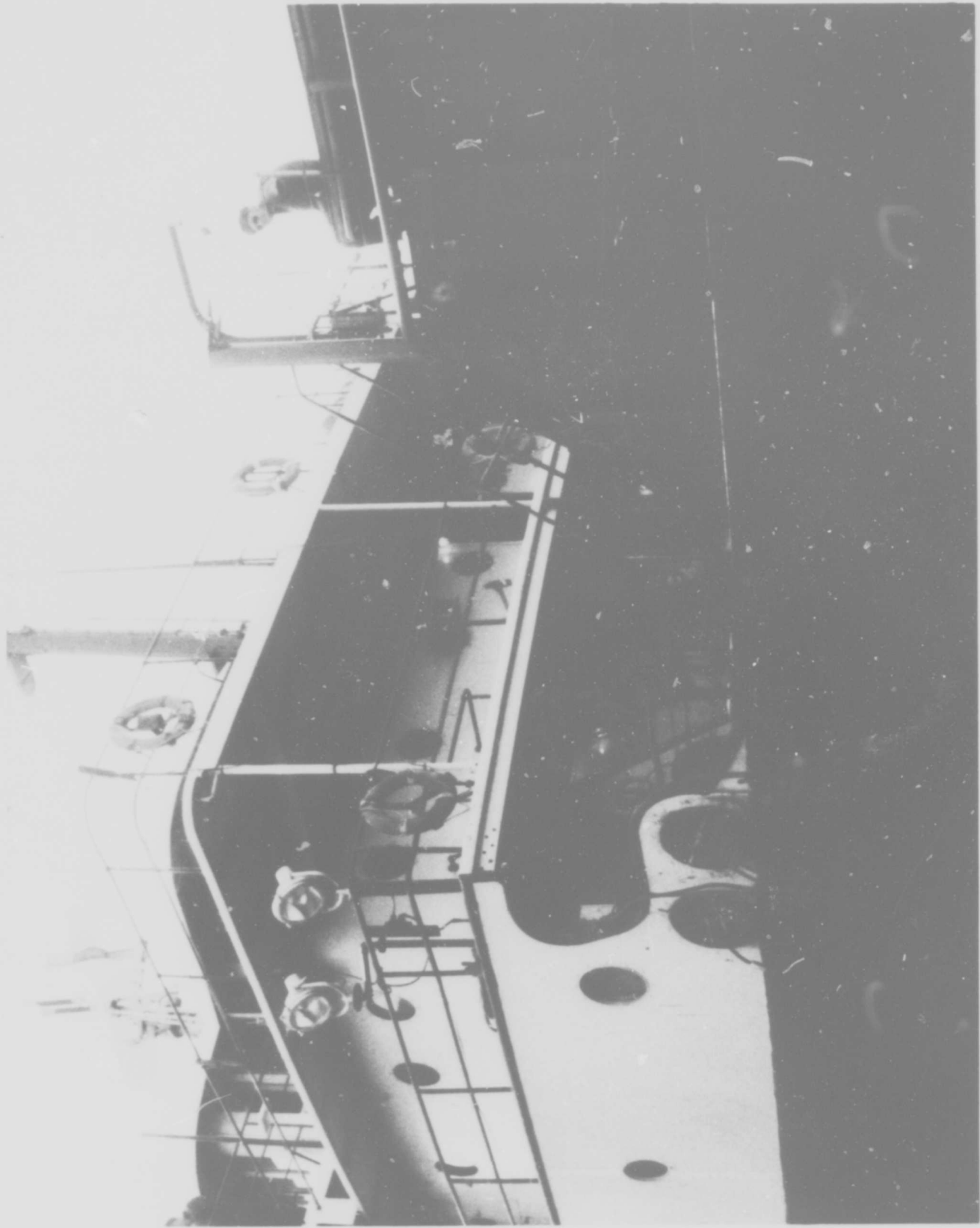


FIGURE 2.4. SPAR DECK THREE WIRE RAIL

2-14

4 44 89

(24)

902



FIGURE 2.5. SPAR DECK FOUR WIRE RAIL

2-15

4 44 89

(25)

70%

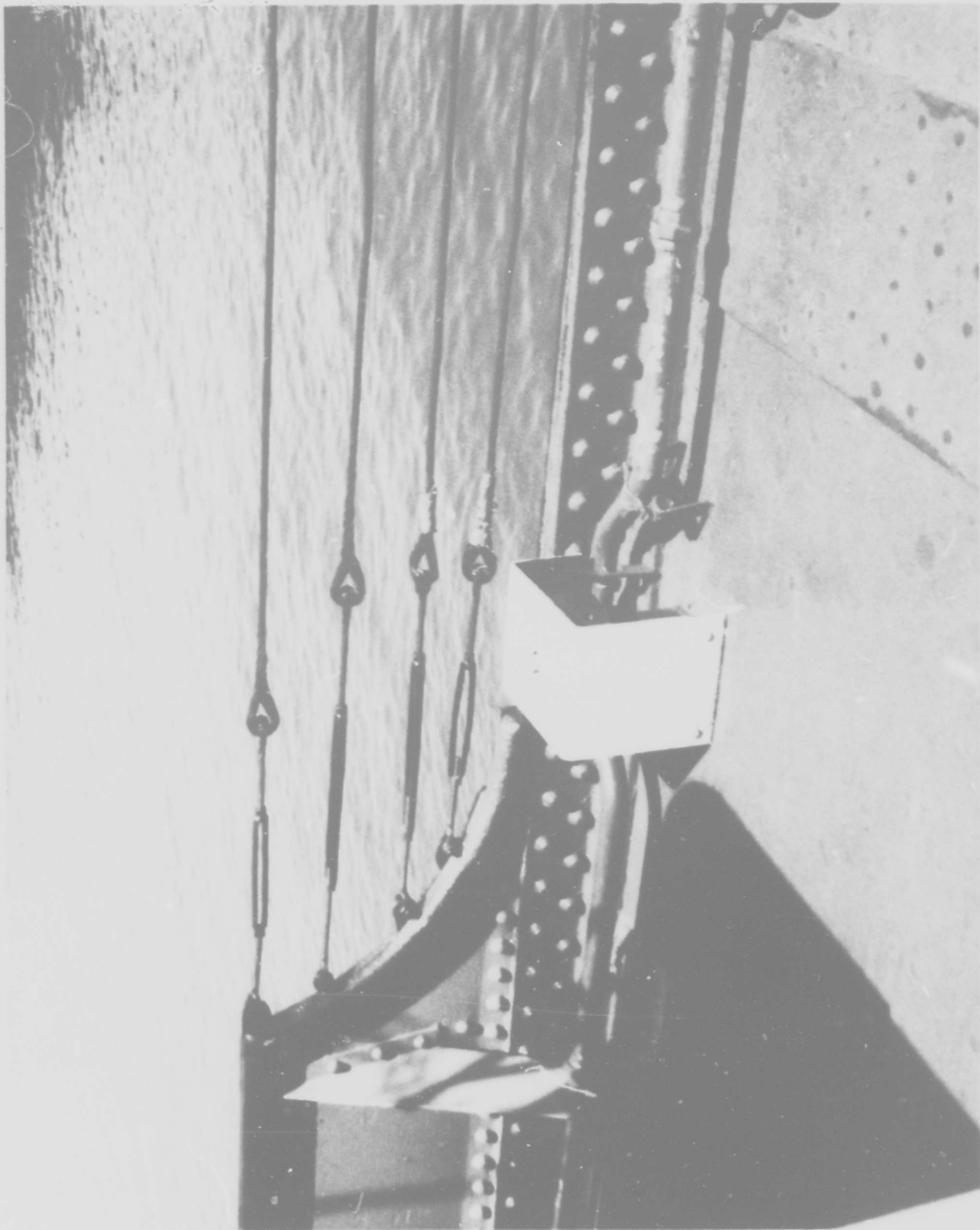


FIGURE 2.6. WIRE TIGHTENERS AND DECK COAMING

2-16

4 44 89

(26)

9073

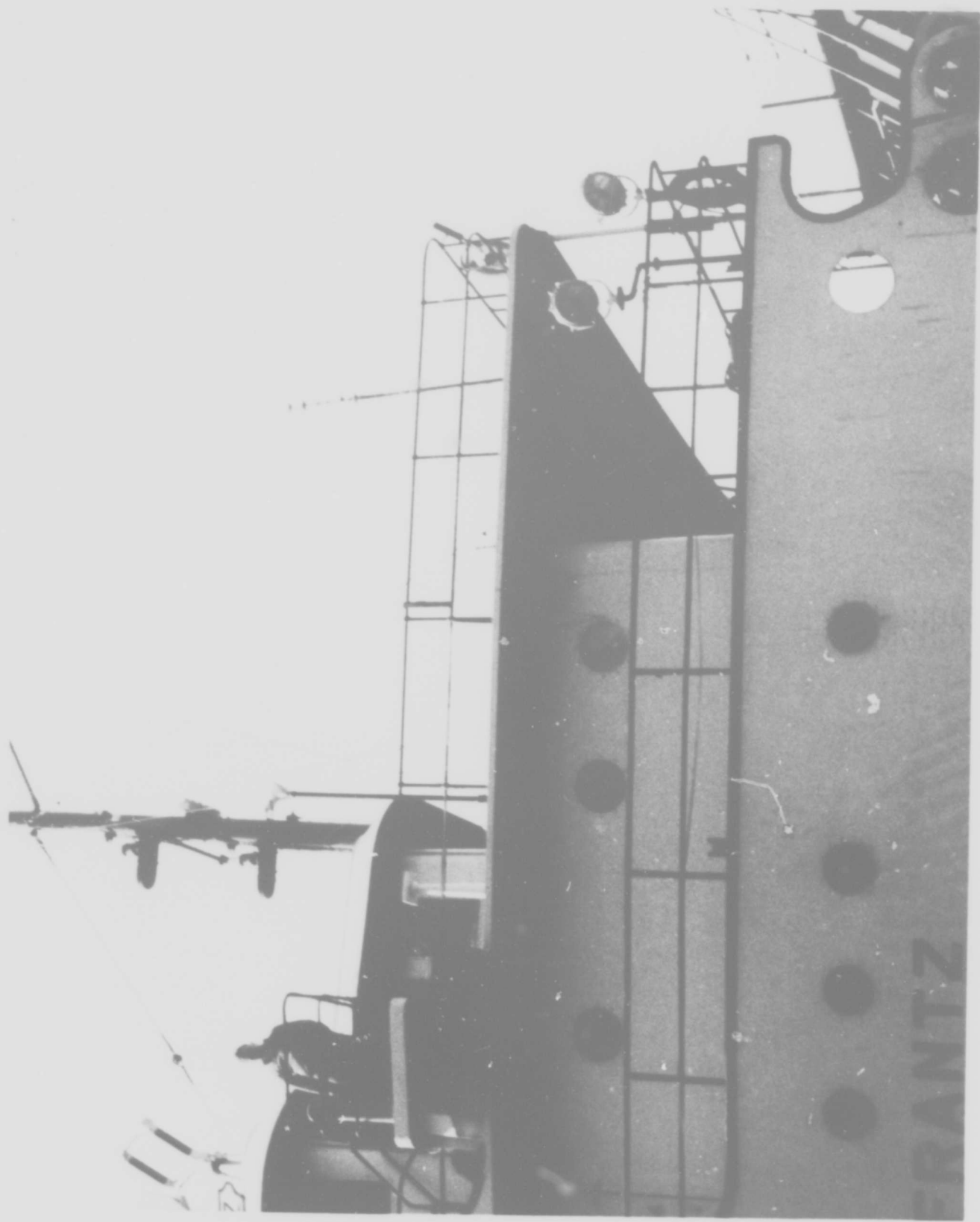


FIGURE 2.7. PIPE RAILINGS

2-17

4 44 89

(27)

