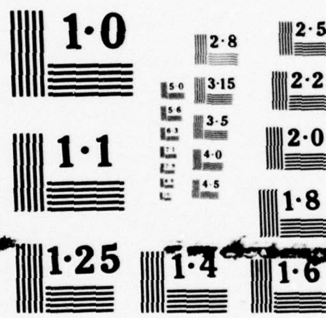
AD-A048 722 COAST GUARD WASHINGTON D C F/G 6/7
PRELIMINARY TESTS OF INFLATABLE LIFERAFTS FOR STABILITY IN HIGH--ETC(U)
DEC 77 M R DANIELS, R L MARKLE, S G MANESS
UNCLASSIFIED USCG-M-1-78 NL

1 OF 1
AD
A048722

END
DATE
FILMED
2-78
DDC



NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

Report No. CG-M- 1-78

PRELIMINARY TESTS OF INFLATABLE LIFERAFTS FOR STABILITY IN HIGH WINDS

December 1, 1977

Document is available to the public through the
National Technical Information Service,
Springfield, Virginia 22151

Prepared for

DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

OFFICE OF MERCHANT MARINE SAFETY
Washington, D.C. 20590

NOTICE

Technical Report Documentation Page

1. Report No. (14) USCG-M-1-78	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle (6) Preliminary Tests of Inflatable Liferafts for Stability in High Winds.		5. Report Date (11) 1 December 1977
		6. Performing Organization Code
7. Author(s) (10) M. R. DANIELS, JR., R. L. MARKLE, S. G. MANESS		8. Performing Organization Report No.
9. Performing Organization Name and Address (12) 38p.		10. Work Unit No. (TRAIS)
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address: Department of Transportation, Office of Merchant Marine Safety, United States Coast Guard, 400 Seventh St., S.W., Washington, D.C. 20590		13. Type of Report and Period Covered (9) Final Report. 10/17/77 to 10/20/77
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

This report presents the results of a preliminary investigation of the stability of various marine-type inflatable liferafts when afloat and exposed to high wind forces. The report describes capsizings resulting from wind forces generated by helicopter downdraft and the slipstream of a fixed-wing aircraft.

17. Key Words		18. Distribution Statement
Inflatable liferafts	Slipstream	UNLIMITED
Liferafts	Wind Forces	Document is available to the public through the National Technical Information Service, Springfield, VA 22151
Capsizings	SOLAS	
Helicopter Downdraft	Drogues	
Stability		

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unlimited	34	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

086 450

LB

TABLE OF CONTENTS

		Page
1.0	INTRODUCTION	1
2.0	APPROACH	2
3.0	DESCRIPTION OF THE LIFERAFTS	3
4.0	TEST METHODS EMPLOYED	5
	4.1 Helicopter Downdraft Tests	5
	4.2 Fixed-Wing Aircraft Slipstream Tests	6
	4.3 Overturning Tests	7
5.0	SUMMARY AND DISCUSSION OF RESULTS	7
	5.1 Helicopter Downdraft Testing	7
	5.2 Fixed-Wing Aircraft Slipstream Testing	8
	5.3 Overturning Tests	10
6.0	CONCLUSIONS	11
7.0	RECOMMENDATIONS	12

LIST OF TABLES

Table I.	Sand Bag Test Weights	13
Table II.	Helicopter Downdraft Test Results	14
Table III.	C-130 Aircraft Slipstream Test Results	16
Table IV.	Beaufort Scale of Wind Force	17

LIST OF FIGURES

Fig. 1 (Sheet 1)	4-person Raft by Switlik Parachute Company, Inc.	18
Fig. 1 (Sheet 2)	Givens 6-person Raft by Res-Q-Raft, Inc.	19

Fig. 1	(Sheet 3)	8-person Raft by C. J. Hendry Company.	20
Fig. 1	(Sheet 4)	20-person Raft by Tul Safety Equipment Ltd.. . . .	21
Fig. 1	(Sheet 5)	25-person Raft by C. J. Hendry Company	22
Fig. 1	(Sheet 6)	25-person Raft by B. F. Goodrich, modified with. . Givens Buoy Bag.	23
Fig. 1	(Sheet 7)	25-person by B. F. Goodrich Company.	24
Fig. 2		Motorboat, Raft and Helicopter Relative Positions.	25
Fig. 3		Positions of C-130 Aircraft and Rafts in Slip- . . stream Tests	26
Fig. 4		C-130 Aircraft Full-Power Slipstream Velocities. .	27
Fig. 5		Hendry '25' Lifting: Table II (7)	28
Fig. 6		Hendry '25' on Beam Ends: Table II (8).	29
Fig. 7		RFD '25' Capsizing: Table II (9).	30
Fig. 8		RFD '25' Capsized: Table II (9)	31
Fig. 9		RFD '25' Capsizing: Table II (10)	32
Fig. 10		Hendry '25' Capsizing Before Rerighting: Table III (2).	33
Fig. 11		Hendry '25' Capsizing Before Rerighting: Table. . III (2).	34

1.0 INTRODUCTION

The discussion following deals with the stability of inflatable life rafts when buffeted by helicopter downdrafts and the slipstream of fixed-wing aircraft. The tests were intended to give a preliminary indication of whether or not it would be advantageous to develop a design standard for the stability required of an inflatable life raft.

In conjunction with the above, it should be noted that the current International Convention for the Safety of Life at Sea (SOLAS) 1960 does not provide a parameter, measure or definitive rule for the degree of stability required of an inflatable liferaft.

2.0 APPROACH

In the investigation described in this report, a variety of marine rafts were exposed to the winds generated by helicopters and fixed-wing aircraft. Artificially generated wind forces were used in order to avoid the delays inherent to awaiting or searching for bad weather at locations ashore or aboard a vessel. The helicopter also gave the investigators a maneuverable source of wind forces at low altitudes, and at the same time showed what might occur to rafts exposed to helicopter downdrafts. The tests were conducted in the Pasquotank River adjacent to the U. S. Coast Guard Air Station, Elizabeth City, N.C.

3.0 DESCRIPTION OF THE LIFERAFTS

The following rafts were used in the exercise:

1. A 4-person raft with a circular waterplane manufactured by the Switlik Parachute Company, Inc. This raft had two water pockets on its underside, each approximately 16 inches in depth and of a size considerably larger than would ordinarily be employed on this design.

2. A 6-person raft with a circular waterplane by Res-Q-Raft, Inc., in which the Givens patented underwater stability device was included. This is essentially a large fabric underwater pocket fitted with an inlet flapper valve.

3. An 8-person "Elliot"-type raft by the C. J. Hendry Company. This is an oblong-shaped raft with four water pockets on the bottom, one at each corner of the raft.

4. A 20-person circular-shaped raft by Tul Safety Equipment, Ltd. This raft had a single mast-tube canopy support, and also had the Givens stability device.

5. A 25-person "Elliot"-type raft by the C. J. Hendry Company. This is essentially a larger version of the 8-person raft described above. It also had a water pocket at each of its four corners.

6. A 25-person davit-launched "RFD"-type circular raft made by the B. F. Goodrich Engineered Systems Co. This raft had a single mast-tube canopy support, internal shrouds, and a lifting ring at the top of its canopy. This raft had been altered to include the Givens stability device on its underside.

7. A 25-person davit-launched "RFD"-type raft made by B. F. Goodrich similar to No. 6 above, but whose stability was limited to two small water pockets on its underside.

The basic design features of the above test units are given in Figure 1. Rafts Nos. 1 and 2 are not common to large merchant vessels, being of sizes frequently employed on yachts and commercial fishing vessels.

4.0 TEST METHODS EMPLOYED

Two sources of artificially generated winds were employed: the "downdrafts" generated by a helicopter and the "slipstream" produced by a fixed-wing aircraft made fast at ground level adjacent to a body of water where the rafts were floated. Testing consisted of separate exposures of the floating rafts to both wind sources. Since it was the general consensus that floors will not be inflated immediately after launching it was decided to test each raft with its floor uninflated. And for reasons of consistency, all rafts had open canopy entrances throughout the tests.

4.1 Helicopter Downdraft Tests

In the tests conducted with a helicopter, each raft was held in place afloat by a painter made fast to a motorboat while the raft was exposed to downdrafts created by a Coast Guard Sikorsky HH-3F helicopter overhead.[1] The motorboat and painter restraining line shown in Figure 2 were included to prevent any of the rafts from being swept up into the helicopter rotors as had been observed to occur with small one-person rafts carried by U. S. Navy aircraft.

For the helicopter exposure, the rafts were tested both empty and with sand bags to simulate their half and 2-person conditions of loading. Table I gives the test weights ballasted in the various rafts. As a

---

[1] The investigation did not include wind velocity measurements resulting from helicopter downdraft. But Coast Guard pilots estimate the HH-3F to generate a 70 knot wind velocity when hovering of altitudes of 50 feet or less.

means of determining the effect of a drogue (sea anchor) on a raft's stability, many of the helicopter tests were conducted both with and without the drogues of the rafts in the water.

In the tests with the helicopter there were no instruments installed in the rafts to measure their lifting, drifting, or upsetting. The recorded results, therefore, consisted of observations made of each raft's performance by attending personnel. In some cases the observations were supplemented by photographs and 16 mm. films taken of the various events. Some of these photographs are included in this report.