9070

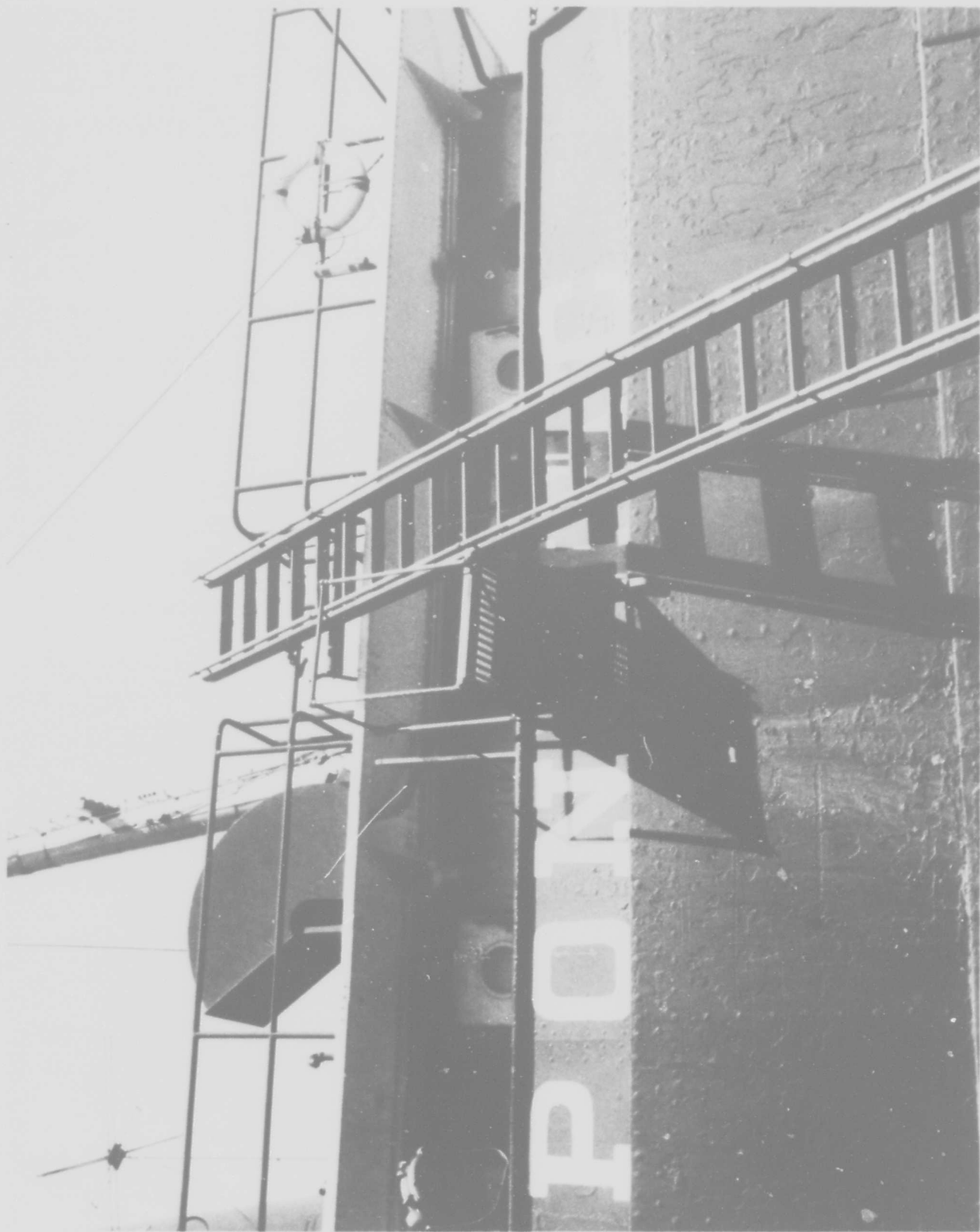


FIGURE 2.8. BOARDING LADDER AND LANDING PLATFORM

2-18

4 44 89

28 907

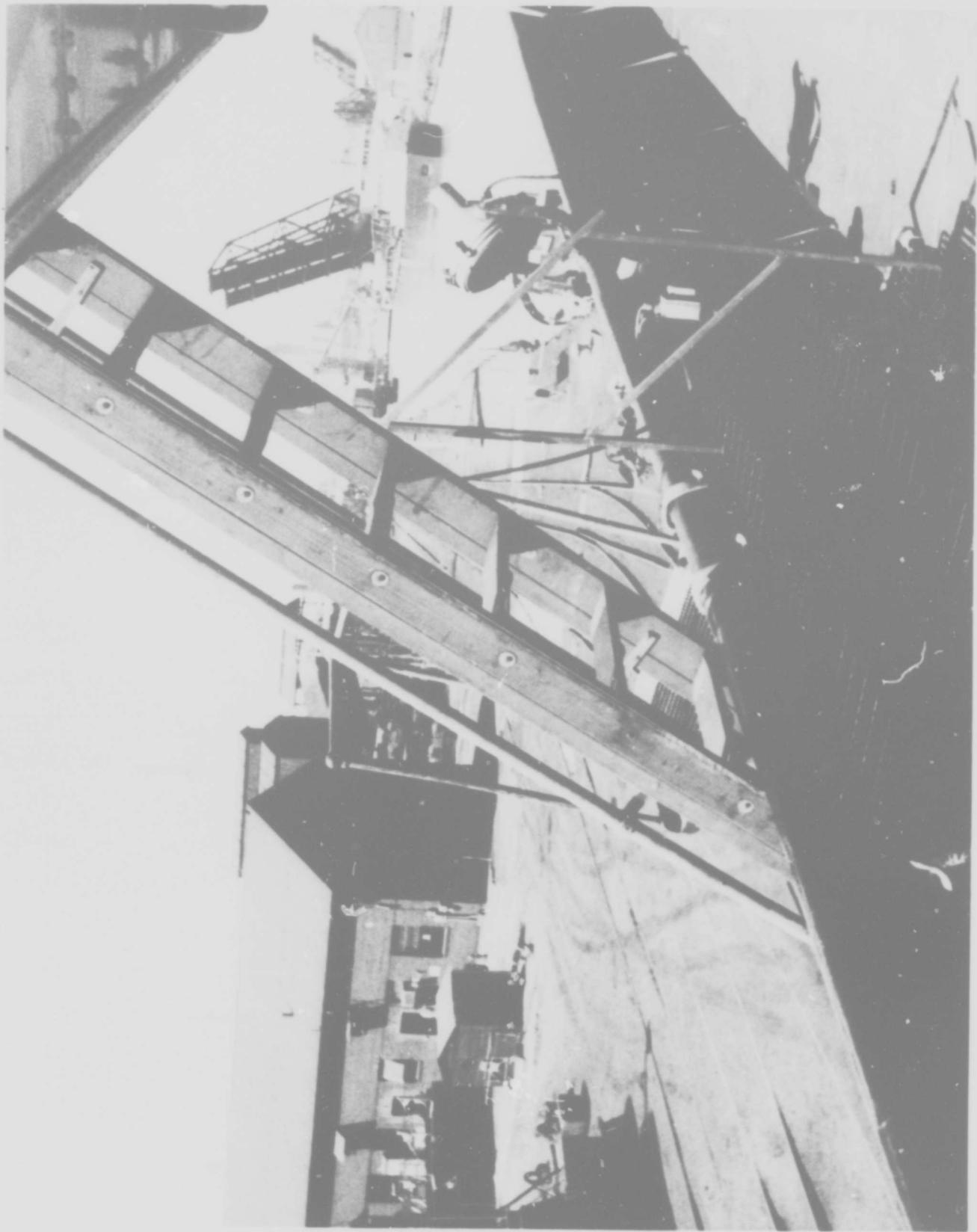


FIGURE 2.9. BOARDING STEPS

2-19

4 44 89

(29) 907

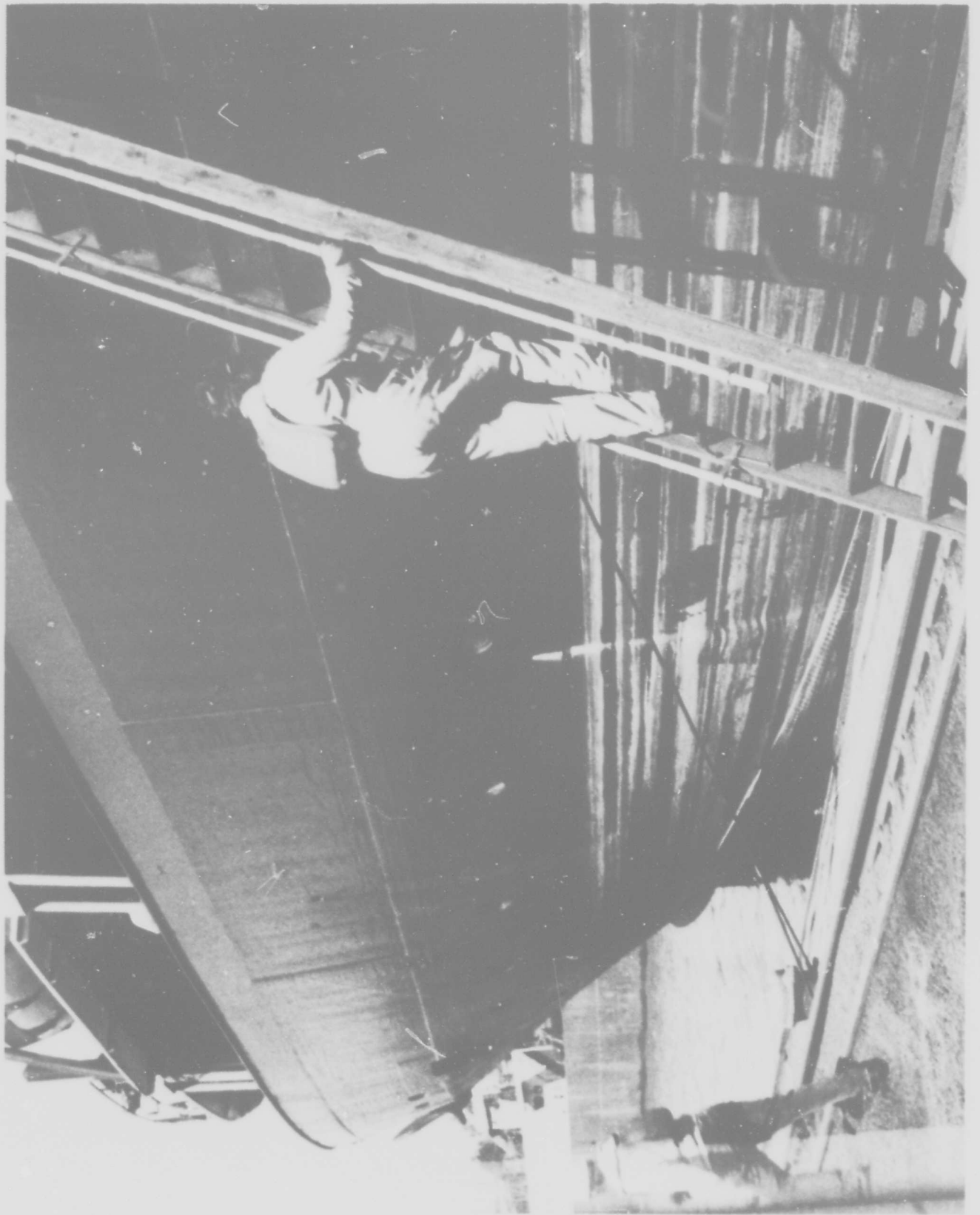


FIGURE 2.10. CREWMAN USING BOARDING LADDER

2-20

4 44 89

(30) 902

A wire cage is superimposed over the same crewman in Figure 2.11 to demonstrate the configuration and installation of a device which will prevent falls from the boarding ladder. The hood design must incorporate several egress points to allow for variations in ship draft, distance from pier and pier height. The cage should not interfere with stowage of the ladder while the ship is underway. Figure 2.12 shows the port and starboard ladders in the stowage position supported at the upper end by a mast projecting above the stack. This is standard stowage procedure on Great Lakes vessels. The lower edge of the ladder is secured at the deck edge. The ladder is hoisted and lowered by a cable at the mast position. The cage should not interfere with any operation or position of the ladder.

#### 2.2.4 Deck Obstructions

Obstructions on the deck and in the vicinity of the rail will interfere with a MOS. A beam type system such as laser or infrared which is installed at the rail are not as sensitive to deck obstructions as the area-type sensors like radar, CCTV and microwave. Obstructions create dead spots or areas that are shielded from surveillance.

In general the spar deck is relatively free of obstructions except for hatches which protrude above the main deck by about four feet. The hatches are approximately 12 feet wide, 46 feet in the athwartship direction and spaced on 24 foot centers.

The conveyor crane on self-unloaders is a large obstruction (Figure 2.3) measuring about 260 feet long. It is mounted on the centerline of the ship and can swing port or starboard when unloading. Most area sensors would have to be readjusted in sensitivity to compensate for the change in location of the conveyor crane. This is only a problem when the ship is at the dock.

Deckhouses may be located at the stern (Figure 2.3), forward, and often split forward and aft. This situation may require multiple detection systems since the deck area to be observed is divided into three separate areas.

#### 2.2.5 Ship Operation

Carriers frequently operate in confined areas such as locks and loading docks. Some of the detection systems under consideration must be mounted outboard from the side of the ship so that the system will not be triggered by a man standing or working at the rail. Figure 2.13a shows two detection systems and their relationship to the side and rail of the ship. Both systems are installed out from the side of the ship and must be hinged to swing inboard or be removed when the ship is operating close to the wall of a lock or moored near some structure at dockside. The system may not be operative in this situation which reduces the effectiveness of a MOS.

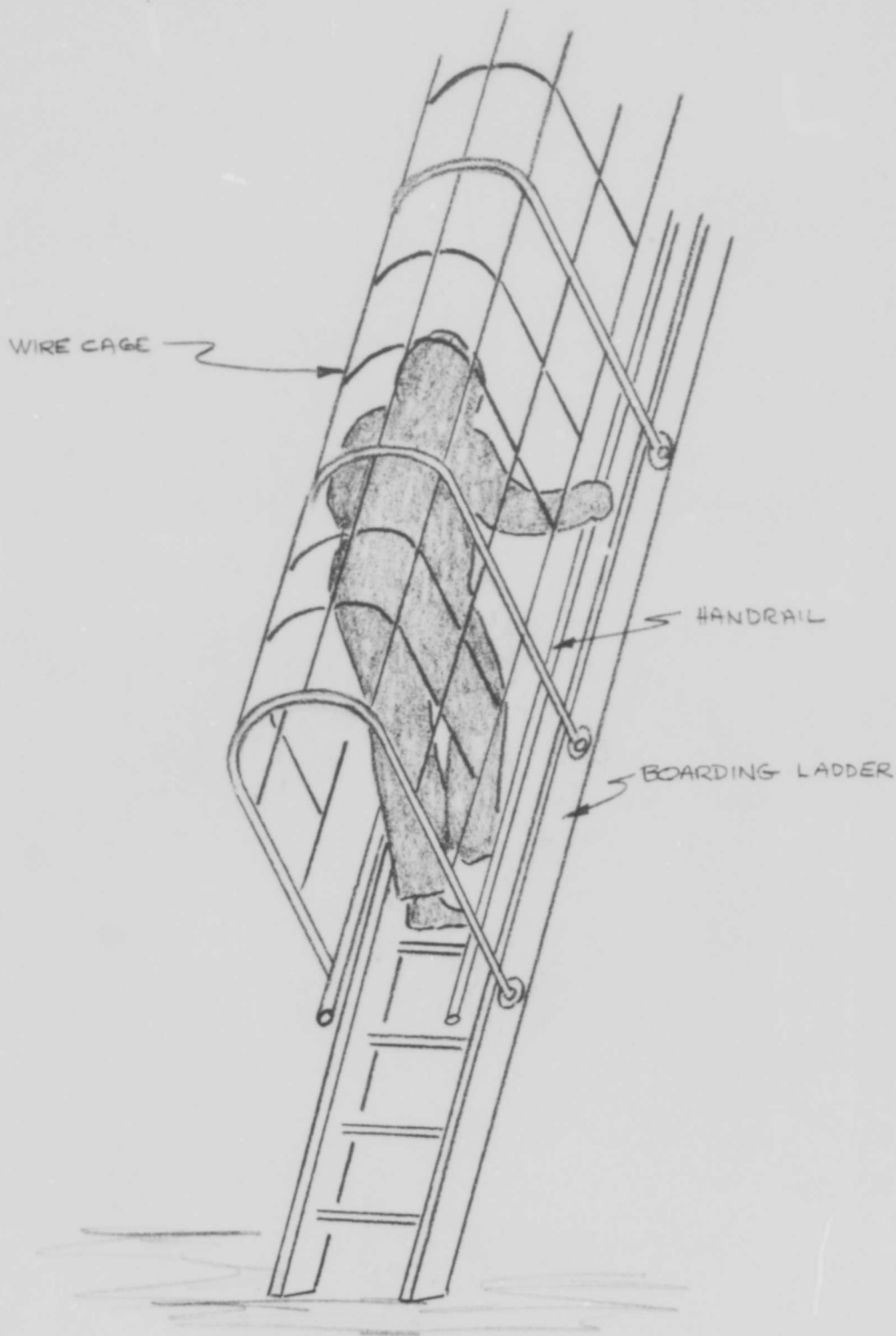


FIGURE 2.11. BOARDING LADDER CAGE

2-22



FIGURE 2.12. STOWED POSITION OF BOARDING LADDER

2-23

4 44 89

33

90013

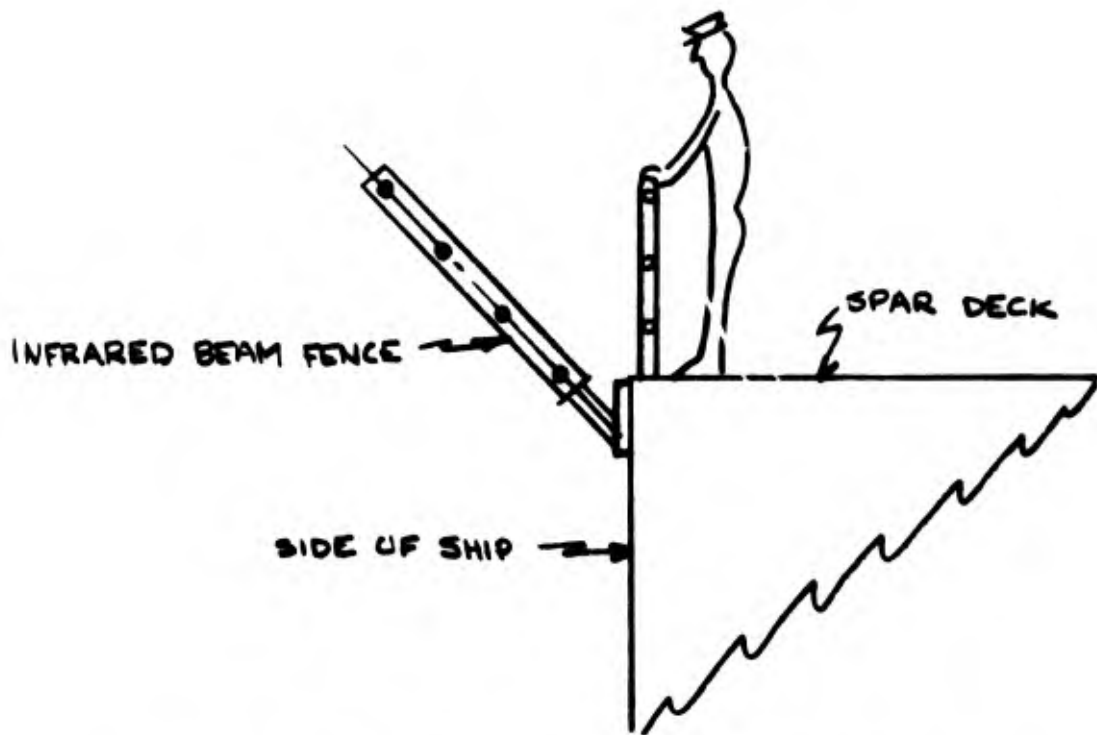
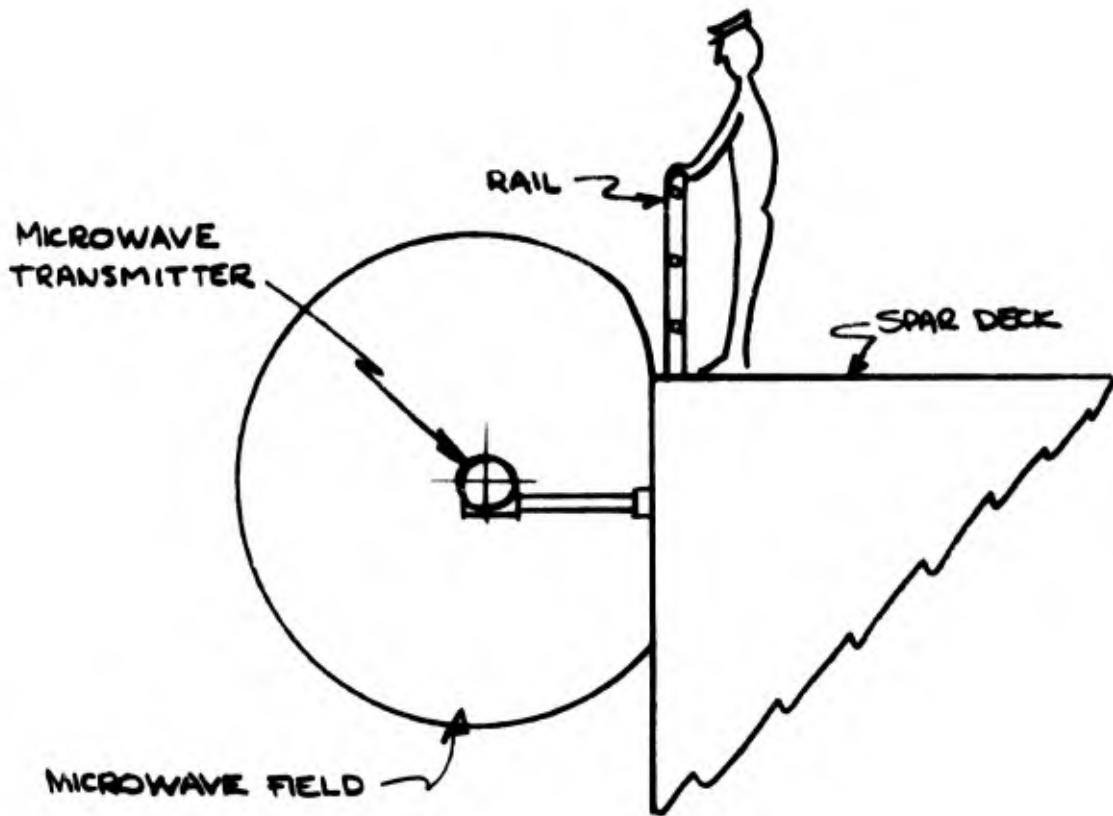


FIGURE 2.13a. TYPICAL DETECTOR INSTALLATIONS

Alternatively the rail could be moved inboard from the deck edge so that the sensors can be mounted inboard of the deck edge as shown in Figure 2.13b.

### 2.3 RESCUE OPERATIONS

There is no evidence of standard rescue procedures for a man overboard casualty. Evidently it is left up to the judgment and experience of the master. Procedures may vary depending on circumstances—for example, the ship may be:

- Underway in open water
- Underway in a channel
- In a lock
- Anchored
- At dockside.

These situations reduce to only two possibilities, either the ship is moving or the ship is dead in the water. Figure 2.14 shows the options that the master has for each possibility. It is immediately evident that the moving situation is much more complex than the non-moving case.

It is evident from Figure 2.2 (Time to Sink or Apparently Become Unconscious) that recovery time must be minimized if the victim is to be rescued alive. This requires a quick decision on which rescue option should be put in operation. Some information taken from trial data, Reference 2, on the 630 foot self-unloader and discussions with Coast Guard personnel indicate the following approximate time histories after the man-overboard alarm is sounded.

1. Restricted water case	
● Crash stop	5 minutes
● Lower lifeboat	8 minutes
● Search and locate (estimate)	<u>10 minutes</u>
Total	23 minutes

The crash stop (5 minutes) is based on a fully loaded ship at a speed of 15 knots. Obviously, other conditions (loading, speed, current, ice cover, etc.) will effect the stopping distance. The stopping distance for the sample case is approximately 4,000 feet. Assuming that the lifeboat has a speed of five knots, the return trip to the location of the casualty is about eight minutes. Assuming daylight hours, good visibility and calm seas, the victim may be located immediately and pulled aboard the lifeboat in two minutes, making a total of 10 minutes for search and locate.