4.2 Fixed-wing Aircraft Slipstream Tests

In the second series of tests, the floating rafts were released to drift into the slipstream astern of a fixed-wing aircraft (the Coast Guard Lockheed C-130, four-engined turboprop) chocked in place on the ground as shown in Figure 3, while generating the wind velocities shown in Figure 4. Full-power rotation of the turboprops generated waves approximately 1-foot in height with white caps at a distance approximately 200 feet astern of the aircraft engines. For the slipstream tests, the rafts were tested both empty and loaded with sand bags to simulate 2-person loads. In several of the slipstream trials, the rafts were exposed with and without their drogues in the water. The recorded results of this series consisted of individual sightings of each raft with photographs and films similar to those described above for the tests with the helicopter.

4.3 Overturning Tests

In conjunction with the tests conducted with the helicopter and fixed-wing aircraft, the effect on the stability of a raft when boarded by swimmers emerging from the water was observed. This exercise employed Test Units Nos. 1 and 2, to obtain a comparison of a water-pocketed raft with a raft having the Givens stability device.

5.0 SUMMARY AND DISCUSSION OF RESULTS

5.1 Helicopter Downdraft Testing

Test results of the rafts exposed to helicopter downdrafts are summarized in Table II. Owing to a lack of sand bags, testing of the C. J. Hendry 25-person raft - No. 5 above - was not possible in this series. The 6 remaining half-loaded rafts stayed upright when buffeted by the downdraft of the helicopter, both with and without their drogues in the water. As could be expected, the stability of the rafts was improved by the presence of the weights simulating their half-loaded condition.

The first capsizings in the tests with the helicopter occurred with the rafts' weights reduced to 2-person and no-load levels. The rafts showing this shortcoming had the smaller water pockets. The helicopter created a realistic high wind (70 -90 KNS) exposure to the test units. In several cases where the helicopter approached rafts that lifted or were upset, the pilot had the machine down to altitudes less than 10 feet above the water. In actual situations, such reduced heights would be exceptional for a helicopter hoisting survivors from a raft, although the Coast Guard does not specify an altitude in its instructions to helicopter pilots for this particular operation.

In addition, it also appears that a drogue is beneficial to the stability of a raft. Although the data in support of this observation is not extensive nor consistent, from the testing of Raft No. 3 with 2-person loads, it appears that the streaming of the drogue made a noticeable contribution to the stability of the raft. Unfortunately, this trait was not demonstrated so clearly when the raft was again tested in an empty condition. In full-size tests of this kind, there were variations in the approach of the helicopter to each raft, a factor which may account for varying results with tests of the same unit.

5.2 Fixed-Wing Aircraft Slipstream Testing

Table III summarizes observations of the rafts' stability in the slipstream of the C-130 aircraft. Figure 3 gives the distances and relationship of the aircraft to the test area of the rafts adjacent to an abandoned seaplane ramp in the estuary of the Pasquotank River.

On the occasion of testing, the undisturbed waters adjacent to the test area were relatively calm, consisting of ripples without white-caps from westerly breezes of an estimated 10 to 15 knots. The slipstream velocities to which the rafts were exposed were continuously in excess of the hurricane intensity (Beaufort Wind Scale 12) given in Table IV, however the normalwave heights associated with a wind of this force were not generated. This contradiction of wind and sea conditions is significant to an evaluation of the rafts' stability. With the wave heights normally present with this wind condition the effect on the rafts could be expected to be worse. Another disparity resulted from the difficulty of positioning the rafts for each test: the personnel handling the rafts from the motorboat could not always locate themselves at an identical starting point for the release of each raft. Consequently, some of the rafts were more severely buffeted in the slipstream than others.

5.3 Overturning Tests

While awaiting the start of the slipstream tests, Rafts Nos. 1 and 2 were subjected to overturning loads developed by swimmers emerging from the water at the canopy entrances. The Switlik 4-person raft (Test Raft No. 1) was overturned by one swimmer when he grasped the canopy while bracing one knee against the lower tube of the raft. For the other raft, the Res-Q-Raft 6-person (Givens buoy equipped), the same evolution exerted by two swimmers did not overturn the raft, although the end opposite the swimmers rose at an angle of approximately 30 degrees. This brief exercise gave evidence of the limited initial stability that can be expected with small rafts having small water pockets.

6.0 CONCLUSIONS

The rafts overturned by the helicopter all had small water pockets on their undersides. The smaller the pockets, the more readily a raft was upset by the helicopter's downdraft. In contrast, the two rafts equipped with the Givens stability device were not overturned. The relationship between a raft's stability and the size of its water pockets was amply demonstrated.

The results of the slipstream tests with the fixed-wing aircraft did not duplicate all of the upsets produced with the helicopter. This is attributed to an inexact positioning of the rafts in the slipstream. But the one overturning that did occur with a conventional 25-person raft gave further evidence of the reduced stability that can be expected with rafts having overly small water pockets. This latter conclusion was again borne out by the comparative stability shown when swimmers tried to overturn the 4-person and Givens 6-person rafts: the Givens raft had the higher degree of stability.

7.0 RECOMMENDATIONS

In order to bring the above preliminary study to a definitive conclusion, the following further efforts are *recommended:*

1. Test the inflatable liferafts in heavy weather at sea in order to avoid the artificiality of aircraft-generated wind forces.
2. Investigate on a theoretical basis a design parameter for the stability desired of an inflatable liferaft.
3. Subject to offshore testing a number of rafts equipped with stability features that follow a predetermined design parameter such as the size of water pockets, static righting moment, length-beam ratio, etc.

TABLE I SAND BAG TEST WEIGHTS

Size of Raft	2-person weights (lbs.) *	Half-load weights (lbs.) *
4-person	330	330
6-person	330	495
8-person	330	660
20-person	330	1650
25-person	330	2145

* On basis of 165 lbs. per person made up of three (3) 55-lb. sand bags.

TABLE II - HELICOPTER DOWNDRAFT TEST RESULTS

Test Condition	Switlik '4'	Givens '6'	Hendry '8'	Tul '20'	Hendry '25'	Givens RFD'25'	RFD '25'
(All floors slack)							
Half-capacity loads:							
Drogue - Streamed	Stable	Stable	Stable(1)	Stable	NT(2)	Stable	Stable
Not streamed	Stable	Stable	Stable	Stable	NT(2)	Stable	Stable
2-person loads:							
Drogue - Streamed	NT(3)	NT(3)	Slight Lifting(4)	NT(3)	NT(3)	NT(3)	NT(3)
Not streamed	Stable	Stable	End Up 30^{o}(5)	Stable	Side Up 30^{0}(7)	NT	Capsized(9)
Unloaded:							
Drogue - Streamed	NT(3)	NT(3)	Stable	NT(3)	NT(3)	NT(3)	NT(3)
Not streamed	Rocking(6)	Stable	Stable	Stable	Up on Beam End (8)	NT	Capsized(10)

NT: not tested
Bracketed numbers refer to comments following:

TABLE II (Continued)

Comments:

(1) Drogue line parted; therefore, the "streamed" and "not streamed" conditions occurred in the same test.

(2) Raft not tested because of a lack of sand bags.

(3) On completion of the tests with the Hendry 8-person raft in the 2-person and no-load conditions, the decision was made to omit the streaming of the drogues during the testing of the remaining six rafts.

(4) Helicopter at ± 10-foot altitude. Observed slight lifting of raft at one end; raft held down by drogue.

(5) Helicopter at ± 20-foot altitude. Raft lifted one end to ± 30° angle and returned upright. Sand bags located in end of raft made fast to the motorboat.

(6) Helicopter at ± 10-foot altitude. Rapid drifting of raft with slight rocking. Stayed upright.

(7) All weights on one side of raft. Helicopter approached raft on its weighted side at 5-foot altitude. Raft lifted one end but remained upright. Test conducted second time: helicopter came in on nonweighted side of the raft, which made one quick 30 lift of one side and came down upright. Refer to Fig. 5.

(8) Raft lifted up on beam end and dropped back upright. Refer to Fig. 6.

(9) Helicopter approached raft on its untethered (the unweighted) end. Raft turned over and stayed upsidedown with loss of sand bags. Refer to Figs. 7 and 8.

(10) Swimmers righted raft. Helicopter approached raft at 10-foot altitude. Raft turned over. Refer to Fig. 9.

TABLE III - C-130 AIRCRAFT SLIPSTREAM TEST RESULTS

Test Condition	Switlik '4'	Givens '6'	Hendry '8'	Tul '20'	Hendry '25'	Givens RFD'25'	RFD '25'
(All floors slack)							
2-person loads:							
Drogue - Streamed	Stable	NT	List & slewed (1)	Stable	Capsizes & Rerights (2)	Stable	Slight Lifting (4)
Not streamed	Stable	Stable	Stable	NT	NT	NT	NT
Unloaded:							
Drogue - Streamed	NT	NT	NT	Stable	Slight Lift Wind End (3)	NT	Skids (5)
Not streamed	NT	Stable	NT	NT	NT	NT	Stable

NT: not tested
Bracketed numbers refer to comments following:

Comments:

(1) At a distance of 150 ft. from the ramp, the raft listed and slewed around but remained upright.

(2) At a distance of 250 ft. from the ramp, the raft overturned and rerighted itself. Drogue line pulled free. Refer to Figs. 10 and 11.

(3) At a distance of 400 ft. from ramp, the windward end of the raft lifted and strained on the drogue but remained upright.

(4) Raft strained on drogue, lifted leeward end and slewed but remained upright.

(5) At a distance of 150 ft. from the ramp the raft skidded across water but remained upright.