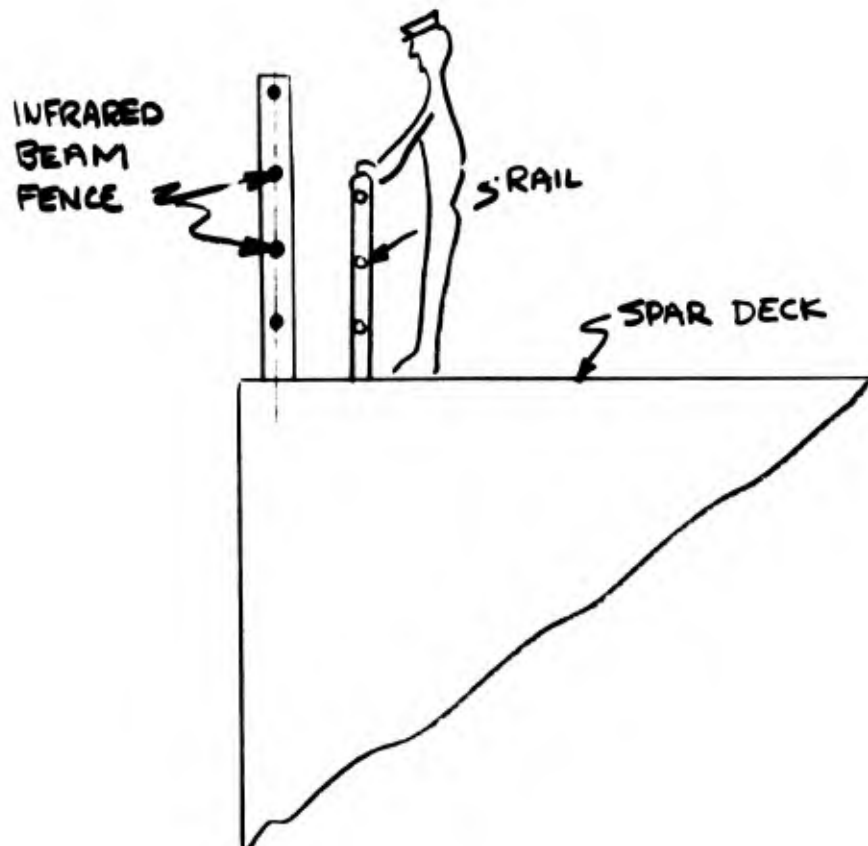
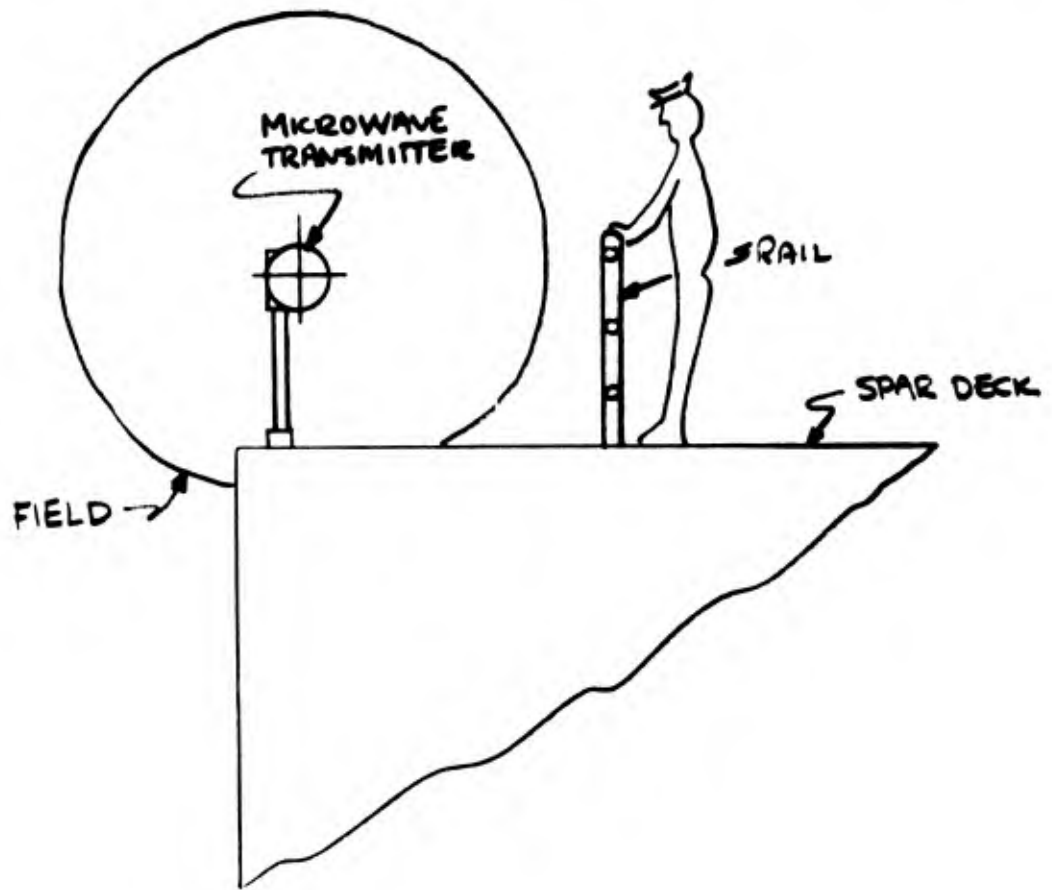


FIGURE 2.13b. TYPICAL DETECTOR INSTALLATIONS

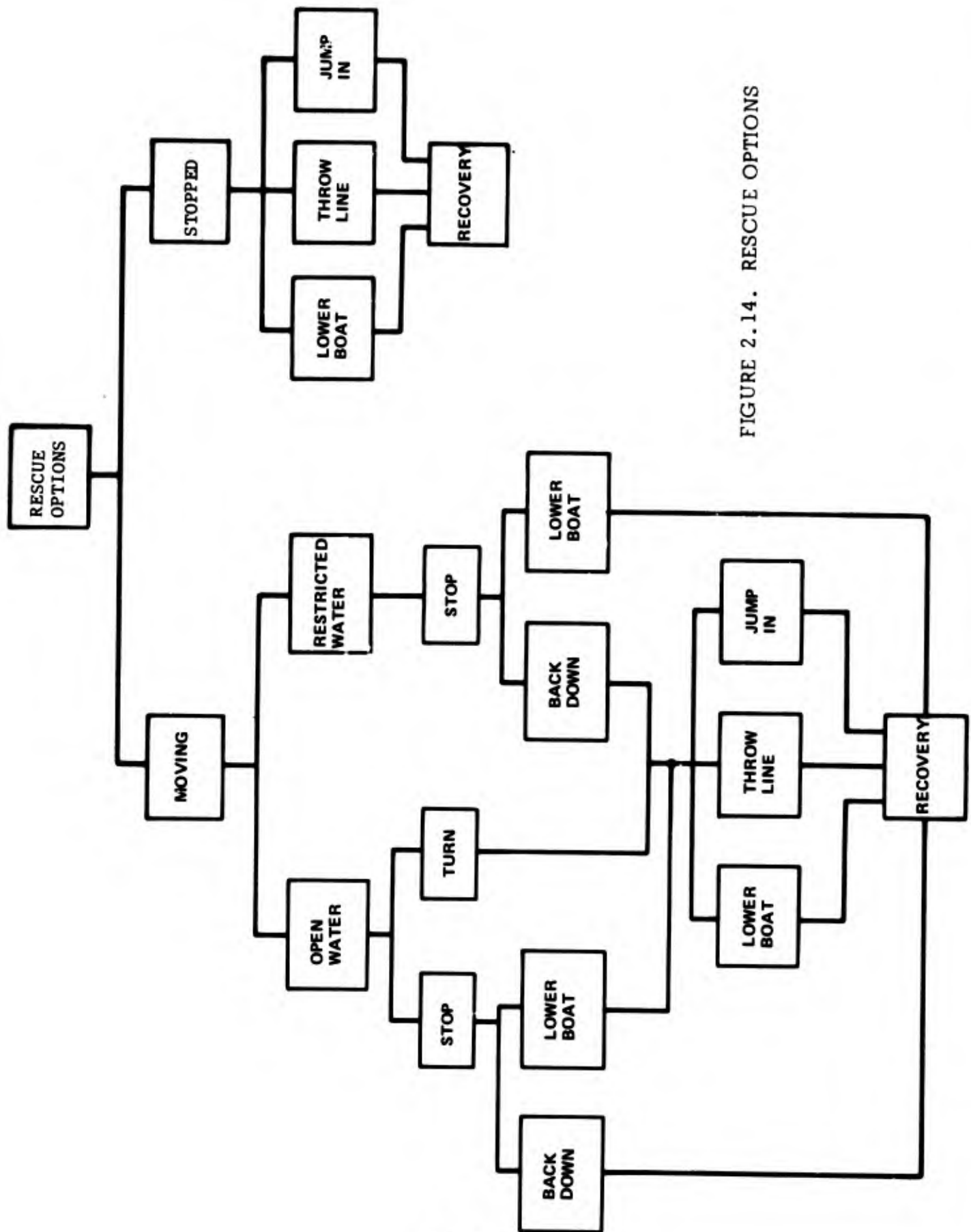


FIGURE 2.14. RESCUE OPTIONS

## 2. Open water case

● Hard turn plus stop	12 minutes
● Lower lifeboat	8 minutes
● Search and locate (estimate)	<u>5 minutes</u>
Total	25 minutes

Note that the total time for case 2 is slightly longer due to the extra time estimated for turning and slowing to a stop. The hard turn trial time data at full speed is eight minutes. Lifeboat search and locate time is reduced because the lifeboat should not have to travel far to locate the victim.

There may be some possibility of reducing total time if the lifeboat is readied for launch prior to stopping completely. This would require a well-drilled crew and at most could reduce the total time to 18 minutes in case 1 and 17 minutes in case 2. It is sobering to note that even at the lower figure, where time could be estimated, all 11 of the casualty cases would probably not have survived without some form of flotation device, and thermal protection in cold water.

### 2.4 SYSTEM REQUIREMENTS—SUMMARY

- Accident statistics emphasize the requirement for quick recovery of the victim if he is to survive. This dictates that:
  1. The fall overboard be detected immediately
  2. The master maneuver the ship to minimize rescue time
  3. The rescue team be well-drilled in the rescue operation
  4. The rescue team have a means of locating the victim under adverse weather and visibility.
- Accident statistics indicate that falls overboard can occur from a variety of locations on and around the ship. A MOS must be capable of detecting a high percentage of these casualties.
- Ship's systems must not interfere with a MOS by reducing its effectiveness or creating false alarms.
- A MOS should not interfere with ship operation in locks, at dockside, or during loading and unloading.
- A MOS must have a near-zero false alarm rate or it will not be used.
- Man-carried sensors must not burden the man in any way or they will not be carried.

## 3.0 DETECTION CONCEPTS AND TECHNIQUES

### 3.1 GENERAL BACKGROUND

There are two basic conceptual possibilities for a MOS. The first is the concept that the body has passed through a hazardous zone such as the region immediately outboard of the ship's rail. The second is that the body is in the water.

In the first case the body can be detected in several ways:

- Body contact with something mechanical that will close a switch, i.e. trip wire
- Body interference with a field
- Body interference with a beam.

In the second case a signal must be transmitted soon after the body hits the water. The signal can be either human-activated or water-activated. In both cases the transmitter must be attached to the user.

It is essential that the system has a near-zero false alarm rate and be adaptable to a seagoing environment.

### 3.2 SCOPE

There is a definite similarity between the requirements for burglar alarm systems and the requirements for a man-overboard alarm system. Each is designed to detect the presence of an intruder. The technology associated with intruder security systems has been the focal point of ORI's investigation.

Contact has been made with the suppliers and manufacturers of security systems to determine their application to a shipboard man-overboard alarm system. System specifications have been obtained for many of the systems and specification sheets have been developed which describe the technique, performance capabilities and factors which cause false alarms.

Other systems and techniques, not directly involved in security, are also included because of their applicability to a MOS.

### 3.3 DETECTION SYSTEM SPECIFICATIONS

This section contains specification sheets on each of the detection techniques investigated by ORI. This data has been obtained from telephone conversations with manufacturers and/or product brochures. The information, while incomplete in some areas, is sufficient to determine the applicability of the technique to a MOS. The techniques reviewed are listed as follows:

Capacitance

Closed Circuit Television (CCTV)

Infrared Beam

Laser

Magnetic (2 variations)

Mechanical (4 variations)

Microwave (3 variations)

Radar

Radio Frequency Transmission and Microwave Transmission

Sonar

Ultrasonic

Visible Light.

### 3.4 SYSTEM TRADEOFF

In this section each detection technique will be compared with the ship system requirements to determine if the technique is a practical candidate for a MOS. Tradeoff charts, Tables 3.1 and 3.2 have been developed as a means of selecting one or more detection techniques for further study and adaptation to a shipboard MOS. In Tables 3.1 and 3.2 the detection systems are divided into three types as follows:

## DETECTION SYSTEM SPECIFICATION SHEET: Capacitance

Principle of Operation: Variation of Capacitance

Source of Information: ADT Security Systems

Range:  $\leq 3 \sim 4$  inches

Place of Operation: Indoor only

Weather Condition: Not recommended for outdoor installation, very sensitive to humidity

False Alarm Potential: High in outside use

Detection Potential: Low-falling body may not have sufficient "ground potential" to trigger alarm

Reliability and Maintainability: Medium reliability and some maintenance required

Required Power: 115 VAC input

Weight and Volume: Unknown

Frequency: Unknown

Beamwidth: 360° field around wire

Source Location of Fall: Yes

Locate Victim in Water: No

Interference with Ship Operation: Possible, if installed outside spar deck rail

Ship Mounted Equipment List: Sensing wires, oscillator, amplifier and alarm

Crew Carried Equipment List: None

Remarks: When a person approaches the sensing wire, capacitance between the sensing wire and ground changes. The variation of capacitance changes the oscillating frequency, which can be detected and triggers the alarm. Since the system is quite sensitive, there is some possibility of false alarm. The body must be very close to the sensing wire to be detected.

## DETECTION SYSTEM SPECIFICATION SHEET: CCTV

Principle of Operation: TV monitoring

Source of Information: Mountain West/Security Product News

Range: Up to 1,000 feet

Place of Operation: Indoor and outdoor

Weather Condition: Fog, rain and darkness affect outdoor operation

False Alarm Potential: Low

Detection Potential: Unknown

Reliability and Maintainability: Average reliability and requires some maintenance

Required Power: 115 VAC, 11 watts (camera), 30 watts (monitor)

Weight and Volume: Camera (8" x 3-5/8" x 4-3/4", 4-1/2 lbs),  
Monitor (8.6" x 9.2" x 8.7")

Frequency: Unknown

Beamwidth: Wide angle and variable

Source Location of Fall: Yes, from a general area

Locate Victim in Water: No

Interference with Ship Operation: No.

Ship Mounted Equipment List: Camera, monitor, cable, alarm

Crew Carried Equipment List: None

Remarks: Specially-developed monitor shows the area under surveillance. Presence of an intruder changes the stationary pattern the monitor shows. The monitor electronically detects any changes caused by motion of the intruder and sets off alarm. The area must be lighted at night and during poor visibility.

## DETECTION SYSTEM SPECIFICATION SHEET: Infrared Beam

Principle of Operation: Infrared sensing beams

Source of Information: Mountain West catalogue/Arrowhead Enterprises, Inc.

Range: 500 to 1,000 feet

Place of Operation: Outdoor

Weather Condition: Weather will not affect system according to manufacturer

False Alarm Potential: Some possibilities from waves and heavy spray

Detection Potential: High

Reliability and Maintainability: Unknown for ship installation

Required Power: 115 VAC

Weight and Volume: 5-1/2" x 4-1/4" x 8"

Frequency: Unknown

Beamwidth: Narrow beam

Source Location of Fall: Yes, within range of single unit

Locate Victim in Water: No

Interference with Ship Operation: Possible, if installed outside the spar deck rail

Ship Mounted Equipment List: IR transmitter, receiver, supports, alarm

Crew Carried Equipment List: None

Remarks: Several parallel infrared beams are installed at the ship's rail similar to a fence. The body must interrupt one or more beams to set off alarm. The system is reported to be relatively free of false alarms from severe weather conditions.

## DETECTION SYSTEM SPECIFICATION SHEET: Laser

Principle of Operation: Laser beam - pulsed beam  
Source of Information: Data Optics Corp. - brochure  
Range: Up to 3 miles, 1,000 feet guaranteed under all weather conditions  
Place of Operation: Outdoor  
Weather Condition: Unaffected by rain or snow, fog will cause problems  
False Alarm Potential: Unknown for marine application  
Detection Potential: Good if contact is made with beam  
Reliability and Maintainability: Probably good, waterproof housing approved by USCG and ABS  
Required Power: 115 VAC  
Weight and Volume: Unknown  
Frequency: Unknown  
Beamwidth: Narrow beam  
Source of Location of Fall: Yes, within range of single unit  
Locate Victim in Water: No  
Interference with Ship Operation: Possible if installed outside spar deck rail  
Ship Mounted Equipment List: Transmitter, receiver, repeater units, alarm, supports  
Crew Carried Equipment List: None  
Remarks: Beams can be set up parallel to the ship's rail by using repeaters to position the beams in any new direction. Several beams may be required to ensure contact with the falling body. The beams form a protective boundary around the periphery of the spar deck or other area to be protected.

## DETECTION SYSTEM SPECIFICATION SHEET: Magnetic

Principle of Operation: Mutual inductance  
Source of Information: Magnetometric Devices, Inc.  
Range: 1 ~ 2 feet  
Place of Operation: Indoor and outdoor - airport metal detector  
Weather Condition: Independent  
False Alarm Potential: Very low  
Detection Potential: Detects relatively large metallic object  
Reliability and Maintainability: Very high reliability and little maintenance  
Required Power: 115 VAC input, power at primary coil is at least 100 watts  
Weight and Volume: Unknown  
Frequency: Unknown  
Beamwidth: Omnidirectional  
Source Location of Fall: Yes, within range of a single unit  
Locate Victim in Water: No  
Interference with Ship Operation: Possible, if installed outside spar deck rail  
Ship Mounted Equipment List: Primary and secondary coils, supports, detector, alarm  
Crew Carried Equipment List: Metallic object

Remarks: The primary and secondary coils are magnetically coupled. The presence of a metallic object alters the magnetic coupling and the secondary coil experiences induced voltage change. A voltage detector detects the voltage change and triggers the alarm. Primarily used for metal detection.

DETECTION SYSTEM SPECIFICATION SHEET: Magnetic

Principle of Operation: Magnetic field - tags and labels

Source of Information: General Nucleonics, Inc. - brochure

Range: 1-2 feet

Place of Operation: Threshold operation

Weather Condition: Independent

False Alarm Potential: Unknown

Detection Potential: Unknown

Reliability and Maintainability: Assumed high reliability, low maintenance

Required Power: Unknown

Weight and Volume: Tags are small pins or brooches

Frequency: Unknown

Beamwidth: Omnidirectional

Source Location of Fall: Yes, within range of a single unit

Locate Victim in Water: No

Interference with Ship Operation: Possible, if installed outside of spar deck rail

Ship Mounted Equipment List: Threshold detector, supports, detector, alarm

Crew Carried Equipment List: Tag

Remarks: Used as anti-shoplifting devices. Tags are attached to merchandise. If tags not removed by sales clerk alarm will sound when item is carried out through threshold detector.

DETECTION SYSTEM SPECIFICATION SHEET: Mechanical

Principle of Operation: Electromechanical (Trip-wire)

Source of Information: None

Range: Limited by length of wire

Place of Operation: Indoor and outdoor

Weather Condition: Temperature affects the false alarm probability

False Alarm Potential: Some possibilities from wind and waves

Detection Potential: Man must contact wire to trigger alarm

Reliability and Maintainability: Very high reliability and virtually free of maintenance

Required Power: 1.5 VDC

Weight and Volume: Light and compact

Frequency: None

Beamwidth: None

Source Location of Fall: Yes, within range of single unit

Locate Victim in Water: No

Interference with Ship Operation: Possible, if installed outside spar deck rail

Ship Mounted Equipment List: Taut wire, spring, switch, support, alarm

Crew Carried Equipment List: None

Remarks: A temperature compensating component is necessary to minimize false alarm due to the temperature change. More than one wire will be required to ensure body contact.

## DETECTION SYSTEM SPECIFICATION SHEET: Mechanical

Principle of Operation: Strain measurement

Source of Information: Systron Donner Corp.