TABLE IV BEAUFORT SCALE OF WIND FORCE[1]

Beaufort Number	Wind Character	Appearance of Sea	Nautical M.P.H.
0	Calm	No ripples	0-1
1	Light airs	Rippled in patches	2-
2	Light breeze	Ripples and wavelets form	-6
3	Gentle breeze	Occasional whitecaps	7-10
4	Moderate breeze	Spotted with whitecaps	11-16
5	Fresh breeze	Sea covered with whitecaps	17-21
6	Strong breeze	Scud from whitcaps; large waves	22-27
7	High wind (moderate gale)	Waves begin to break; foam blown from crests in lines	28-33
8	Gale (fresh gale)	Foam blown in dense streaks along direction of wind; sea very rough	34-40
9	Strong gale	Dense streaks of foam on all sides	41-47
10	Whole gale	High waves with long overhanging crests and sea white with foam	48-55
11	Storm	Medium size ships lost to sight in troughs and air filled with spray	56-65
12	Hurricane[2]		over 65

1. Data from the "Merchant Marine Officer's Handbook" by E. A. Turpin & W. A. MacEwen, 1965 ed., Cornell Maritime Press

2. "The Beaufort Wind Scale actually extends to Force 17 (up to 118 knots) but Force 12 is the highest which can be identified from the appearance of the sea." (Quoted from Page H-20 of "Reed's Ocean Navigator", 2nd ed. 1970, Thomas Reed Publications Limited, London-Glasgow

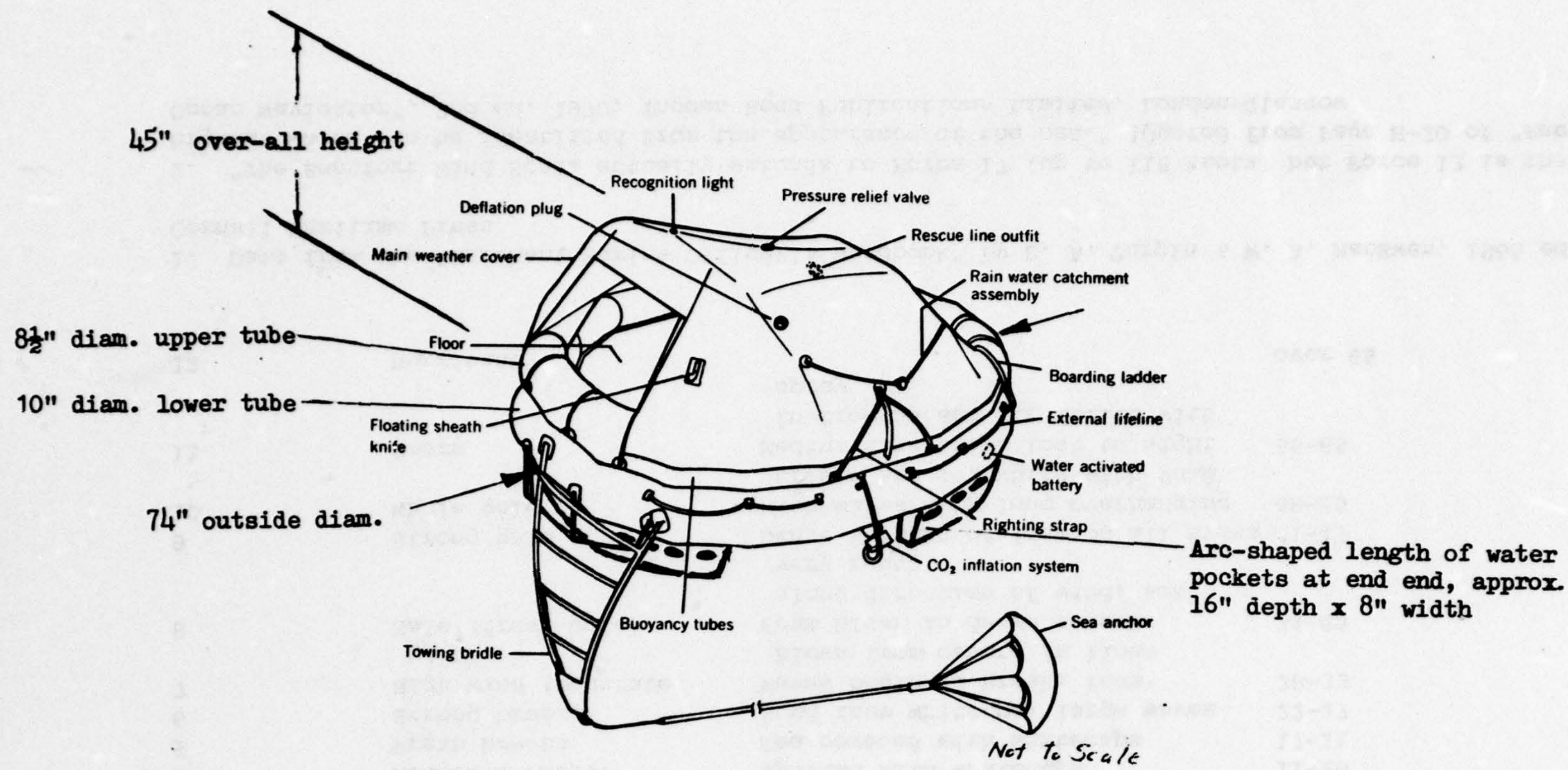


Fig. 1- Test Raft No.1: 4-person raft by Switlik Parachute Company, Inc.

Sheet 1 of 7

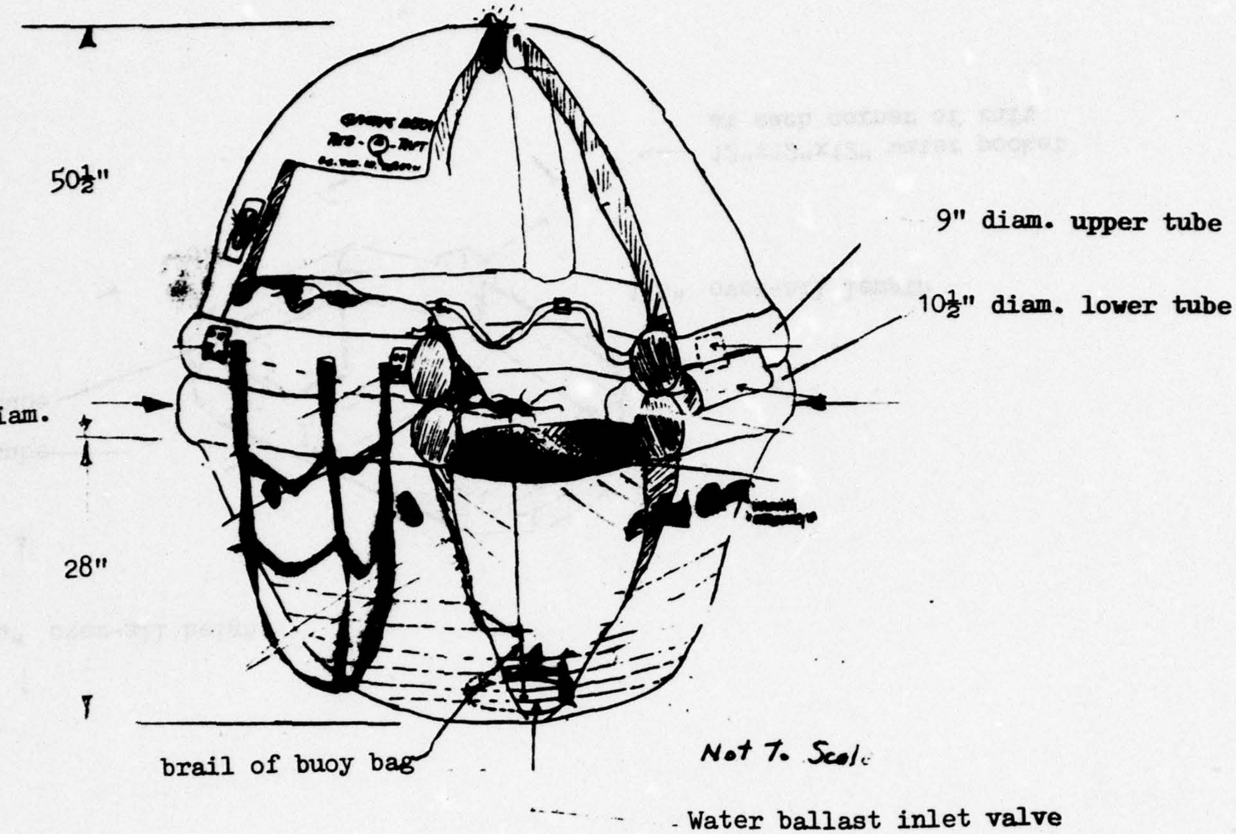


Fig. 1- Test Raft No. 2: Givens 6-person raft by Res-Q-Raft, Inc.