Range: Similar to trip-wire installation

Place of Operation: Outdoor

Weather Condition: Independent

False Alarm Potential: Low

Detection Potential: High if body contacts wire

Reliability and Maintainability: Should be high reliability and low maintenance

Required Power: Minimal

Weight and Volume: Light, compact

Frequency: None

Beamwidth: None

Source Location of Fall: Yes, with proper design

Locate Victim in Water: No

Interference with Ship Operation: Possible, if installed outside spar deck railing

Ship Mounted Equipment List: Wire, detectors, strain gages and supports, alarm

Crew Carried Equipment List: None

Remarks: This device will sense the strain in a trip wire. Other strain sensors on market will sense strain in window glass and loaded surfaces. Surface application not practical for ship installation. Several wires, similar to a fence, will be required to ensure body contact.

DETECTION SYSTEM SPECIFICATION SHEET: Mechanical

Principle of Operation: Electromechanical (hydraulic)

Source of Information: **None**

Range: Limited by length of tube

Place of Operation: Indoor and outdoor

Weather Condition: Independent

False Alarm Potential: Low

Detection Potential: Man must contact to trigger alarm

Reliability and Maintainability: Very high reliability and medium maintenance

Required Power: 1.5 VDC

Weight and Volume: Depends on tube diameter

Frequency: None

Beamwidth: None

Source Location of Fall: Yes, within range of a single unit

Locate Victim in Water: No

Interference with Ship Operation: Possible, if installed outside spar deck rail

Ship Mounted Equipment List: Rubber or plastic tube pressurized with liquid,  
hydraulic switch, supports, alarm

Crew Carried Equipment List: None

Remarks: Pressurized liquid activates the hydraulic switch, which sets off the alarm. Tube must be installed parallel to ship's rail in order to ensure body contact. More than one tube will be required.

DETECTION SYSTEM SPECIFICATION SHEET: Mechanical

Principle of Operation: Net or fence

Source of Information: None

Range: Limited by length of fence

Place of Operation: Outdoor

Weather Condition: Independent

False Alarm Potential: Low

Detection Potential: High if area covered ensures contact

Reliability and Maintainability: High reliability - low maintenance

Required Power: 1.5 VDC

Weight and Volume: Typical of 5' high wire farm fence

Frequency: None

Beamwidth: None

Source Location of Fall: Yes, within range of a single unit

Locate Victim in Water: No

Interference with Ship Operation: Possible, if installed outside of spar deck rail

Ship Mounted Equipment List: Fence, supports, switches, alarm

Crew Carried Equipment List: None

Remarks: Acts both as a fall preventor and alarm system. System can indicate location on ship where accident occurred. This system is too complex mechanically for spar deck where rails are removable.

## DETECTION SYSTEM SPECIFICATION SHEET: Microwave (Field Disturbance)

Principle of Operation: Disturbance of stationary microwave field

Source of Information: Advanced Devices Laboratory, Inc.

Range: 500 to 1,000 feet

Place of Operation: Outdoor

Weather Condition: Independent

False Alarm Potential: Not affected by heavy rain, fog, snow or wind

Detection Potential: Quite high in 50' to 500' range

Reliability and Maintainability: Unknown for seagoing systems

Required Power: 3.0 watt for transmitter, 1.5 watts for receiver

Weight and Volume: 7.5# plus mount, 16" long x 5.5" diameter

Frequency: ~ 10.5 GHz

Beamwidth: Maximum width is 26' for 1,000' range

Source Location of Fall: Yes, but not very precise if beam range is large

Locate Victim in Water: No

Interference with Ship Operation: Possible, if installed outside spar deck rail

Ship Mounted Equipment List: Microwave transmitters, receivers, supports  
and alarm

Crew Carried Equipment List: None

Remarks: Microwave gives a stationary field pattern at the receiver. Movement of an intruder disturbs the microwave field pattern, which can be detected by the signal processor in the receiver and triggers alarm. There is a possibility of false alarm due to heavy spray and waves.

## DETECTION SYSTEM SPECIFICATION SHEET: Microwave (Reradiation)

Principle of Operation: Reradiation of microwave energy

Source of Information: Sensormatic Electronics Corp. and Fairchild Space and Electronics Co.

Range: 10 - 20 feet

Place of Operation: Entrance (indoor and outdoor), or highway vehicle counter

Weather Condition: Independent

False Alarm Potential: Portable radios and pacemakers will trigger

Detection Potential: Human body will shield sensor from microwave field

Reliability and Maintainability: Estimate reliable and easy maintenance

Required Power: AC power

Weight and Volume: Department store tag is 4-1/2" x 1-1/4" x 1/4", highway tag is 5" x 4" x 1/2", weighs 0.4 lbs.

Frequency: 915 MHz and 50 kHz

Beamwidth: Unknown

Source Location of Fall: Yes, precise location due to limited range between sensors

Locate Victim in Water: No

Interference with Ship Operation: Possible, if system mounted outside of spar deck rail

Ship Mounted Equipment List: Transmitters, receivers, supports, alarm

Crew Carried Equipment List: Sensor tag carried by each crewman. The tag is small and lightweight.

Remarks: As the sensor tag passes thru the microwave and static field, the nonlinear effect of the diode in the sensor tag produces reradiation of microwave energy. The reradiated energy is received by the receiver and processed for signal detection.

DETECTION SYSTEM SPECIFICATION SHEET: Microwave (Doppler)

Principle of Operation: Microwave Doppler motion detection

Source of Information: Mountain West catalogue

Range: 3 ~ 40 feet

Place of Operation: Indoor use

Weather Condition: Independent

False Alarm Potential: Low

Detection Potential: High

Reliability and Maintainability: Quite reliable and easy to maintain - not recommended for ship applications

Required Power: 12 VDC and 70 mA

Weight and Volume: 4-1/2' x 3-1/2" x 3"

Frequency: 915 MHz

Beamwidth: Omnidirectional

Source Location of Fall: Yes, within range of a single unit

Locate Victim in Water: No

Interference with Ship Operation: Possible, if installed outside spar deck rail

Ship Mounted Equipment List: Detector, power supply, supports, alarm

Crew Carried Equipment List: None

Remarks: Slow motion of an intruder reflects microwave. The frequency of the reflected wave shifts when the reflecting body moves toward or away from the microwave source. This system also contains a signal processing unit to prevent false alarm which might be caused by small and fast moving objects on lightning impulses.

## DETECTION SYSTEM SPECIFICATION SHEET: Radar

Principle of Operation: Radar interrogation of transponder

Source of Information: Raytheon Corp. and Hazeltine Corp.

Range: 2 miles

Place of Operation: Outdoor

Weather Condition: Independent

False Alarm Potential: Low

Detection Potential: High

Reliability and Maintainability: Unknown

Required Power: Unknown

Weight and Volume: Unknown

Frequency: Unknown

Beamwidth: Omnidirectional transponder

Source Location of Fall: Yes, if signal can be received from uncertainty zone

Locate Victim in Water: Yes

Interference with Ship Operation: None

Ship Mounted Equipment List: Secondary radar or modification to ship's radar, alarm

Crew Carried Equipment List: Transponder - size unknown

Remarks: Transponder carried by crewman will be activated when the victim hits the water. The radar will receive the coded signal and sound alarm. The radar will be used to locate the victim and guide the rescue party.

This is not an off-the-shelf system and requires development before the system specifications can be defined.

DETECTION SYSTEM SPECIFICATION SHEET: Radio Frequency Transmission  
and Microwave Transmission

Principle of Operation: System 1—Interruption of a continuous signal  
System 2—Activation of a signal

Source of Information: Various

Range: 200 feet to 2 miles depending on power

Place of Operation: Outdoor

Weather Condition: All weather

False Alarm Potential: Low

Detection Potential: High

Reliability and Maintainability: High reliability and very little maintenance  
for System 2. Increased reliability and main-  
tenance problems with System 1 due to increased  
operation.

Required Power: Transmitter: Battery, Receiver: 115 VAC

Weight and Volume: Transmitter can be carried in shirt pocket, cigarette pack  
size.

Frequency: Radio frequency range/Microwave range

Beamwidth: Omnidirectional for transmitter, both omnidirectional and directional  
for receiver

Source Location of Fall: Yes, function of directional capabilities of receiving  
antenna

Locate Victim in Water: Yes

Interference with Ship Operation: None

Ship Mounted Equipment List: Receiver, antennas and alarm

Crew Carried Equipment List: Transmitter, pocket size

Remarks: System 1—Transmitter carried by each crewman transmits signal con-  
tinuously on a unique frequency. If a crewman falls into the water, the signal  
transmission is stopped, and alarm is triggered. Simultaneously, the trans-  
mitter starts transmitting a signal on a unique frequency, which distinguishes  
an accident from a false alarm and helps in locating the victim. Problems can  
occur with this system when a crewman inadvertantly carries the transmitter  
below deck and signal is lost or he goes out on deck and neglects to turn the  
transmitter on. Continuous transmission will require that the batteries be re-  
placed frequently and servicing will be required more often than System 2.

DETECTION SYSTEM SPECIFICATION SHEET: Radio Frequency Transmission  
and Microwave Transmission  
(Continued)

Remarks: System 2—Transmitter carried by crewman has water activated switch and transmits only if man is in water. Transmitter is inactive most of its lifetime except for routine testing. This system is not affected by a crewman going below deck or neglecting to turn it on as in System 1. System 2 is the more practical alternative.

## DETECTION SYSTEM SPECIFICATION SHEET: Sonar

Principle of Operation: Underwater Acoustic Transmission

Source of Information: Bayshe System Corp. and EDO Western Corp.

Range: 100 yards to 2 miles

Place of Operation: Underwater

Weather Condition: All weather

False Alarm Potential: Low

Detection Potential: High

Reliability and Maintainability: High reliability and easy maintenance

Required Power: Battery power for acoustic transmitter, 115 VAC for receiver

Weight and Volume: Acoustic transmitter (2.6" dia. x 2"), Hydrophone (1.5" dia. x 5") Receiver (15" x 10" x 4")

Frequency: 50 ~ 90 kHz, 38 kHz

Beamwidth: Transmitter: omnidirectional, Hydrophone: omnidirectional,  
Portable hydrophone: directional

Source Location of Fall: Yes, with directional hydrophone

Locate Victim in Water: Yes, with either ship mounted or portable directional hydrophone

Interference with Ship Operation: None

Ship Mounted Equipment List: Hydrophones, receiver, alarm, stowage for portable hydrophone and receiver

Crew Carried Equipment List: Acoustic transmitter, pocket size

Remarks: If a crewman falls into the water, the acoustic transmitter is activated by water contact and starts transmitting an acoustic signal. The acoustic receiver on the vessel receives the signal and triggers alarm. Since this system uses an underwater acoustic wave as the signal, signal transmission is always guaranteed. The acoustic transmission will help locate the victim in the water. One possible limitation is that there is a possibility of false alarm and/or no detection from certain locations behind the ship due to underwater noise such as propeller noise and vessel self-noise.

DETECTION SYSTEM SPECIFICATION SHEET: Ultrasonic

Principle of Operation: Ultrasonic

Source of Information: Mountain West catalogue

Range: 5 ~ 30 feet

Place of Operation: Indoor - not recommended outdoor

Weather Condition: Indoor use only, sensitive to air movement

False Alarm Potential: Some false alarm probabilities

Detection Potential: Very high

Reliability and Maintainability: Quite reliable, some maintenance efforts  
are required

Required Power: 110 VAC

Weight and Volume: 9-1/2" x 4-1/8" x 1-1/8"

Frequency: 20 kHz ~ 50 kHz

Source Location of Fall: Yes, within range of a single unit

Locate Victim in Water: No

Interference with Ship Operation: Possible, if installed outside of spar deck  
rail

Ship Mounted Equipment List: Transmitter, receiver, supports and alarm

Crew Carried Equipment List: None

Remarks: Ultrasonic waves from the transmitter propagate to all parts of the closed room. At the receiver, the received ultrasonic wave is a standing wave consisting of the direct and reflected wave. Slight frequency shift caused by intruder movement is detected and activates the alarm.

DETECTION SYSTEM SPECIFICATION SHEET: Visible Light

Principle of Operation: Visible light sensing

Source of Information: Three B Electronics, Inc.

Range: Unknown

Place of Operation: Indoor, not recommended outdoor

Weather Condition: Not recommended for outdoor use

False Alarm Potential: High possibility, from spray and waves

Detection Potential: High

Reliability and Maintainability: High reliability and easy maintenance

Required Power: Unknown

Weight and Volume: Unknown

Frequency: Unknown

Beamwidth: Narrow beam

Source Location of Fall: Yes, within range of a single unit

Locate Victim in Water: No

Interference with Ship Operation: Possible, if installed outside of spar deck rail

Ship Mounted Equipment List: Light source, detector, supports, alarm

Crew Carried Equipment List: None

Remarks: To cover an obstructed area, many mirrors are required to route the light beam. There are some possibilities of false alarm when the mirrors are out of alignment or become dirty.

- Beam Systems. A beam must be broken by the body to trigger the alarm.
- Mechanical Systems. There are a variety of mechanical devices that could be used to sense the falling body; all require body contact.
- Area Systems. These systems create a field which senses the presence of the victim within an area.

Table 3.1 represents initial tradeoff decisions. Those techniques that are not feasible for a marine application or MOS application are omitted from further consideration. Table 3.2 compares the characteristics of the remaining detection techniques to the ship system requirements. Only those techniques that passed the initial tradeoff are considered. The first three columns of Table 3.2 list the areas on and around the ship that are covered by each technique should a fall overboard take place in one of the three listed areas. The Required Ship Modification column refers to the magnitude of the installation of a system, i.e. foundations and attachments to the ship for mounting equipment, alterations to ship structure, and installation of equipment and antennas in the bridge area. The next column, Interference With Ship Operation, refers to the added work required due to a MOS, i.e., removal of equipments mounted outboard of the hull when transiting a lock, removal of a rail installation during loading and unloading. The Sensor Location column addresses both the area coverage parameter and the human factors problem. The ship mounted sensors are limited, in the fall overboard area protected, and as a result have reduced effectiveness.

The man-carried sensors are the most effective in terms of area coverage but, are somewhat encumbering to the crewman. The extent of the encumbrance or inconvenience is a function of the size and weight of the device. The next column is an estimate of the maintenance requirements. Those systems that are ship mounted near or outboard of the rail are subject to severe environmental conditions and are assumed to require high maintenance. Those devices that are carried by crewmen are stowed inside the ship for most of their life and are not required to operate until a fall overboard occurs. These devices are considered to require minimal maintenance. Items of equipment that are installed on the bridge are considered equal in maintenance requirements for all systems under consideration. The next column, In-water Direction Sensing, refers to the capacity of a MOS to assist in the rescue operation by providing a direction finding capability in addition to the initial detection and alarm. The last column identifies the optimum systems.

TABLE 3.1  
INITIAL TRADEOFF CHART

Detection Type	Marine Application	Remarks	MOS Application
Beam Type			
1. Visible	no	Rendered inoperative by bright sunlight	no
2. Laser	yes	Rail installation provides perimeter protection	yes
3. Infrared	yes	Rail installation provides perimeter protection	yes
Mechanical			
1. Electromechanical	yes	Rail installation of wires or fence required for perimeter protection—too complex	no
2. Strain	yes	Rail installation of wires or fence required for perimeter protection—too complex	no
3. Hydraulic	yes	Rail installation of pressure tube required for perimeter protection—too complex	no
4. Fence	yes	Rail installation—perimeter protection both prevention and alarm—too complex	no
Area Type			
1. Ultrasonic	no	Rendered inoperative by air turbulence	no
2. Microwave Field	yes	Rail installation provides perimeter protection	yes
3. Microwave Transmission	yes	Transmitters carried by crewmen	yes
4. Capacitance	yes	Rail installation of wire grid required for perimeter protection—too complex	no

TABLE 3.1 (Continued)

Detection Type	Marine Application	Remarks	MOS Application
5. Radio Frequency	yes	Transmitters carried by crewmen	yes
6. Radar	yes	Transponder carried by crewmen	yes
7. Acoustic (sonar)	yes	Acoustic transmitter carried by crewmen	yes
8. Microwave Re-radiation	yes	Man carried tag-body can shield tag from sensor field	no
9. CCTV	yes	Requires monitor, lights at night-too complex	no
10. Magnetic (tags)	yes	Threshold sensors must be installed every 2' of deck perimeter-too complex	no
11. Magnetic (mutual inductance)	yes	Threshold sensors must be installed every 2' of deck perimeter-too complex	no

TABLE 3.2  
MOS SELECTION CHART

DETECTION TYPE	SHIP SYSTEM REQUIREMENTS									
	Accident Area Covered			Required Ship Modification	Interference With Ship Operations	Sensor Location	Estimated Maintenance Requirements	In Water Direction Sensing	Selection System	
	Rail	Ladder	Ship Vicinity							
Beam Type										
1. Laser	yes	yes	no	medium	medium	Rail installation restricts system coverage to ship perimeter	high	no		
2. Infrared	yes	yes	no	medium	medium		high	no		
Area Type										
1. Microwave Field	yes	no	no	medium	medium	Rail installation restricts system coverage to ship perimeter	high	no		
2. Microwave Transmission	yes	yes	yes	slight	none	Man carried device has area coverage potential. Accident can happen from ship or vicinity of ship, i.e.: dock, barge, ladder, etc.	low	yes		x
3. Radio Frequency Transmission	yes	yes	yes	slight	none		low	yes		x
4. Radar	yes	yes	yes	slight	none		low	yes		x
5. Acoustic (Sonar)	yes	yes	yes	slight	none		low	yes		x

### 3.5 SYSTEM SELECTION

Only seven of the techniques meet requirements of the initial trade-off screening process. All the others are either not effective outdoors, have minimal ranges or are too complex to be practical. The seven candidates will be analyzed in detail to determine those that are most effective.

#### 3.5.1 Laser and Infrared Systems

These two systems will be discussed as one since they both operate on the beam breaking principle. The system would consist of a series of parallel beams located just outboard of the ship's rail and parallel to it. Interruption of any one of the beams by a falling body will trigger the alarm.

This system has many of the problems associated with the microwave field. It must be set up outboard of the ship's rail and will be exposed to damage from waves. It may require removal during transit through locks and while docking.

Alternatively, the rail can be relocated inboard several feet to allow installation of the beam equipment inboard of the side of the ship as shown in Figure 2.13b.

Accident area coverage is limited to the perimeter of the ship and possibly the boarding ladder. The boarding ladder installation could be the cause of many false alarms. It is estimated that there will be medium interference with ship operation and the system will require medium modification to the ship for mounting the beam transmitters and receivers. There is no direction finding capability and maintenance is estimated to be high due to the exposed location of the units.

#### 3.5.2 Microwave Field

This is a perimeter protection type of system and has good potential for normal outdoor use. Outdoor systems of this type are presently in use in military installations, warehouse areas, etc. They have not been used in a ship environment. The false alarm rate is expected to be low and the system has an advertised range between transmitter and receiver of 1,000 feet. This makes the microwave field technique a definite possibility for a man overboard detection system.