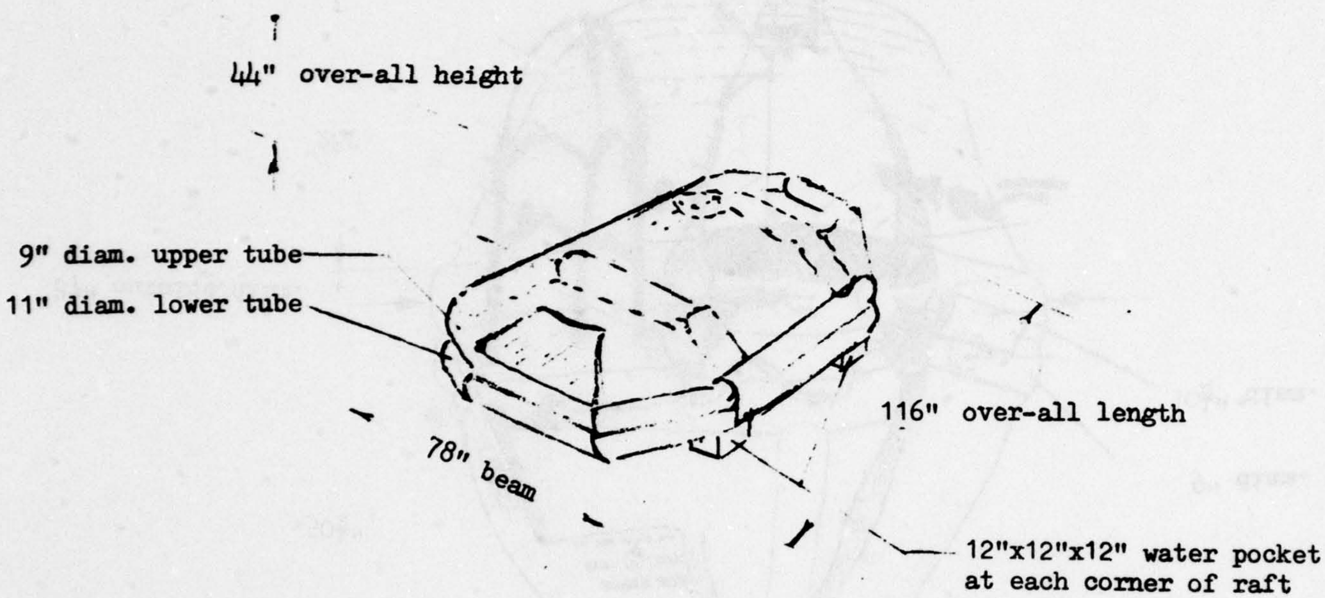


Fig. 1- Test Raft No. 3: 8-person raft by C.J. Hendry Company

Sheet 3 of 7

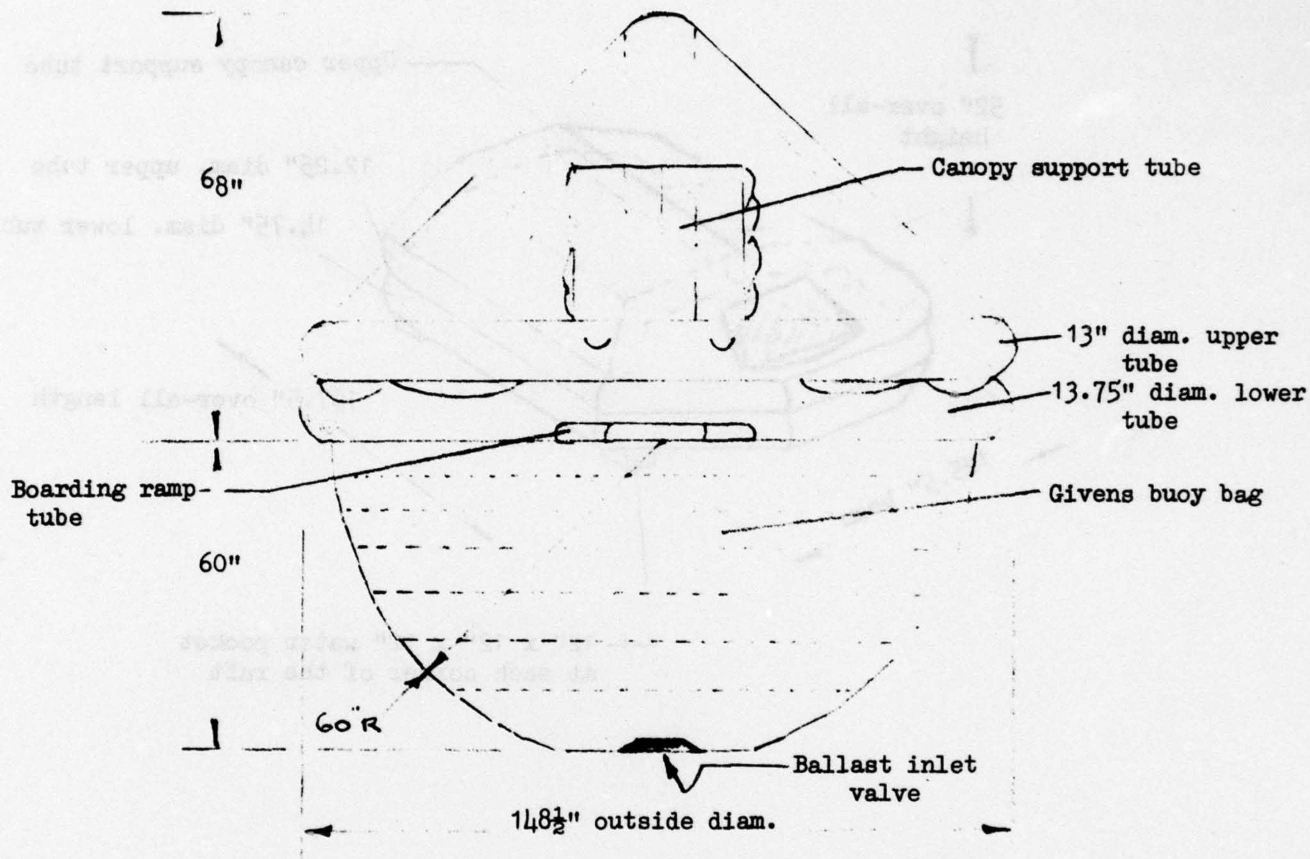


Fig. 1- Test Raft No. 4: 20-person raft by Tul Safety Equipment Ltd.

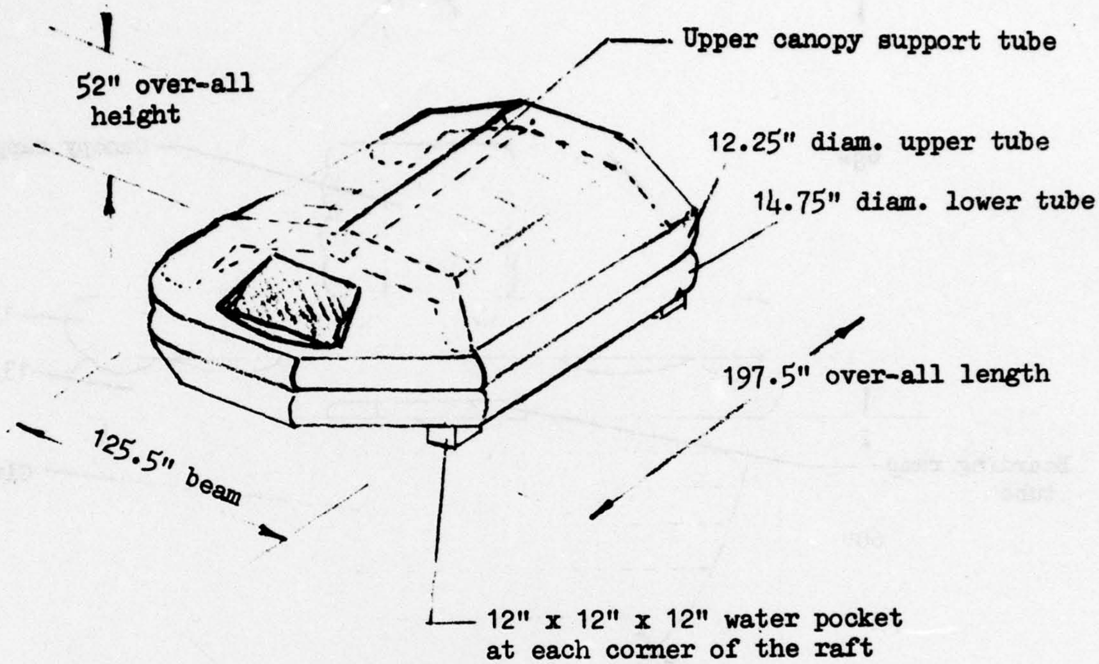


Fig. 1- Test Raft No. 5: 25-person raft by C.J. Hendry Company

Sheet 5 of 7

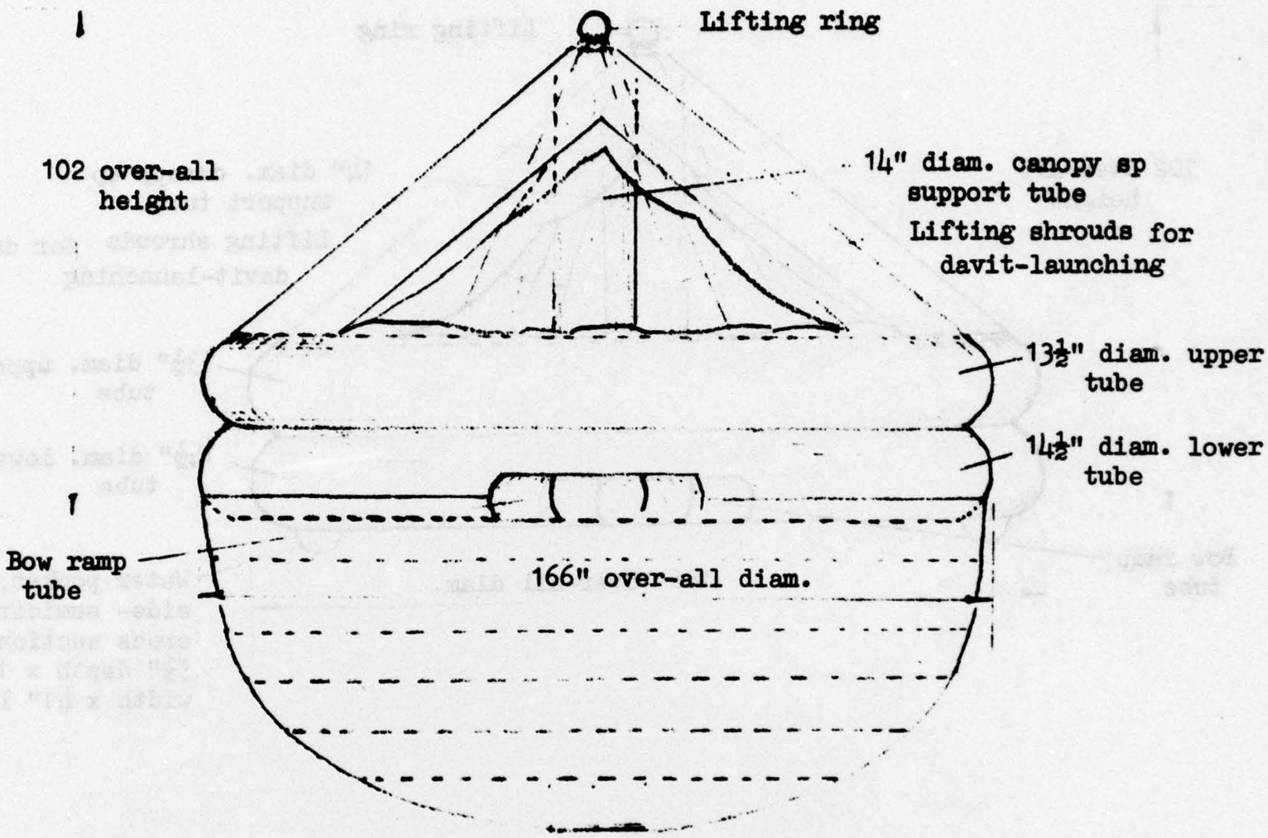


Fig. 1- Test Raft No. 6: 25-person raft by B.F. Goodrich Company Modified with Givens Buoy Bag