As presently envisioned the system would be set up outside the ship's rail. A microwave field is set up between transmitter and receiver that is parallel to the deck edge or ship's rail and senses the presence of an intruder or falling body. Unfortunately, the field width increases from approximately zero at the transmitter and receiver to 26 feet at the midpoint, based on a 1,000-foot installation. This means that the transmitter and receiver must be mounted off the side of the ship at a distance of 13 feet to prevent accidental alarms from crewmen working or standing near the rail.

Another solution is to mount the sensors approximately five feet off the side of the ship, but below the deck edge as shown in Figure 2.13a. This in effect provides a one-sided field below the spar deck which will detect the falling body, but will not interfere with on-deck activity. Unfortunately, this places the units close to the water surface where false alarms from waves and heavy spray may become a problem. It also increases the potential for damage to the units themselves. In general, devices that are mounted outboard of the ship's sides are subject to damage from a variety of sources. They may also require removal when transiting locks or docking.

A third installation technique would be to move the rail inboard from the deck edge a sufficient distance to permit the installation of sensors inboard of the deck edge as shown in Figure 2.13b. This may be impractical for the microwave system since the rail would have to be moved in about 13 feet.

Accident area coverage of the microwave field is limited to the perimeter of the ship. It may be possible to install two units along each side of the ladder for additional coverage, but this is not a practical application of the system due to the short range and concentrated activity in the area of the ladder. Anyone approaching the side of the ladder from the dock will trigger an alarm.

Ship modification is rated as medium due to the requirement for unit supports along the side of the ship. Maintenance is estimated as high due to the exposed location of the sensors. The microwave system has no capability for in-water direction sensing.

Because of the problems listed above this system has a relatively low effectiveness rating and will be dropped from further consideration.

### 3.5.3 Radio Frequency Transmission and Microwave Transmission

These two systems are almost identical and will be treated as a single system in the following discussion. The most practical system consists of a transmitter which transmits a pulsed CW signal on contact with water. Each crewman must carry one of these transmitters while on deck or working in the vicinity of the ship. The system has complete accident area coverage because it triggers the alarm when the victim falls in the water. The location of the accident does not matter as long as it occurs within the range of the receiver. Ship modifications are minimal consisting of a receiver and an alarm mounted on the bridge and a receiving antenna. No interference is anticipated with the ship operation. The level of maintenance requirements will be a function of the shelf life of the batteries. The transmitting device which is stowed inside the ship when not being used should preclude hardware reliability problems. The system has direction finding capabilities for quickly locating the victim in the water. A direction finder can be mounted on the ship and/or hand-carried for search operations from a life boat.

One drawback is that the man must carry the transmitter on his person. At the very least this is an inconvenience to the crewman and at the worst a disturbing encumbrance depending on the weight and size of the device. The units get larger and heavier as transmission range is increased.

One unknown still exists regarding the transmission of a submerged transmitter through the water-air interface. It is assumed that the device will be attached to the belt of the man treading water and must broadcast from a depth of about one to two feet or have an antenna deployed above the water surface. One of ORI's contacts, Scan Security Systems, Inc., has tested their TPH-10 transmitter in a swimming pool. The transmitter which is used commercially as a garage door opener was enclosed in a glass jar to make it water-tight and submerged to a depth of four feet in a backyard swimming pool. The signal was received at a range of 200 feet from the pool by a portable receiver. The devices rated-range is 200 feet in air. Transmitter specifications are as follows:

- Carrier Frequency      225-310 MHz
- Coding Tone              17-32 KHz
- Power Supply            15 volt battery
- Dimension                1-3/4" x 2-3/4" x 7/8"
- Weight                    1-3/4 ounces.

Regardless of this test, the transmission of an RF signal from beneath the water surface must be further investigated.

#### 3.5.4 Radar System

This system will provide complete area coverage and will sound the alarm regardless of where the fall overboard takes place as long as it is within range of the transmitted signal. Each crewman must carry a **transponder which** is activated when he hits the water. This system is similar to the Air Traffic Control Radar Beacon System (ATCRBS) presently in use by the FAA and the military. The ATCRBS is representative of the current state of the art. The equipment is relatively large and long-range (200 miles). The adaptation of this technique to a MOS would require a design and development effort to prove feasibility.

Assuming that this is a feasible MOS system the ship modifications are expected to be minimal consisting of a modification to the ship's radar or the installation of a secondary radar unit plus an alarm unit and antenna. No interference is anticipated with normal ship operation. Maintenance requirements are expected to be comparable to other active RF Systems. The transponder is battery powered and water activated and its maintenance requirements should be similar to the RF and Sonar Systems. The system has direction finding and range capabilities via the radar screen. It is anticipated that there

will be a dead area or uncertainty zone around the ship which may create a detection problem while the ship is anchored or at the dock.

Each crewman must carry a transponder on his person. At this stage in ATCRBS development information could not be obtained on the predicted size and weight of such a device. The people that ORI contacted regarding this system are all in agreement that the transponder antenna would have to project above the water surface. This means that the crewman must erect the antenna or it must be deployed automatically. Both the RF and Microwave transmitters will probably require the same antenna development effort.

#### 3.5.5 Acoustic (Sonar)

This system is inherently a marine system and similar in operation and effectiveness to the system described in the previous section. It is water-activated and will trigger an alarm anywhere within the range of the device which is advertised to be two miles. There is no interference with ship operation and modifications are minimal consisting of installation of a hydrophone, receiver, and alarm. Maintenance requirements are estimated to be low because the unit is designed as a seagoing system and is not required to operate except for testing and in case of an accident. There are two commercial versions of this system, one is used for tracking fish and the other is used by divers to mark underwater positions. It has direction finding capabilities. The diver unit is portable, consisting of a pinger which is 2.6" in diameter and 2" thick, a hand held receiver with directional probe and miscellaneous gear useful to a diver. The pinger is designed for a submergence depth of 600 feet and will operate (ping) for ten days. Redesign for a lesser depth (50 feet) and reduced life (24-hours) should significantly reduce the unit's size and weight. The divers unit is advertised as "fully qualified by the U.S. Navy."

The only problem with this system is that the man must carry the pinger while on deck or working around the ship. The pinger is quite small for the 2-mile transmission range and should not be too serious an inconvenience. The effects of ship self-noise and wake turbulence on signal strength must be investigated.

#### 3.5.6 Summary

The three detection systems that demonstrate the most effectiveness and capability are:

- Radio Frequency Transmission and Microwave Transmission
- Radar
- Acoustic Sonar.

The principal reasons for the selection of these three techniques are:

- In-water direction sensing
- Minimal effects on ship
- Provide total accident area coverage.

## 4.0 MAN-OVERBOARD SYSTEM DESCRIPTIONS

### 4.1 INTRODUCTION

In this section the three basic Man-Overboard Systems will be described. The three systems are the combined Microwave and RF Transmission Systems (referred to as the RF System), the Sonar System and the Radar System. These systems are intended to provide the following basic capabilities:

- Detect and locate a man-overboard while underway in any weather, day or night, with a location range, from the vessel, of 2500 yards
- Detect a man-overboard while the vessel is anchored or berthed at a pier in any weather, day or night
- The system, when implemented, must not result in excessive interference with the normal activities of crew members.

The three systems addressed will be described in terms of the coverage they provide, equipment configurations, equipment specifications; operational characteristics, and design problems/tradeoffs.

The descriptions given can be considered "conceptual designs." Prior to implementation these designs must be "iterated" several times to achieve a final detailed design.

Basic to both the RF and Sonar Systems is the use of omnidirectional antennas/transducers for detecting the initial man-overboard signal during the times the ship is at anchor or at the dock. When the ship is underway the directional antenna/transducer will be pointed aft to pick up any signal originating from behind the ship which will be the logical position of the victim soon after falling overboard. The high gain of the directional antenna will be useful in tracking the weakening signal as the distance between the ship and the victim increases. After the ship has come to a stop the directional antenna/transducer will be used to guide the rescue party back to the victim.

## 4.2 SYSTEM DESCRIPTIONS

### 4.2.1 RF System 1

The first system uses transmissions from a miniature transmitter, carried by a crew member, to detect that he has fallen overboard and to locate his position. System 1 utilizes a steerable ( $360^{\circ}$ ) antenna for detection and location underway. While underway the antenna is pointed directly aft providing a detection zone is shown in Figure 4.1. The uncertainty zone shown in Figure 4.1 is a region close to the vessel where because of the possibility of "RF shadowing effects" due to the sides of the vessel, good reliable reception of signals from the transmitter is questionable. Note that tests should be conducted to verify the existence or non-existence of this zone. In any event, if a man falls overboard while the vessel is underway he will eventually enter the detection zone shown. The time required for him to enter this zone will depend on the speed of the vessel and the height of the antenna.

Once the man enters this zone and is detected, the vessel must begin some rescue maneuvers. It is assumed here that the vessel will require approximately one-mile to stop and come about thus the transmission link between the emitter and the vessel must be adequate for a range of 2500 yards (allowing for some margin). While maneuvering to recover the man in the water, the system must allow for a continuous link between the emitter and the vessel. Thus the antenna must have a  $360^{\circ}$  steering capability. Note that with RF System 1, the technique for recovery is simply Radio Direction Finding (RDF). That is the vessel "homes-in" on the man in the water.

While the vessel is berthed or at anchor, RF System 1 will rely on a separate antenna for detection only. Location would be achieved by disposing crew members to assigned locations on the vessel to look for the man in the water once an alarm has sounded. The antenna coverage for this case is shown in Figure 4.2.

In addition to the miniature transmitter carried by crew members, RF System 1 would consist of the equipment shown in Figure 4.3. As shown in the Figure there are two antennas one for use underway and one for use while anchored or berthed at a pier. The underway antenna could be a log-periodic

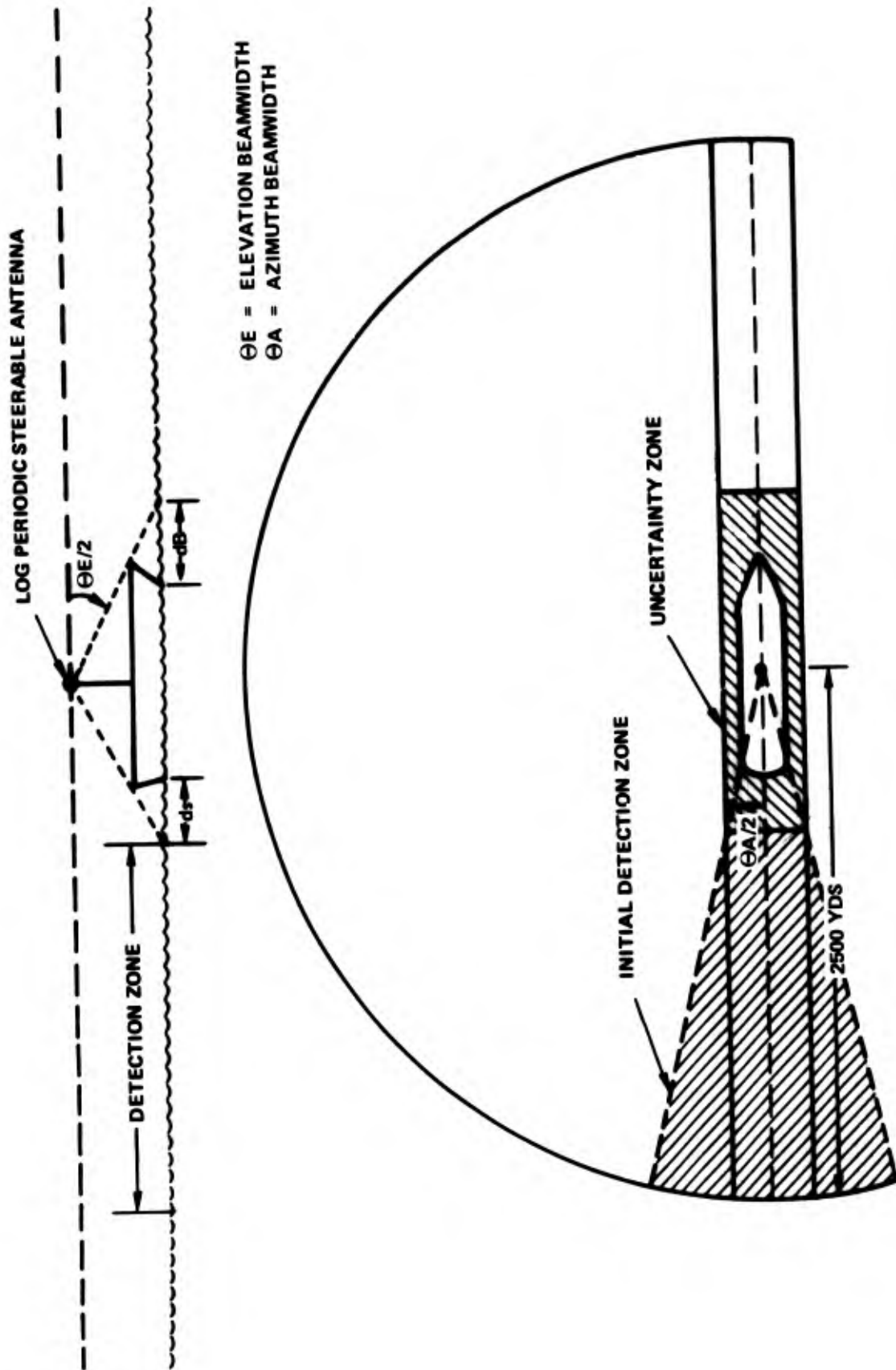


FIGURE 4.1. RF SYSTEM 1 COVERAGE UNDERWAY

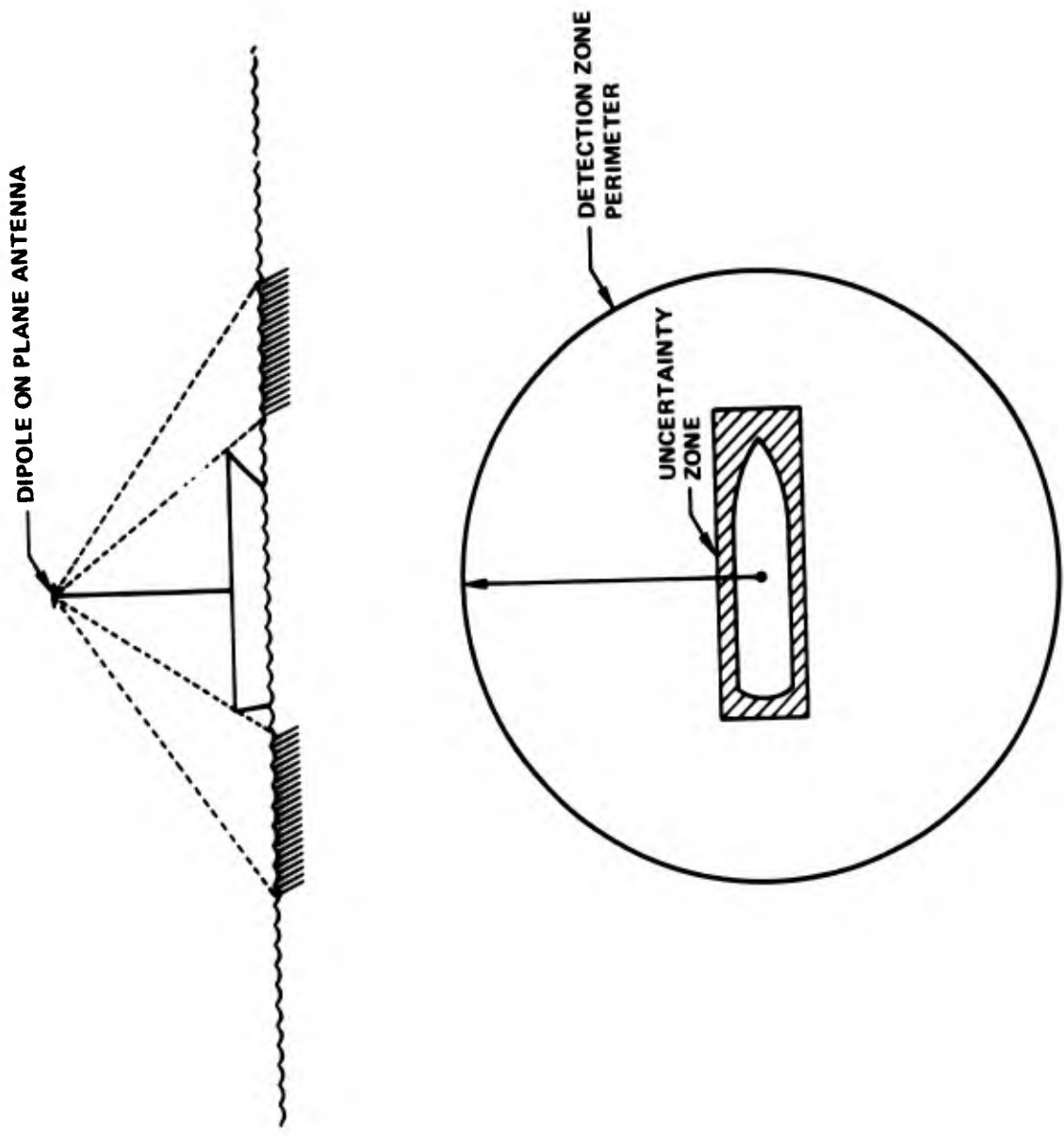


FIGURE 4.2. RF SYSTEM 1 COVERAGE AT ANCHOR OR TIED-UP

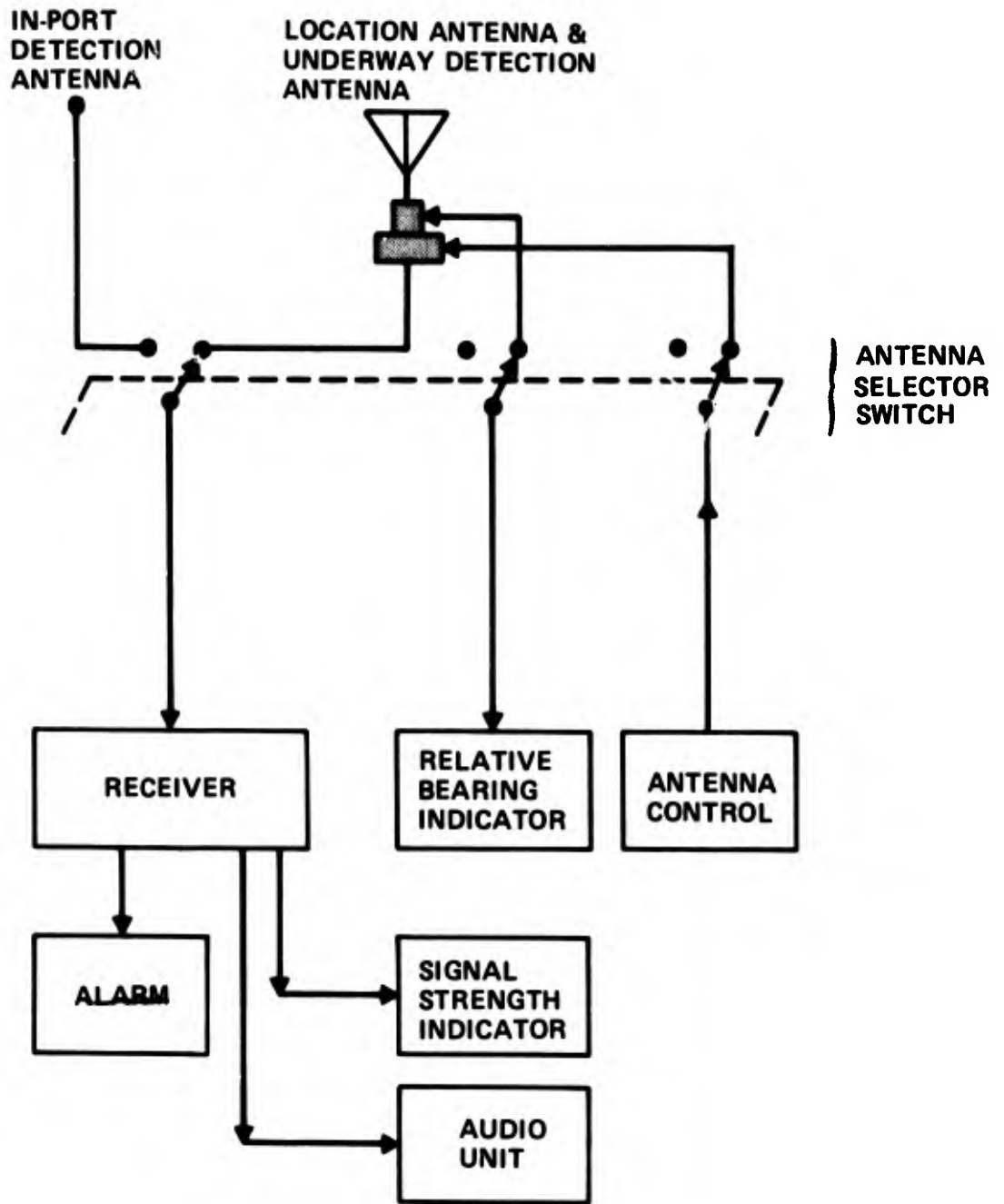


FIGURE 4.3. RF MOS SYSTEM 2

type antenna similar to commercial T.V. antennas and should be relatively inexpensive. Also the steering mechanism for the antenna could be a standard antenna rotor if compatible with a marine environment. The rotor must be calibrated to provide relative bearing information so that location of the man in the water relative to ships heading will be known. The inport antenna might be a dipole with a ground plane. Note the need to switch between antennas. The receiver type used will depend on the modulation used by the emitter. As shown in Figure 4.3, it must be capable of receiving and demodulating the emitter signal and, in turn, driving an alarm unit, a signal strength meter and an audio unit. The alarm unit would be a bell or siren to sound the alarm. The signal strength meter would be used to indicate when the signal is at maximum which in turn corresponds to the direction (antenna bearing) of the man in the water. The audio unit would provide an audible tone when a distress signal is present. Such devices sometimes aid in the locating process particularly when the signal is temporarily lost. All of the equipment shown in Figure 4.3, exclusive of the antennas would be centrally located on the vessel, perhaps on the bridge. The antennas would be located on a mast as close to the center of the vessel as possible and as high as possible. On lakes vessels with superstructures located fore and aft a duplicate set of antennas may be desirable.

#### RF System 1 Equipment Specifications

RF System 1 will consist of the following basic equipments:

- In-Port Detection Antenna
- Underway Location and Detection Antenna
- Antenna Selector Switch
- Receiver
- Alarm Unit
- Audio Unit
- Signal Strength Indicator
- Relative Bearing Indicator
- Antenna Control Unit
- Emitter.

The in-port antenna should provide a gain/directivity pattern which provides the coverage shown in Figure 4.2. A dipole antenna with a ground plane may be sufficient; however, it must be realized that the gain of this antenna, among other things, will determine the required transmit power of the emitter which in turn determines the physical size of the emitter. Since the emitter must be carried by each crew member it is important that it be as

small and as lightweight as possible. This dictates a study of antenna performance versus emitter size for selection of the optimum combinations. Such an antenna should be available, in production quantities, for under \$100.00.

The underway antenna, which is steerable through  $360^{\circ}$ , should provide a gain/directivity pattern as shown in Figure 4.1. The initial detection zone would be bounded by the 3dB points of the antenna pattern. The angular displacement between the 3dB points (beam width) will be determined by the gain required to adequately receive an emitter signal at 2500 yards. A log-periodic antenna should be sufficient. Such an antenna should be available, in production quantities, for under \$100.00. The underway antenna must be remotely steerable. The antenna steering mechanism including the control unit, relative bearing pick up and indicator should be available, in production quantities for under \$200.00. The drive mechanism itself can be similar to a commercial antenna rotor. However, the unit must be sufficiently rugged to operate in a marine environment. Most commercial rotors are equipped with a control box and antenna direction indicators. The antenna direction indicator could be calibrated to indicate relative bearing.

The antenna selector switch would be a co-axial switch located with the other equipment. This should be an off-the-shelf item and should cost no more the \$25.00.

The receiver must be capable of receiving and demodulating the emitter signals and providing drive signals for the alarm unit, the signal strength indicator and the audio unit. The drive signal for the alarm unit would come from a threshold detector in the receiver. The drive signal for the signal strength indicator would be a voltage proportional to received power level and would come directly from the demodulator. The drive signal for the audio unit would also be the output of the demodulator. It would be an audio tone. The receiver should cost no more than \$400.00 in production quantities.

The signal strength indicator would be a meter with an illuminated face. Depending on the final design a driver amplifier may be required between the receiver and the meter. Such a unit should cost no more the \$100.00 in production quantities.

The audio unit would consist of a driver amplifier and a speaker with a headphone option jack. Such a unit should cost no more than \$100.00 in production quantities.

The emitter would be a water actuated device. The basic components of the emitter are shown in Figure 4.4. The electronics portion of the emitter can be implemented in an extremely small package. The antenna and the battery power supply will determine the final size of the emitter. The characteristics of both of these will determine signal strength, at the vessel.

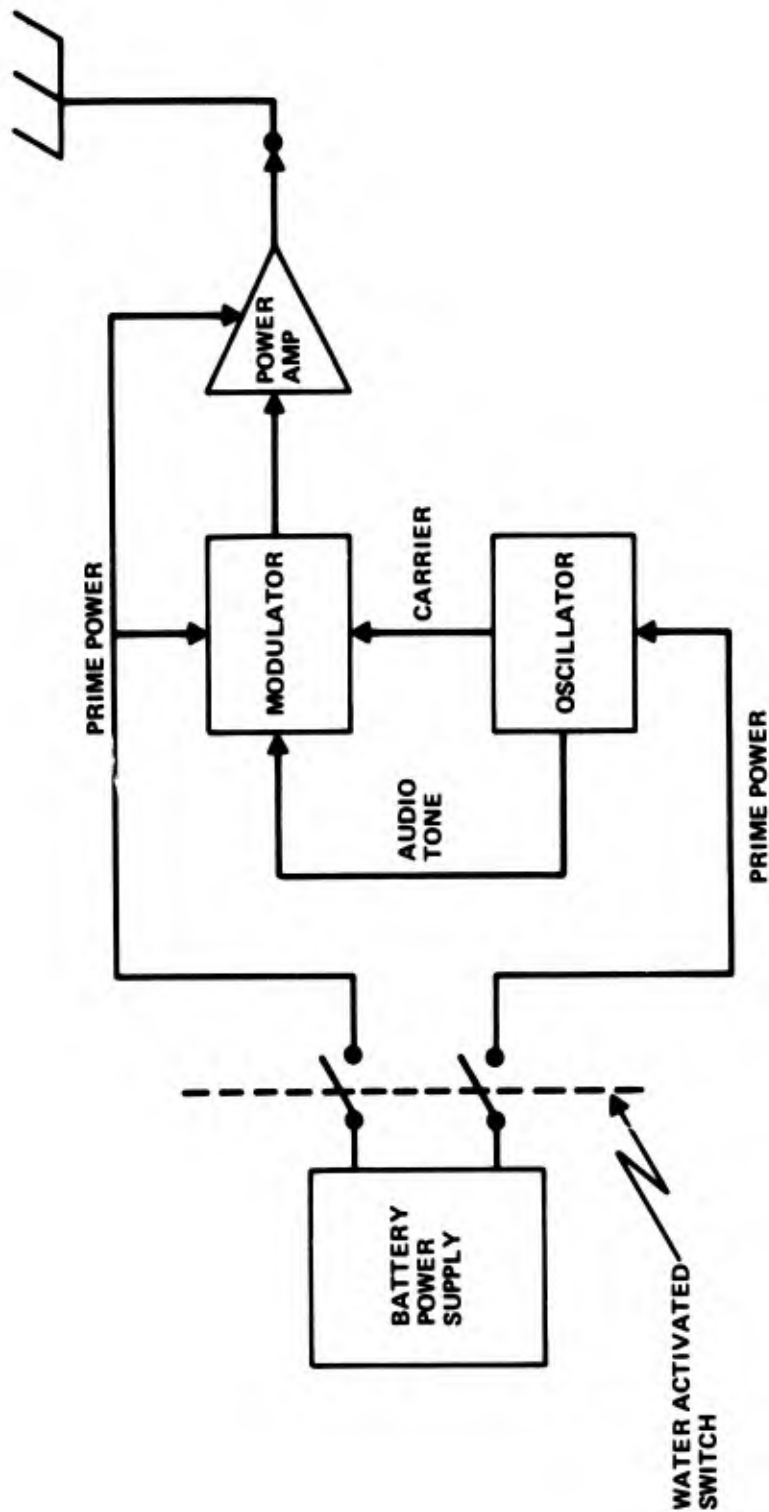


FIGURE 4.4. BASIC COMPONENTS OF EMITTER

Extensive analysis would be required to determine an exact value for the Effective Radiated Power (ERP) of the "emitter". Note that the ERP is the product of antenna gain and transmitter power. It is the ERP, along with the gains and losses in the transmission link, which determines the received signal strength. In selecting a battery for the emitter advantage can be taken of the fact that the emitter need transmit for not more than about 90 minutes. Battery size is directly related to the required ampere-hours. Electronic Position Indicating Radio Beacons (EPIRBs) capable of transmitting for 48 hours have been built which are the size of a cigarette package. Thus there is hope for finding an emitter that is smaller than a cigarette pack. Incidentally, it should be noted that not all of the technology associated with miniature radio transmitters is easily accessible since most of it is classified and manufacturers are hesitant to give specific information. Based on discussions with a single manufacturer, emitters could be purchased in production quantities for under \$200.00.

#### 4.2.2 RF System 2

The second RF system considered is similar to System 1 with the difference being the way in which the man in the water is rescued. In RF System 1, the vessel turned and maneuvered to pick up the man overboard. In RF System 2, a lifeboat is dispatched from the vessel. The lifeboat is equipped with DF equipment for locating the man in the water. This then is the basic difference between RF System 1 and RF System 2.

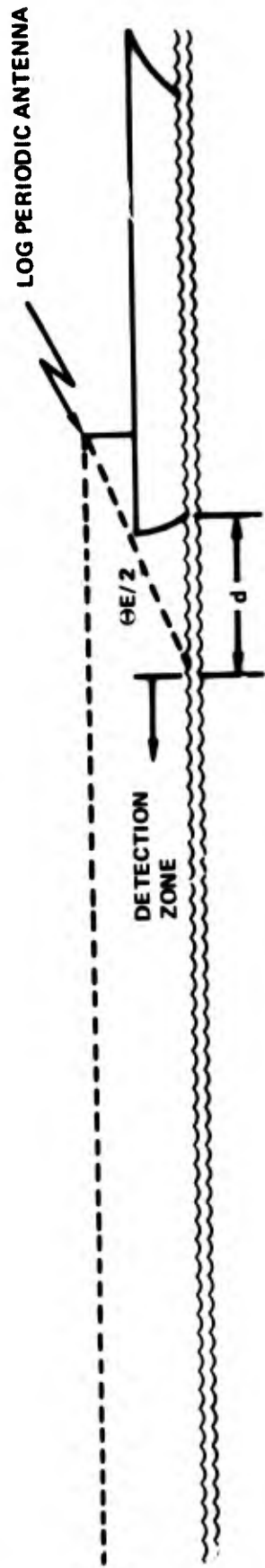
The antenna coverage required for RF System 2 underway for detection is that shown in Figure 4.5. This coverage provides the same detection capability underway as RF System 1. The "in-port" coverage is identical to that for RF System 1. In fact the "in-port" segments of the two systems are identical.

#### RF System 2 Equipment Specifications

RF System 2 will consist of the equipment shown in Figure 4.6. Note that there is equipment fixed on-board the vessel and portable equipment on the lifeboat. The fixed equipment on the vessel consists of the following:

- In-Port Detection Antenna
- Underway Detection Antenna
- Receiver
- Alarm Unit.

The in-port detection antenna will be identical to that used in RF System 1. The underway detection antenna will be identical to that used in RF System 1 with the exception that it will not be steerable but pointed directly aft. The fixed receiver will be identical to that in RF System 1 except for the lack of drive signals for a signal strength indicator and an audio unit. The alarm unit will be identical to that used in RF System 1.



$\theta_E$  = ELEVATION BEAMWIDTH  
 $\theta_A$  = AZIMUTH BEAMWIDTH

INITIAL DETECTION ZONE

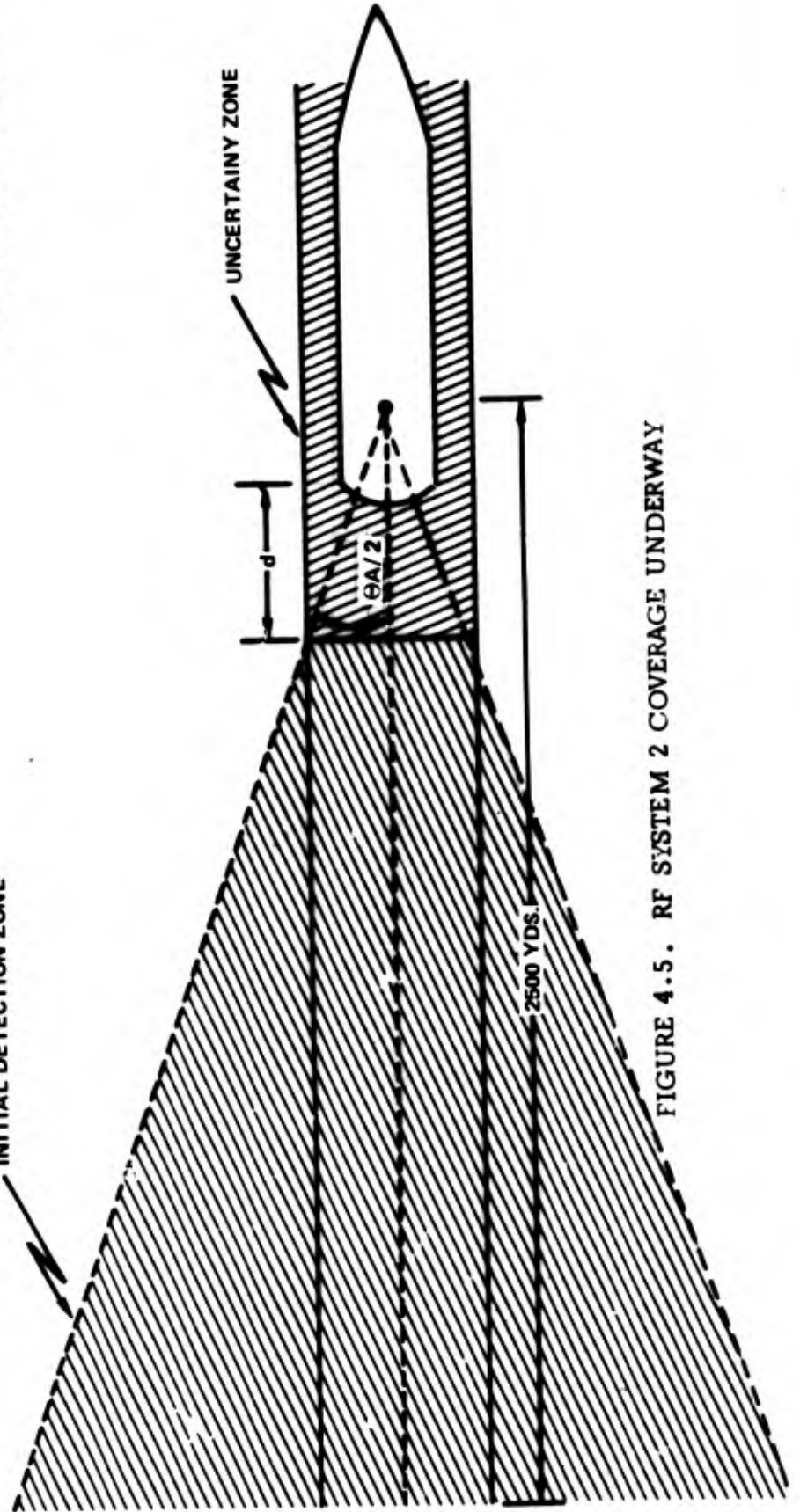


FIGURE 4.5. RF SYSTEM 2 COVERAGE UNDERWAY

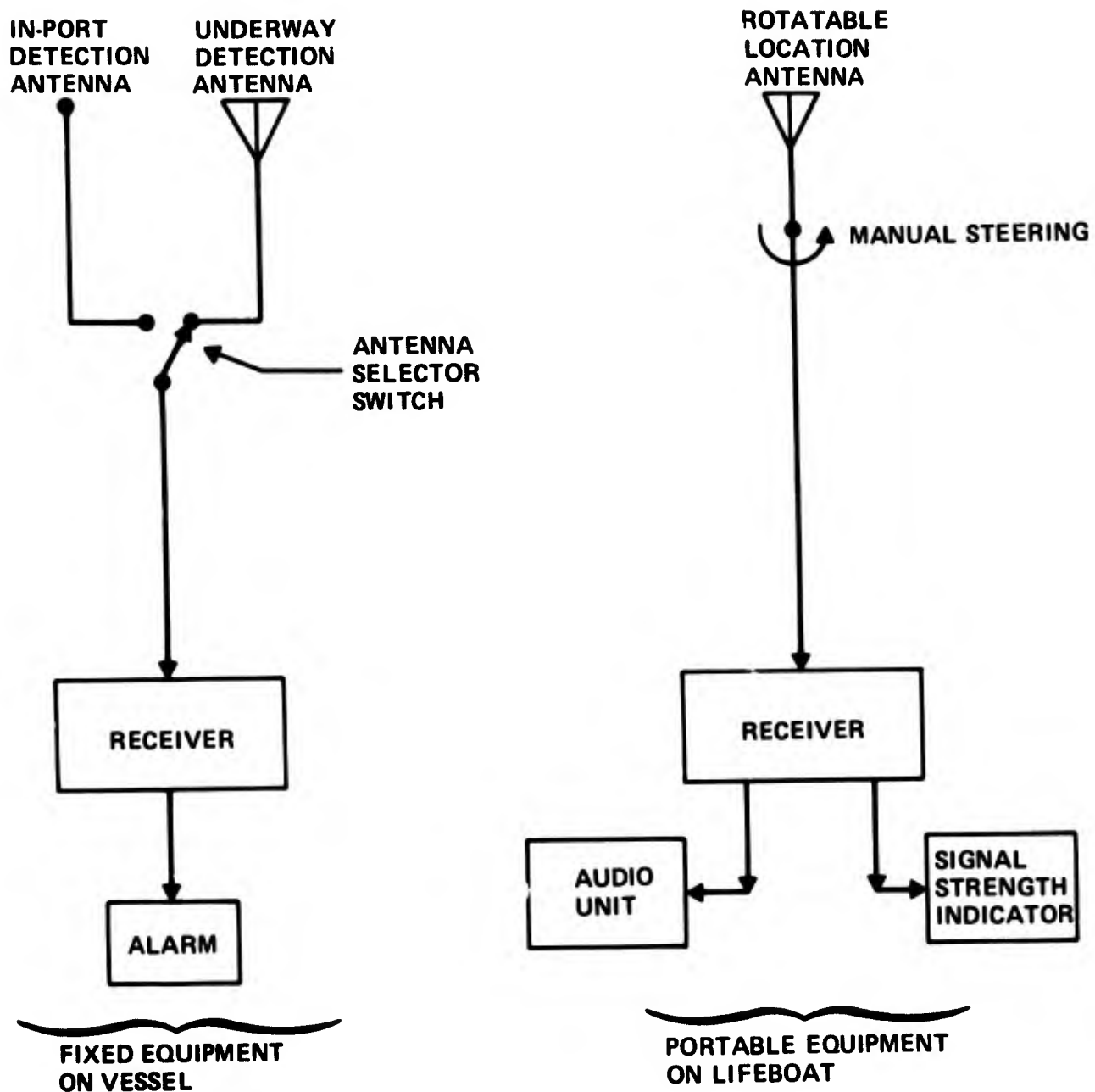


FIGURE 4.6. RF MOS SYSTEM 2

The portable equipment carried on the lifeboat will consist of the following:

- Directional, manually steerable antenna
- Receiver
- Audio Unit
- Signal Strength Indicator.