Sheet 6 of 7

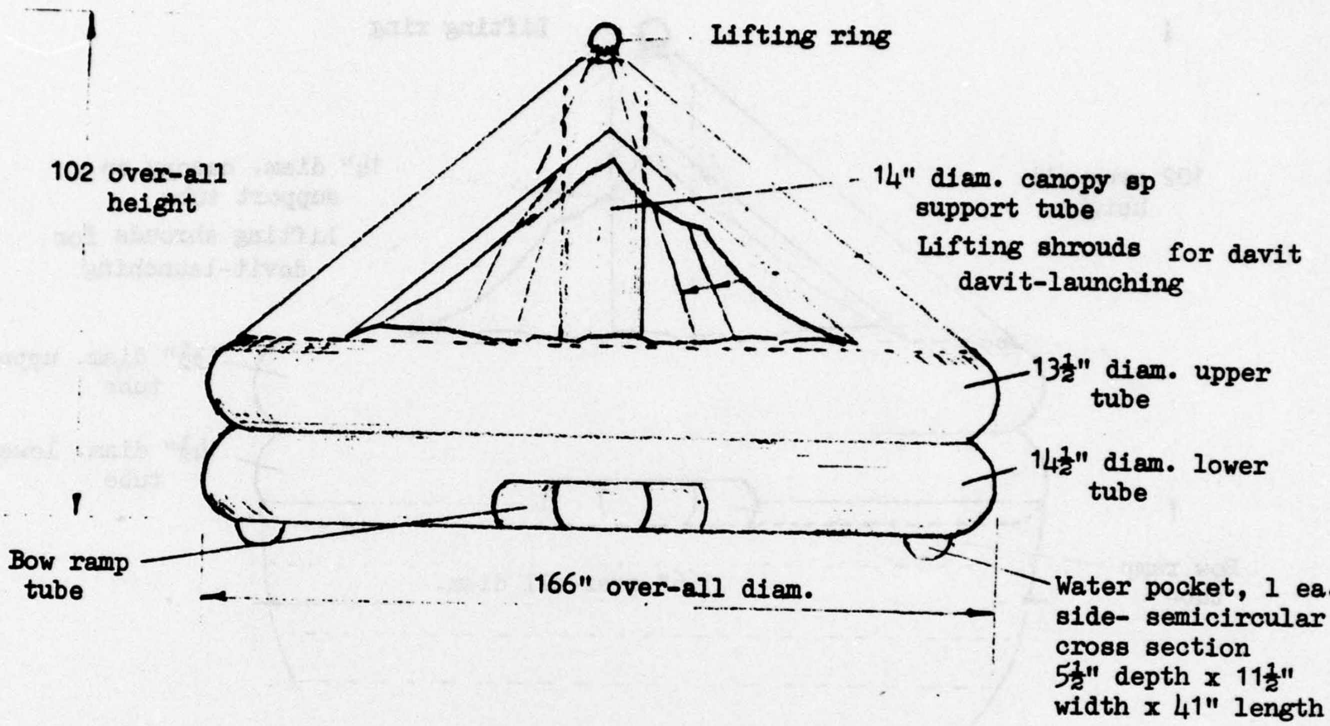


Fig. 1- Test Raft No. 7: 25-person raft by B.F. Goodrich Company

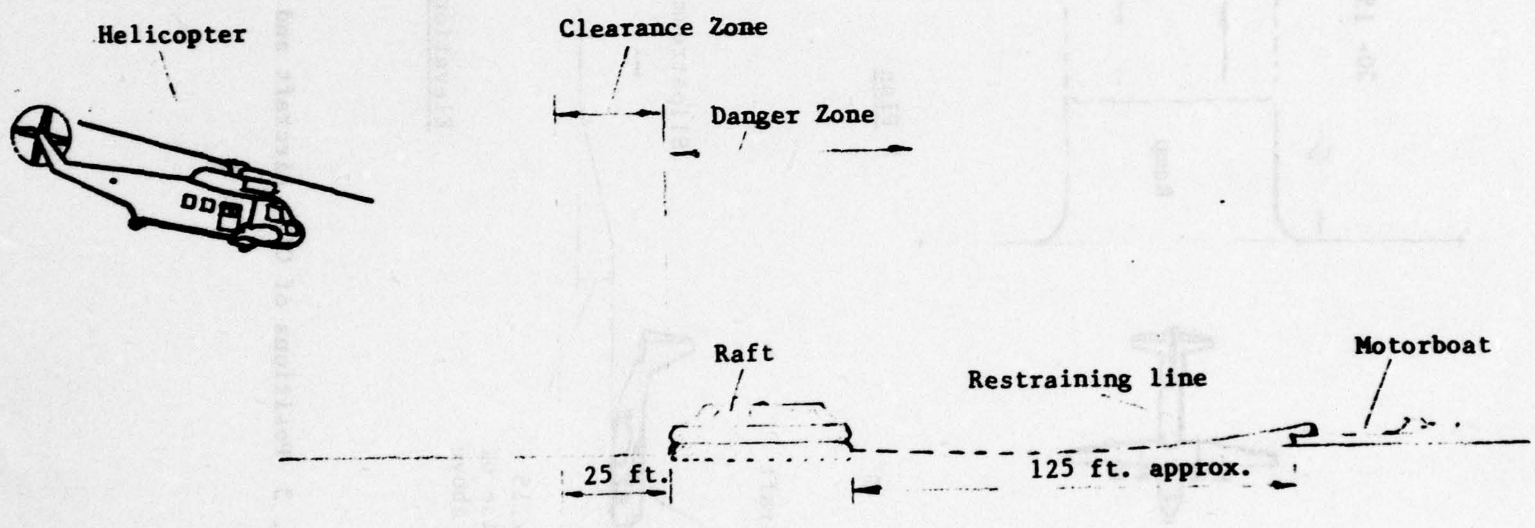


Fig. 2 Motorboat, Raft and Helicopter Relative Positions

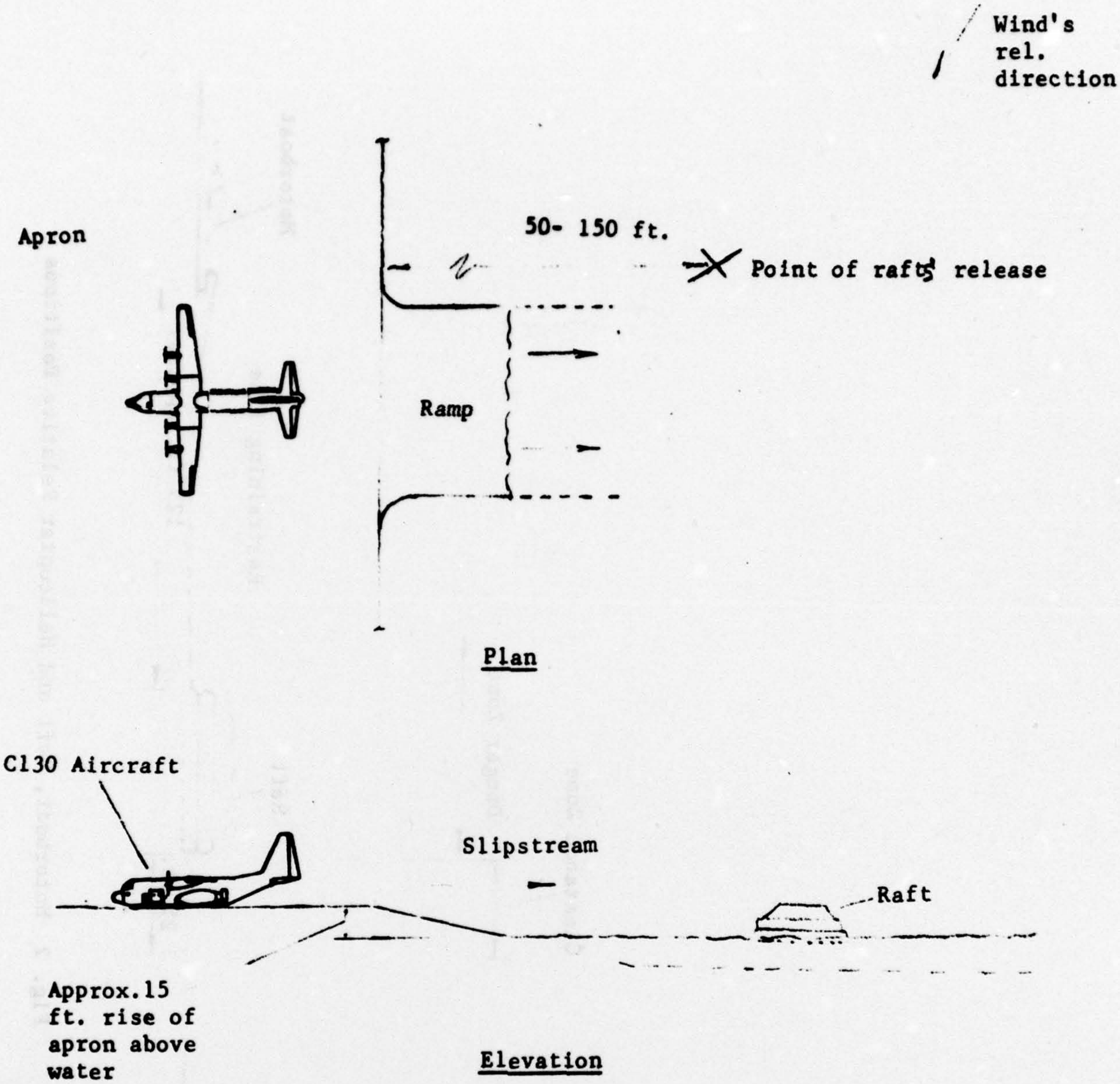


Fig. 3 Positions of C130 Aircraft and Rafts in Slipstream Tests

Not to Scale

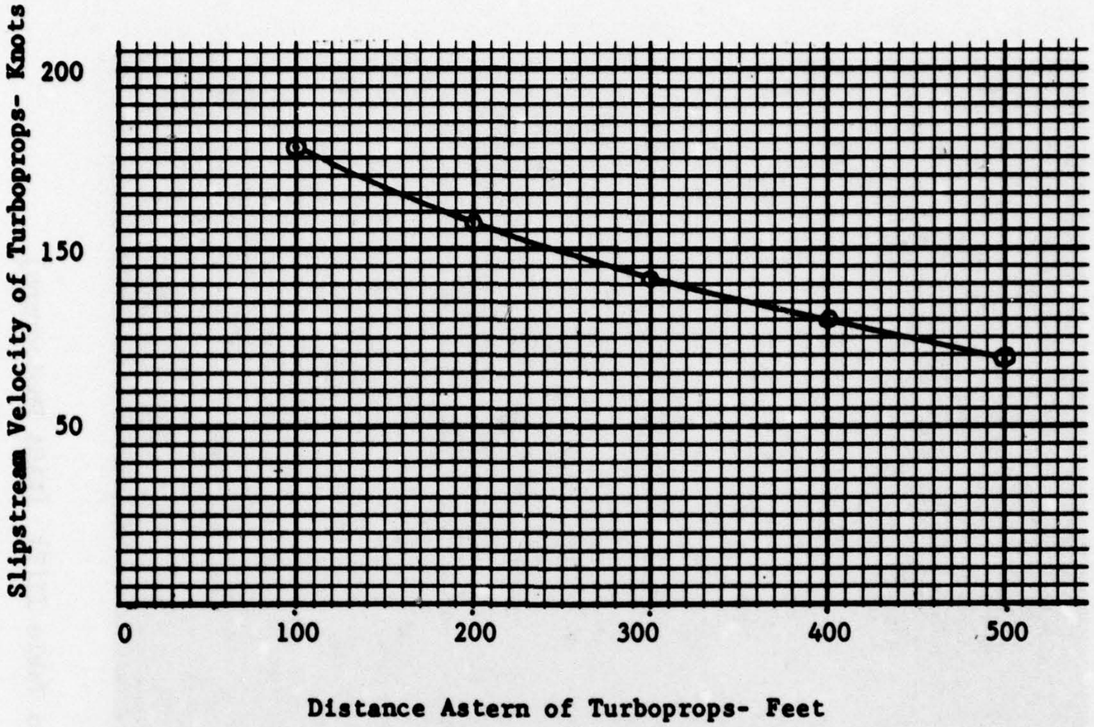


Fig.4 C-130 Aircraft Full-Power Slipstream Velocities [1]

[1] Data from C-130 Pilot's Handbook

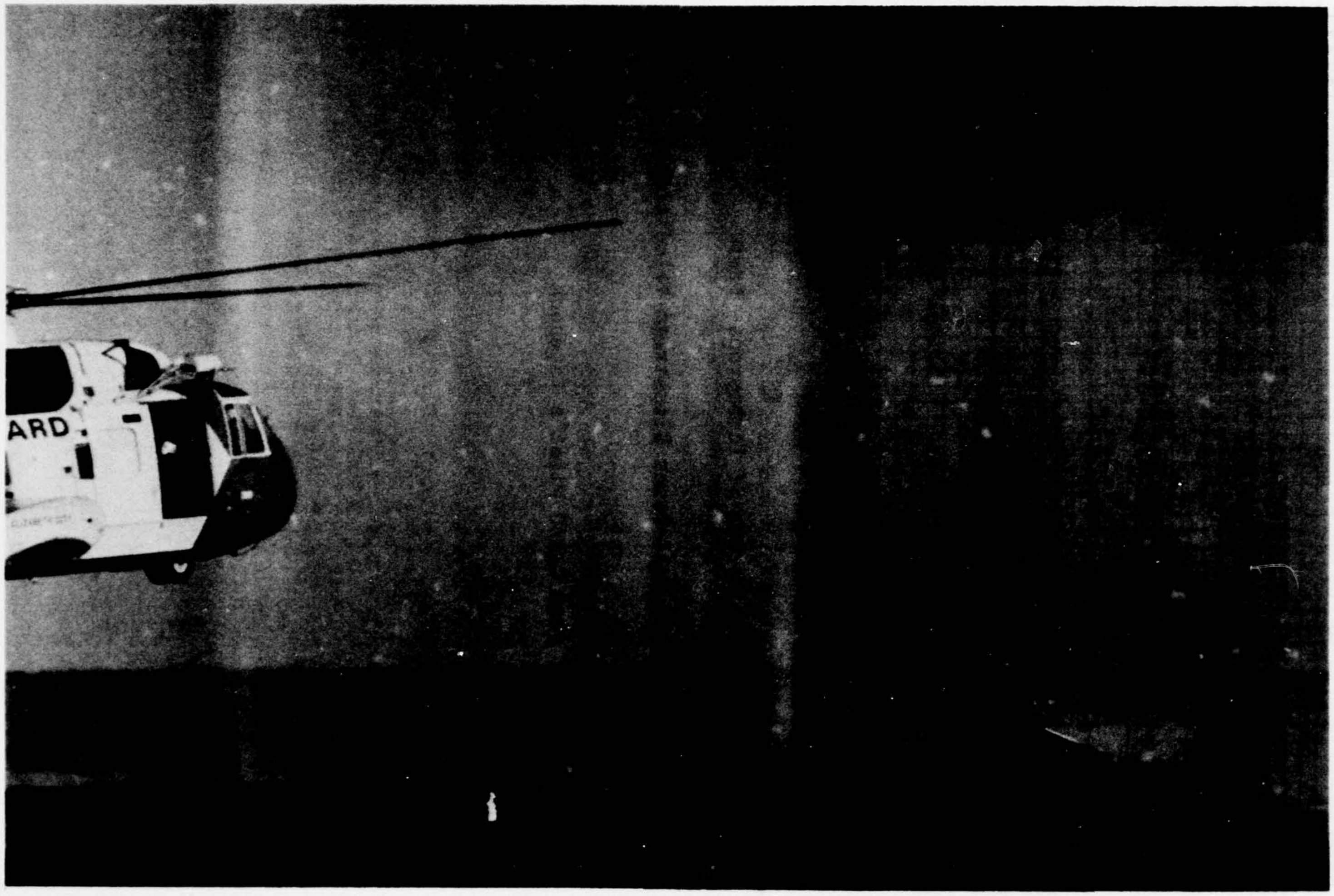


Figure 5- Hendry '25' Lifting: Refer to Table II(7) (NASA Photograph)