The portable antenna must not be cumbersome and at the same time provide sufficient directivity/gain to detect the emitter signal at ranges up to 2500 yards and to "home-in" on the signal. A log-periodic antenna might be too cumbersome for this application (unless UHF is used) thus some research would have to be done to find an optimum antenna which is easily mounted in the bow of a lifeboat. In any event this antenna should cost no more than \$100.00 in production quantities. Once again the receiver would be the same with the possible need for increased sensitivity. The audio unit and the signal strength indicator would be identical to those used in RF System 1.

#### 4.2.3 Sonar System 1

The second technique considered for use as a MOS utilizes underwater sound transmissions from an emitter, carried by the man in the water. Sonar System 1 completely parallels RF System 1 with the exception that sound energy instead of RF energy is used. As with the RF System 1, this system assumes that the vessel will maneuver to pick up the man in the water. Also, the operational scenario "in-port" is the same as RF Systems 1 and 2.

#### Sonar System 1 Equipment Specification

Sonar System 1 will consist of the equipment shown in Figure 4.7. As shown three transducers will be used. The location of these transducers on the vessel and the coverage they provide "in-port" and underway is presented in Figures 4.8 and 4.9. The transducers have been so placed to avoid, the uncertainty zones shown. These zones may result because of shadowing. Tests should be conducted to verify their existence. Sound-wave "bottom bounce" may preclude their existence. The "in-port" detection transducer would be an omnidirectional hydrophone. The underway detection hydrophone would be a directional hydrophone pointing aft. The underway detection zone would be bounded by the 3dB points of the hydrophone response pattern. Note that sound transmissions to this hydrophone may be hampered by the vessel's wake. The emitter must have sufficient power to be detected in spite of "wake-losses". The location transducer would be a steerable narrow-beam hydrophone mounted under the bow of the vessel. Steering could be achieved electronically, electrically, or by hydraulic methods. The production quantity costs of the transducers would not exceed the following figures:

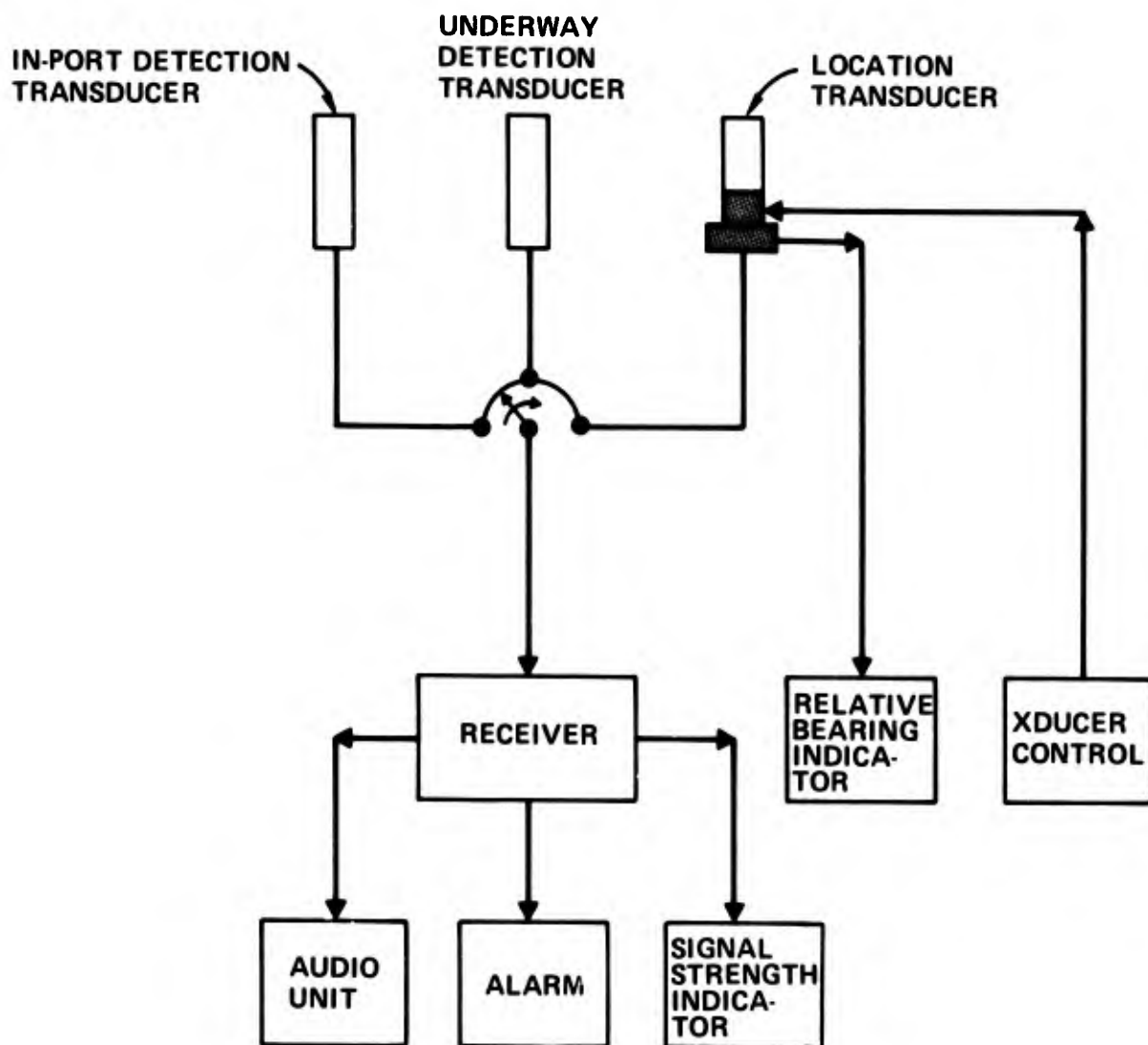


FIGURE 4.7. SONAR MOS 1

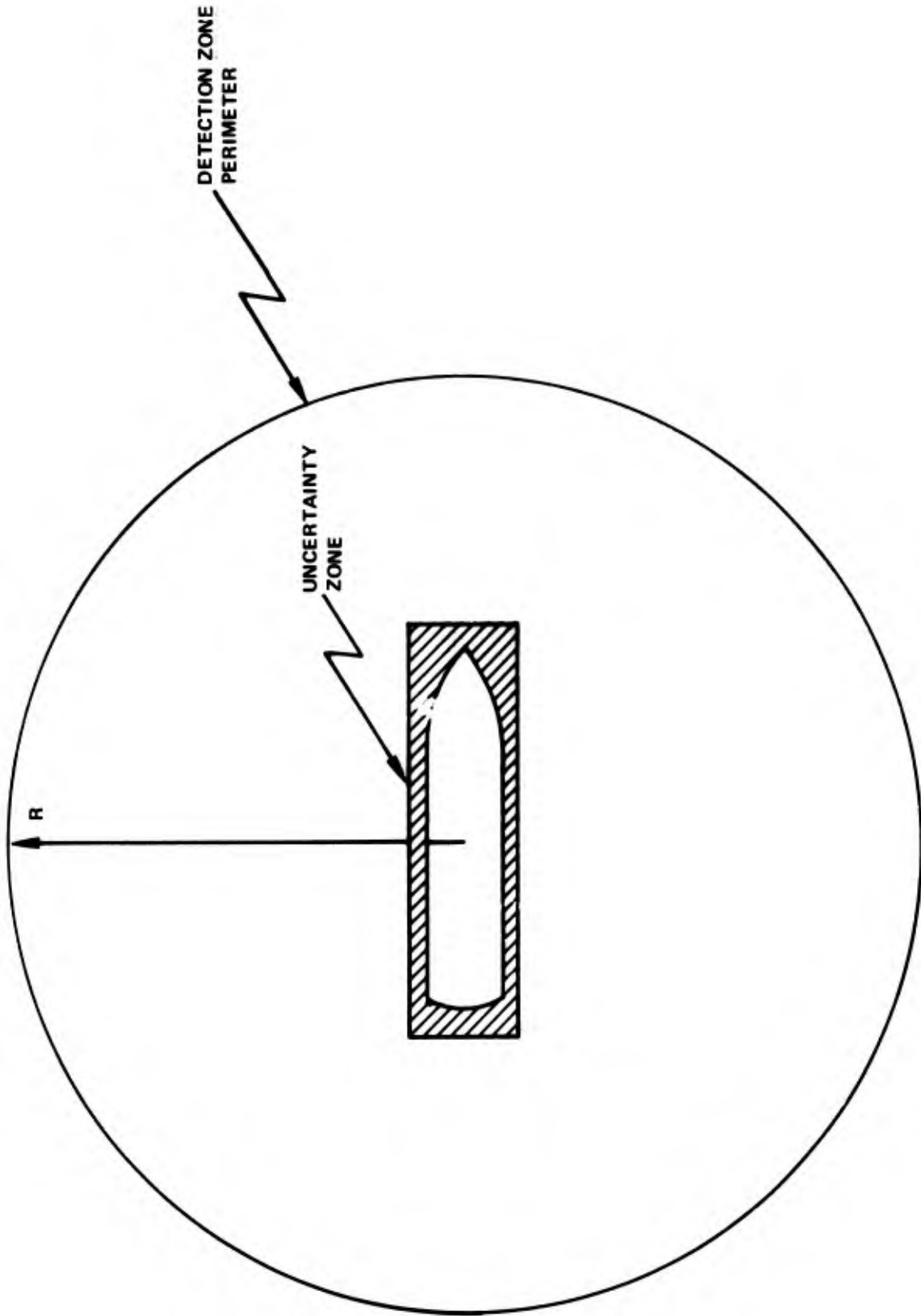


FIGURE 4.8. SONAR SYSTEM 1 COVERAGE AT ANCHOR OR TIED-UP

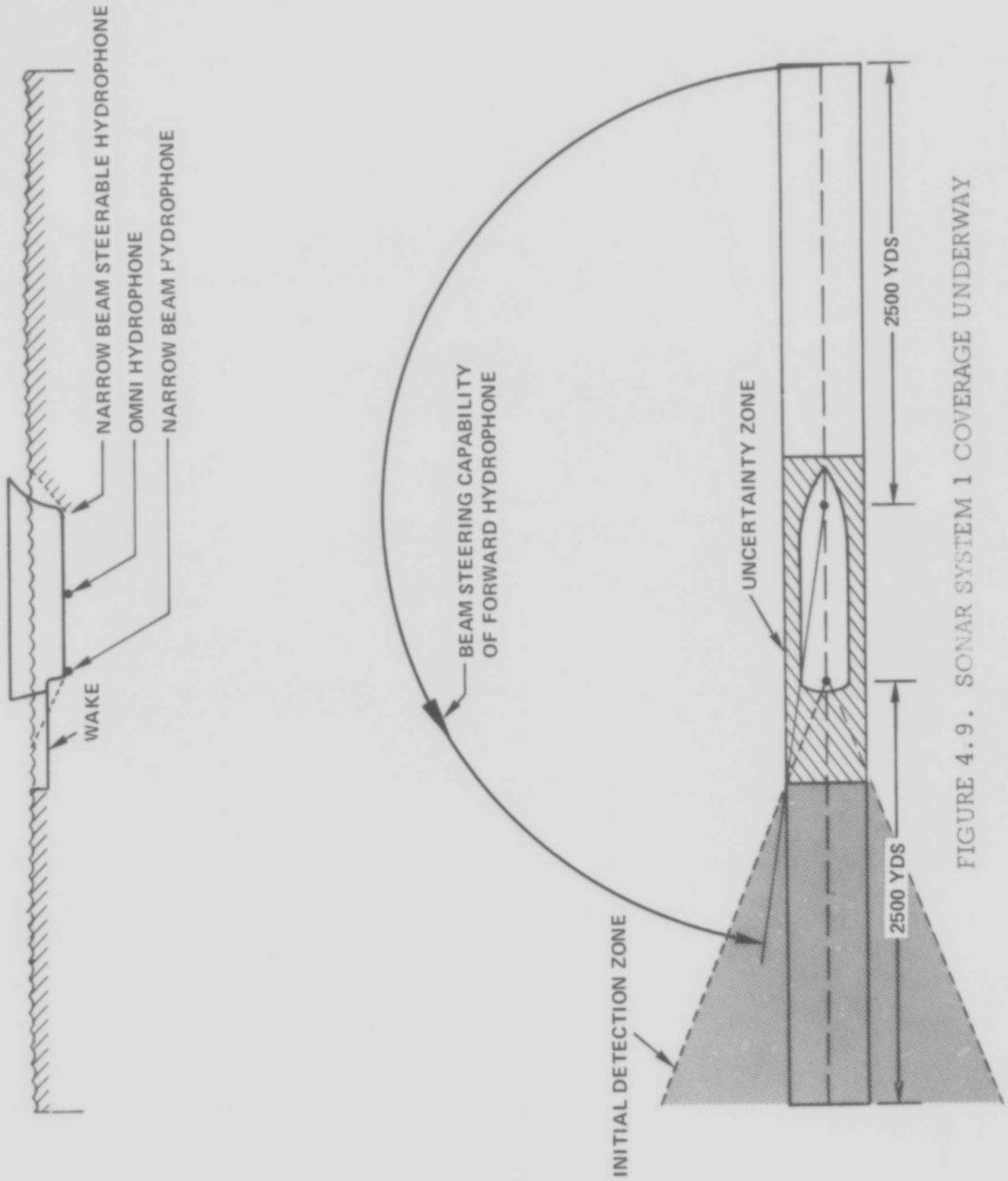


FIGURE 4.9. SONAR SYSTEM 1 COVERAGE UNDERWAY

- In-Port Transducer: \$300.00
- Underway Detection Transducer: \$390.00
- Location Transducer\*: \$500.00.

The receiver must be sensitive enough to detect emitter transmissions at ranges up to 2500 yards. This is a considerable range for an underwater sound system. Further, it must be capable of driving the audio unit, the alarm unit, and the signal strength indicator. The audio unit, the alarm unit and the signal strength indicator are essentially the same as those used in the RF systems. The receiver, in production quantities should cost no more than \$650.00.

The emitter for the system would be a miniature pinger, small enough to minimize interference with the normal activities of the crew members. The pinger will resemble that shown in Figure 4.10. The electronics portion of the pinger can be implemented in a very small package using integrated circuits. The battery and transducer will determine the ultimate size of the pinger since they will contribute most to size. The characteristics of both of these will determine how strong the received signal, at the vessel, will be. Extensive analysis would be required to determine an exact value for pinger output power required for a 2500 yard range. As an alternative to analysis, certain off-the-shelf pingers could be tested to see if they can meet the 2500 yard range requirement. As with the RF emitter, selection of a battery should take advantage of the fact that the pinger need only operate for about 90 minutes. It should be noted that pinger units presently off-the-shelf may be adequate. Testing, of course, would be required to verify this. Pingers should be available in production quantities not exceeding \$100.00.

#### 4.2.4 Sonar System 2

Sonar System 2 differs from Sonar System 1 in operation as well as equipment. With this system it is assumed that once a man-overboard is detected underway, a lifeboat equipped with homing equipment is dispatched to expedite a rescue. In port, both sonar systems are the same.

##### Sonar System 2 Equipment Specification

Sonar System 2 will consist of the equipment shown in Figure 4.11. As shown in the Figure there will be two hydrophones fixed to the vessel. One for in-port detection and one for underway detection. The in-port hydrophone is identical to that for Sonar System 1. The underway hydrophone is identical

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\*Including beam steering control unit, beam steering mechanism, and relative bearing indicator.