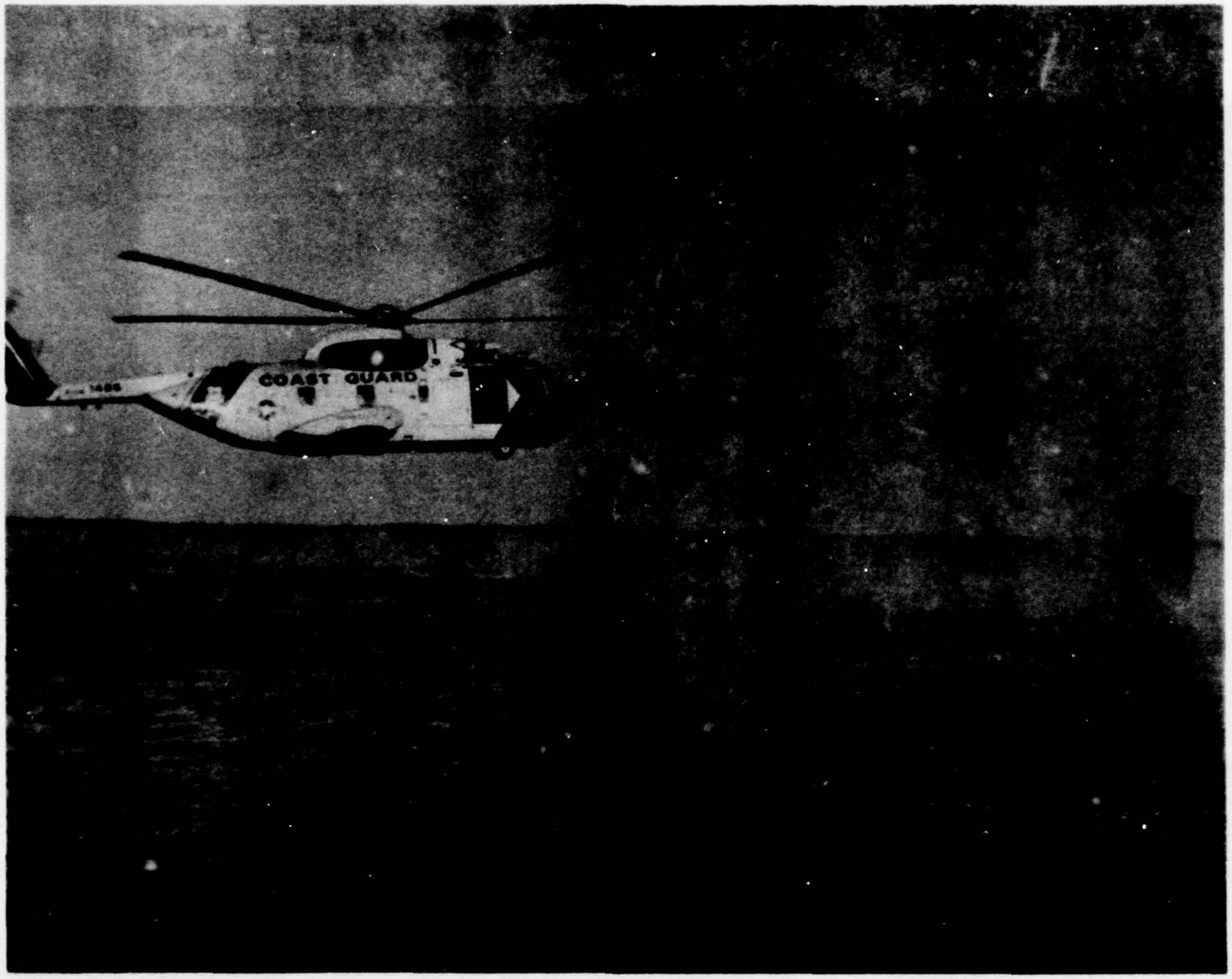


Figure 6- Hendry '25' on Beam Ends: Refer to Table II(8) (NASA Photograph)

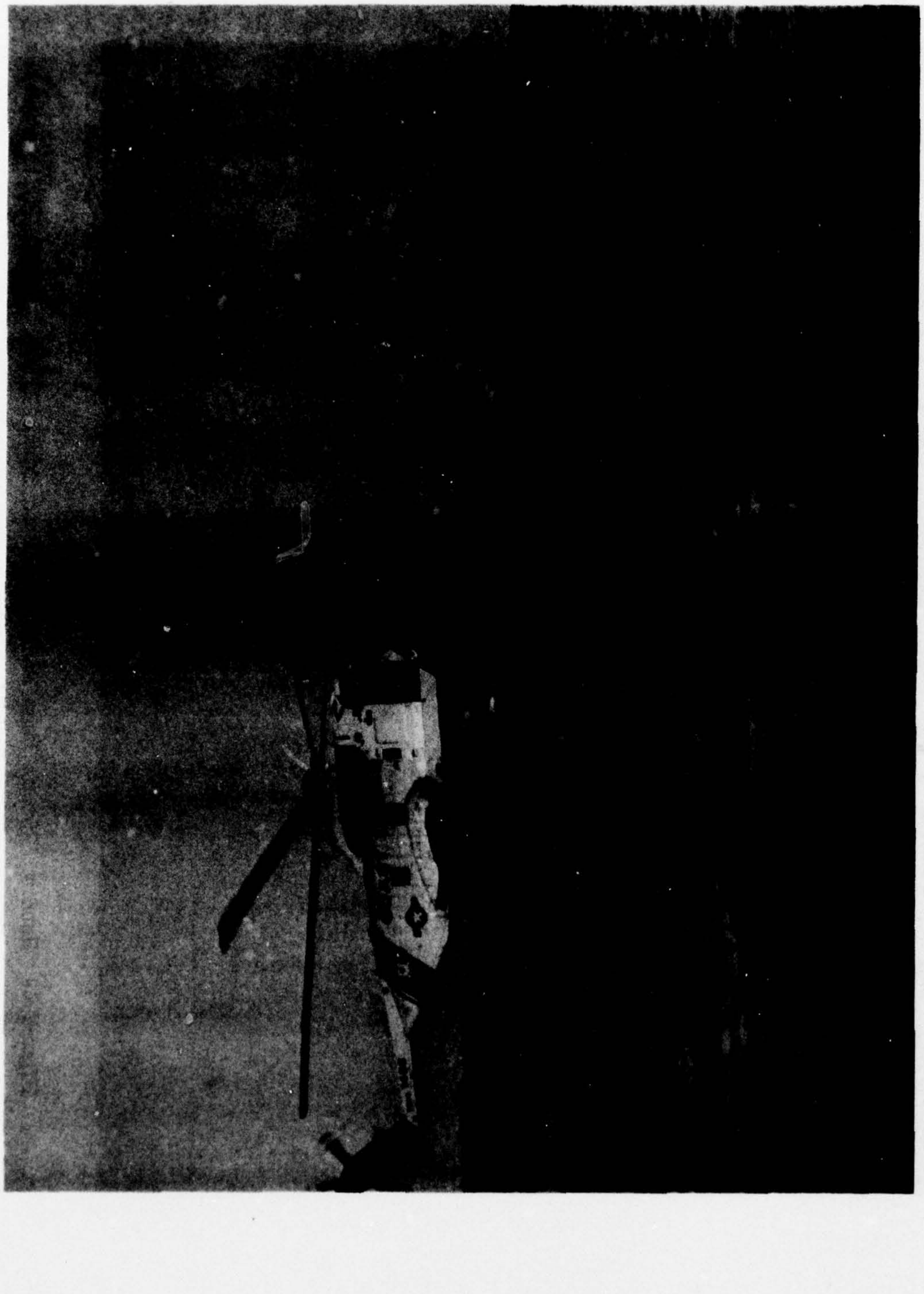


Figure 7- RFD '25' Capsizing: Refer to Table II(9) (NASA Photograph)