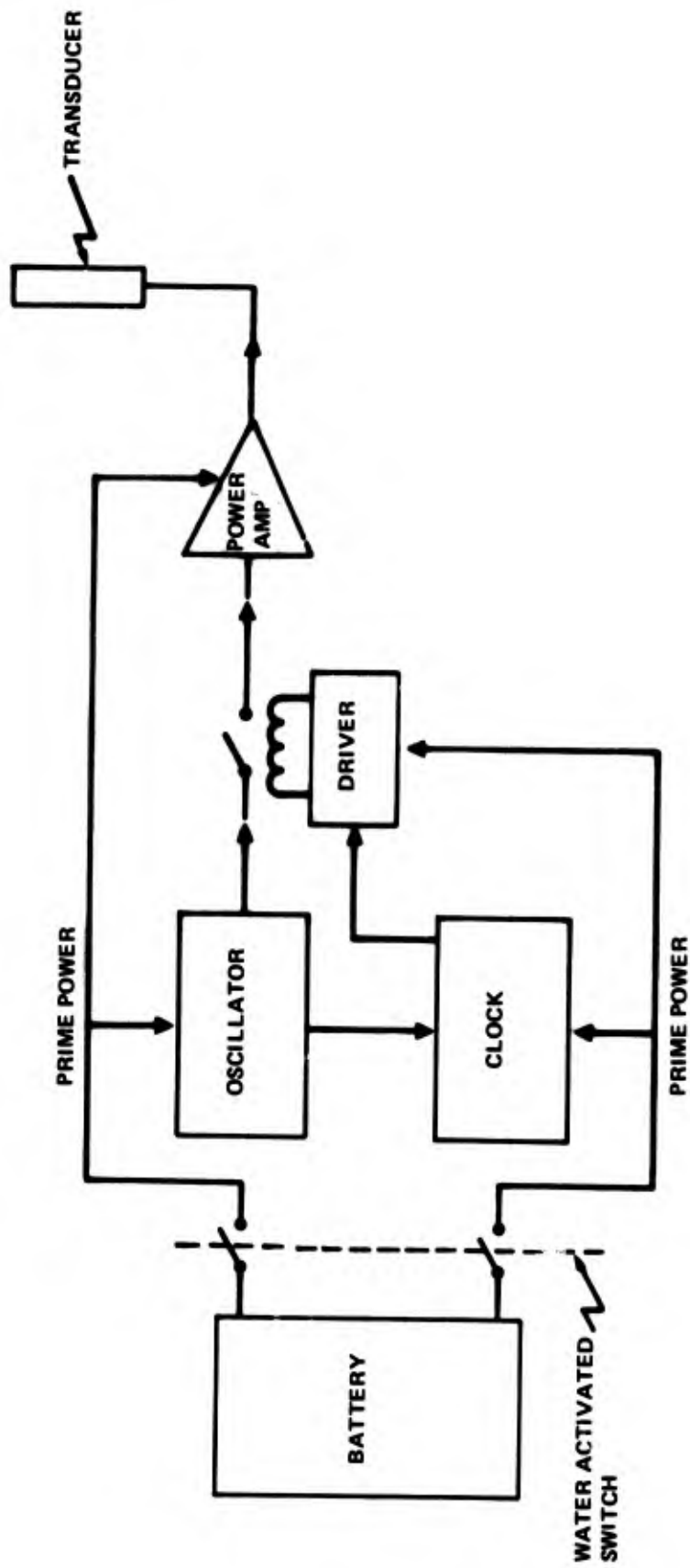
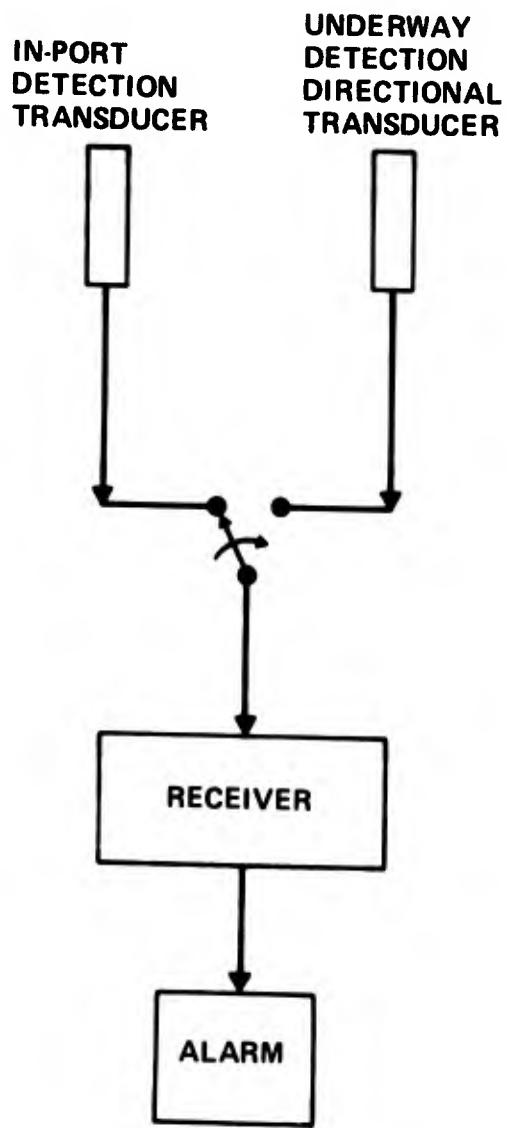
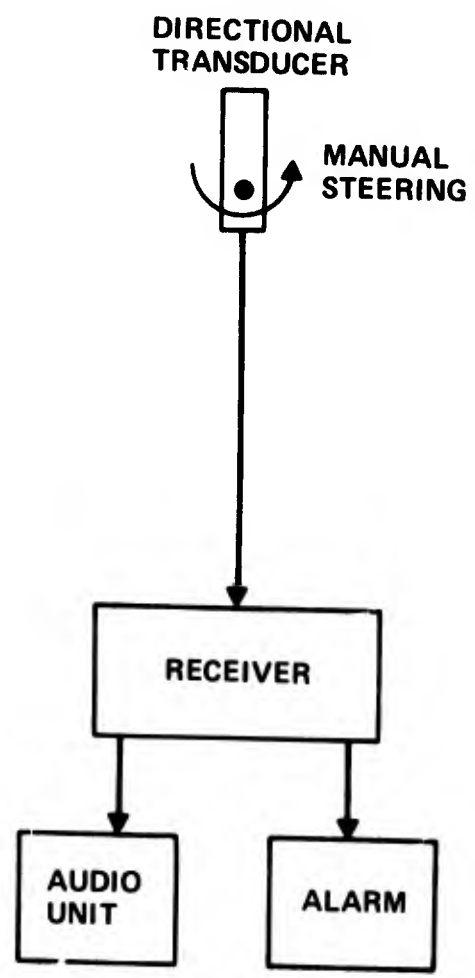


FIGURE 4.10. MOS SONAR PINGER



FIXED EQUIPMENT  
ON VESSEL



PORTABLE EQUIPMENT  
ON LIFEBOAT

FIGURE 4.11. SONAR MOS 2

to the after hydrophone for Sonar System 1. The fixed receiver would be essentially the same as that for System 1 with fewer outputs. The alarm unit would also be the same.

The portable equipment would consist of a manually steerable directional hydrophone, a receiver, an audio unit, and a signal strength indicator. The hydrophone could be identical to the underway detection hydrophone with a steering capability added. The receiver would be the same as the fixed receiver. The audio unit and signal strength indicator would be identical to those in System 1.

#### 4.2.5 Radar System

The third technique considered for a MOS utilizes the ship's radar or secondary radar unit to sound the initial man-overboard alarm and to provide location capability. This system will not be as well defined as the previous systems because the various components are not off-the-shelf items.

##### Radar System Equipment Description

The basic equipment configuration for a Radar MOS System is shown in Figure 4.12. The basic principle governing operation of the system is the use of a miniature water activated transponder carried by each crewman. The transponder receives transmissions from the ship's radar and retransmits a coded signal which can be detected by the radar receiver. Detection of the coded transmission by the radar is achieved by the use of an additional detector in the radar receiver. When a coded signal is received, the man-overboard alarm is actuated. The victim will be located by removing the normal video from the radar Plan Position Indicator (PPI). Thus only man-overboard signals would be displayed. Note that the transponder is activated by radar pulses from the ship's radar, thus range information is available.

Assuming that a typical ship's radar would be used with MOS system modifications, the system would provide 360° coverage around the vessel. The specific coverage zone would be similar to that for Sonar System 1 (Figures 4.8 and 4.9). The size of the uncertainty zone would depend on the radar antenna pattern and its height above the main deck of the vessel. The range of the system would be limited by the radar receiver sensitivity, the radar antenna gain and the Effective Isotropic Radiated Power (EIRP) of the transponder.

If a man falls overboard while the ship is underway, he will be detected after he leaves the uncertainty zone. The radar PPI, will provide a continuous bearing to the man in the water. Thus, assuming that he stays within range, maneuvering to pick him up should not interfere with alarm signal reception.

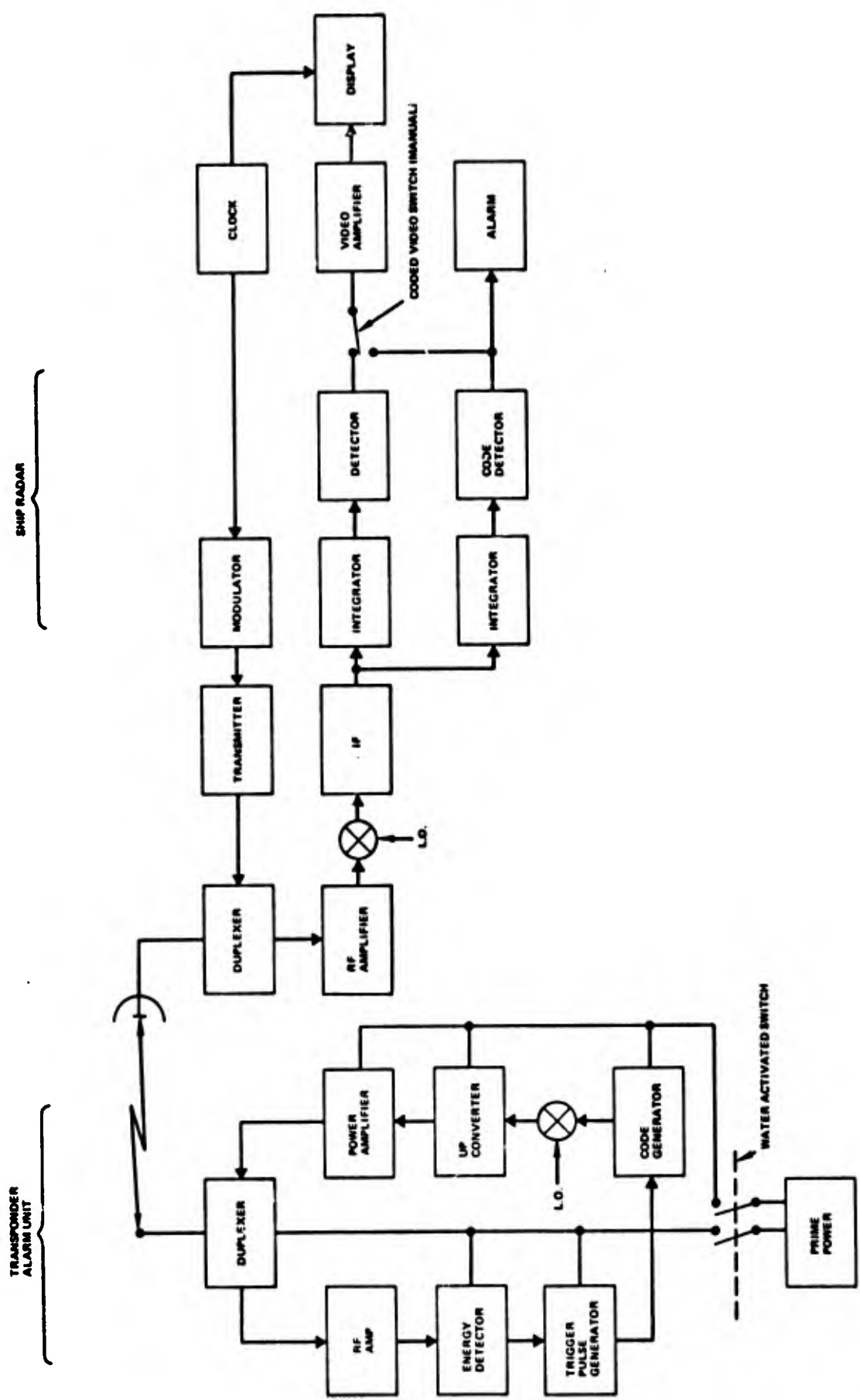


FIGURE 4.12. RADAR MOS SYSTEM

Initial detection will be a problem if the vessel is at the dock or at anchor because the victim will fall into the uncertainty zone and the initial man-overboard alarm may not be given. As in the other systems, tests will be required to determine if the uncertainty zone exists and if it does, to determine if it is acceptably small.

#### Radar System Equipment Specifications

The equipment associated with a radar MOS system is shown in Figure 4.12. This equipment can be broken down into three major categories:

1. Man-Carried Transponder
2. Ships Radar
3. Radar MOS Modification

The transponder is similar in many ways to an electronic radio beacon. However, this transponder must operate at higher frequencies (radar frequencies).

It is not possible, within the scope of this task to estimate the cost of the transponder. Discussions with the developers of ATRBS indicate that considerable development work will be required to adapt and miniaturize the present transponder for MOS application.

The existing ships radar could be used even though tradeoffs involving frequency of operation may make it somewhat less than optimum. A modification kit could be designed to provide the additional detection, alarm and video switching. Development costs must also be estimated for this modification package.

#### 4.2.6 System Summary

Three separate man-overboard systems have been addressed which appear to be applicable to the man-overboard problem. The material presented corresponds to a conceptual design and concept definition. Before these systems could be implemented several design iterations would have to be carried out to produce an implementation specification. The systems are summarized in Table 4.1.

A cost summary of the RF and Sonar Systems is presented in Table 4.2. Costs are not available on the Radar System. The costs given in the table are production quantity costs. The table should be used only as a means of comparing systems since detailed costs associated with these systems have not been established.

Additional costs which are not included in the table are development and hardware costs associated with the following:

- Waterproof housing, antenna deployment and water activated switch for the RF transmitter

TABLE 4.1  
MOS SYSTEM SUMMARY

System	MOS Situation	MOS Rescue Scenario
RF System 1	Underway	<ul style="list-style-type: none"> <li>● Detection by narrow beam antenna pointing aft</li> <li>● Location and rescue by vessel homing on emitter</li> </ul>
	Berthed or Anchored	<ul style="list-style-type: none"> <li>● Detection by near omni antenna</li> <li>● Location and rescue by crew members with MOS stations</li> </ul>
RF System 2	Underway	<ul style="list-style-type: none"> <li>● Detection by narrow beam antenna pointing aft</li> <li>● Location and rescue by lifeboat homing on emitter</li> </ul>
	Berthed or Anchored	<ul style="list-style-type: none"> <li>● Same as RF System 1</li> </ul>
Sonar System 1	Underway	<ul style="list-style-type: none"> <li>● Detection by narrow beam hydrophone pointing aft</li> <li>● Location and rescue by vessel homing on pinger</li> </ul>
	Berthed or Anchored	<ul style="list-style-type: none"> <li>● Detection by omni-hydrophone</li> <li>● Location and rescue by crew members with MOS stations</li> </ul>
Sonar System 2	Underway	<ul style="list-style-type: none"> <li>● Detection by narrow beam hydrophone pointing aft</li> <li>● Location and rescue by lifeboat homing on pinger</li> </ul>
	Berthed or Anchored	<ul style="list-style-type: none"> <li>Same as Sonar System 1</li> </ul>
Radar System	Underway and Berthed or Anchored	<ul style="list-style-type: none"> <li>● Detection by coded signal from transponder</li> <li>● Location and rescue by radar homing on transponder</li> </ul>

TABLE 4.2  
ESTIMATED COST SUMMARY (5) (6)

RF System 1		RF System 2		Sonar System 1		Sonar System 2	
Item	Cost	Item	Cost	Item	Cost	Item	Cost
In-Port Detection Antenna	\$ 100	In-Port Detection Antenna	\$ 100	In-Port Detection Hydrophone	\$ 300	In-Port Detection Hydrophone	\$ 300
Underway Detection and Location Antenna	\$ 200 (1)	Underway Detection Antenna	\$ 100	Underway Detection Hydrophone	\$ 390	Underway Detection Hydrophone	\$ 390
Antenna Selector Switch	\$ 25	Portable Signal Strength Indicator	\$ 100	Relative Bearing Indicator	--	Portable Signal Strength Indicator	--
Receiver	\$ 400	Antenna Selector Switch	\$ 25	Location Hydrophone	\$ 500 (4)	Hydrophone Selector Switch	\$ 25
Alarm Unit	\$ 100	Receiver	\$ 400	Hydrophone Selector Switch	\$ 25	Acoustic Receiver	\$ 650
Signal Strength Indicator	\$ 100	Alarm Unit	\$ 100	Acoustic Receiver	\$ 650	Alarm Unit	\$ 100
Audio Unit	\$ 100 (2)	Portable Location Antenna	\$ 100	Audio Unit	--	Portable Directional Hydrophone	\$ 390
Emitter	\$ 200	Portable Receiver	\$ 400	Alarm Unit	\$ 100	Portable Acoustic Receiver	\$ 650
		Portable Audio Unit	\$ 100 (2)	Signal Strength Indicator	--	Portable Audio Unit	--
		Emitter	\$ 200	Hydrophone Control Unit	\$ 100	Pinger	\$ 100
<b>Total</b>	<b>\$ 1225 (3)</b>	<b>Total</b>	<b>\$ 1625 (3)</b>	<b>Total</b>	<b>\$ 2265 (3)</b>	<b>Total</b>	<b>\$ 2605 (3)</b>

(1) This cost includes the drive mechanism control unit and relative bearing indicator  
(2) This cost includes headphones  
(3) Add \$200 for each additional emitter and \$100 for each pinger  
(4) This cost includes drive mechanism and relative bearing indicator  
(5) See discussion of additional costs on page 4-21  
(6) Costs for the Radar System are not available at this time

- Inclusion of a water activated switch in the sonar pinger unit
- Marinization of receiving antennas and rotors
- Performance tests of RF transmitter transmissions through the air/water interface
- Ship installation costs
- System testing cost.

## 5.0 CONCLUSIONS AND RECOMMENDATIONS

### 5.1 CONCLUSIONS

- There are a variety of techniques that can be adapted to a man-overboard system. Two systems, the RF transmitter and the sonar system offer the most effective capabilities.
- These two systems offer immediate detection and direction finding capabilities.
- Either system should significantly reduce rescue and recovery time.
- Either system should be relatively inexpensive.
- Both systems require a rescue plan and crew training in rescue operations to realize maximum effectiveness.
- The radar system has capabilities similar to the RF and sonar systems but requires extensive development with associated higher costs.
- It is anticipated that the RF system will not broadcast through the air/water interface and that some effort will be required to develop a deployable antenna above the water surface.
- It is unreasonable and impractical to require the victim to deploy the antenna.

- The effectiveness of a floating antenna must be investigated.
- Based on antenna deployment and effectiveness problems associated with the RF system, the sonar system appears to be the best candidate for a MOS.

## 5.2 RECOMMENDATIONS

- ORI recommends that the next phase of this program continue to consider both the RF and sonar systems and that simple tests be conducted to solve some of the anticipated problems and fully define the performance capabilities of each system. These tests can be accomplished for the most part with off-the-shelf equipment.
- ORI would recommend the following work outline for the next phase of this program.
  1. Establish one or more rescue procedures based on discussions with Coast Guard personnel and representative ship operators. The rescue procedure is a function of the number, location and types of MOS equipment required.
  2. Finalize the system requirements for both the RF and sonar systems.
  3. Produce a test plan which will establish the performance characteristics of each system.
  4. Perform tests
  5. Analyze results
  6. Specify the final system. Define equipment, specifications, installation, procedures, performance, etc.
- Integrate the MOS with a wearable Personal Flotation Device (PFD).
- Use of caged boarding ladders should be encouraged.

END