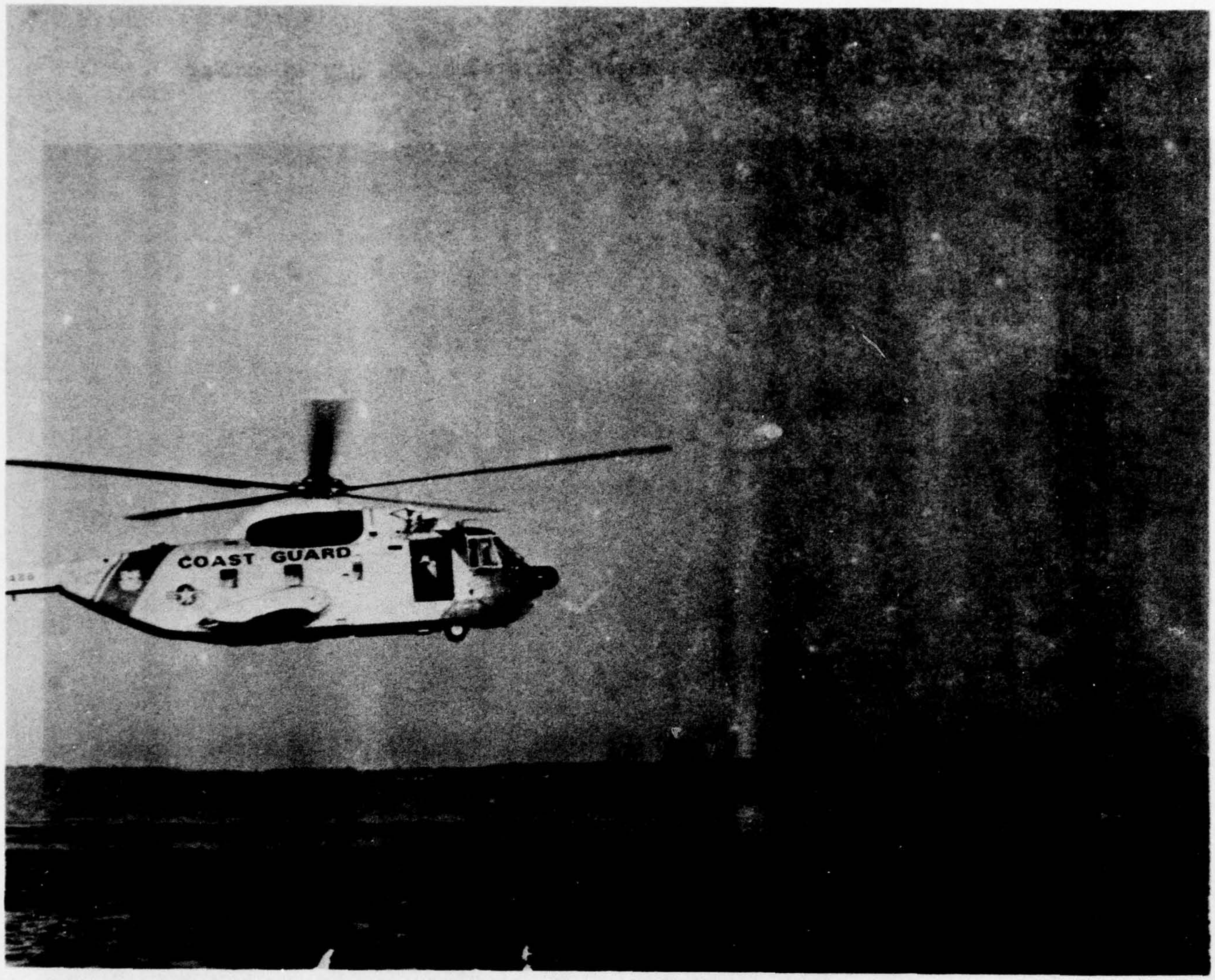


Figure 8- RFD '25' Capsized: Refer to Table II(9) **(NASA Photograph)**

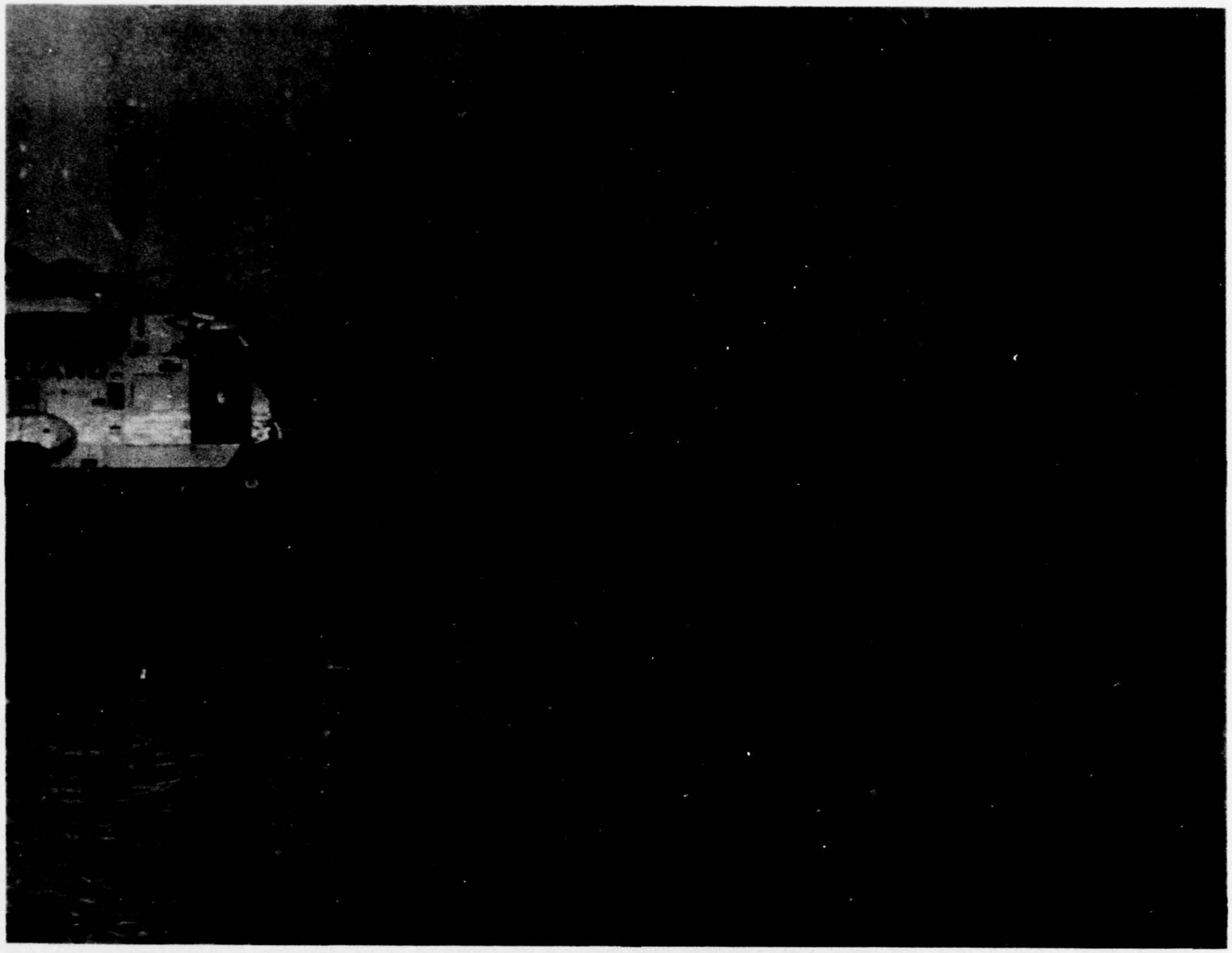


Figure 9- RFD '25' Capsizing: Refer to Table II(10) (NASA Photograph)

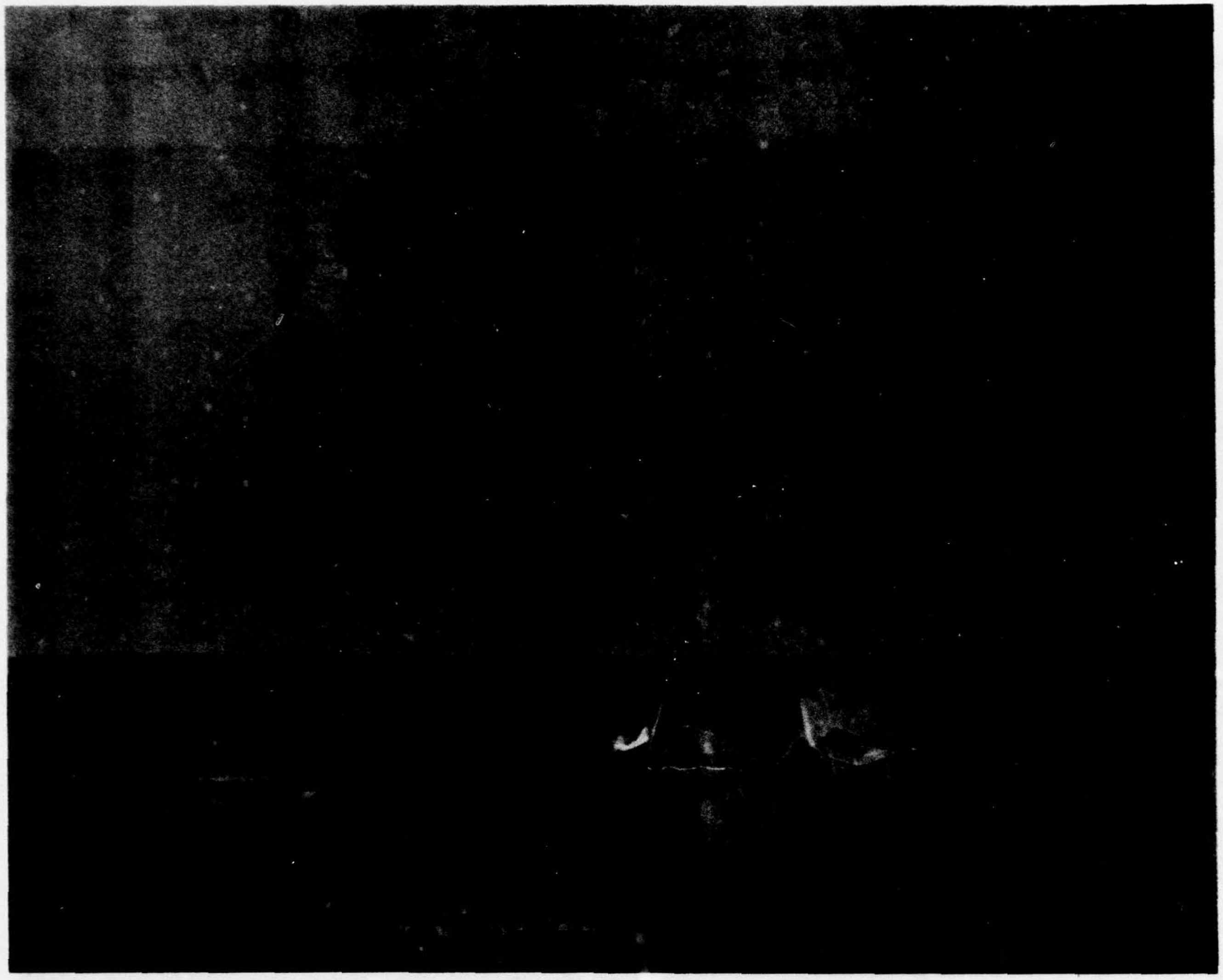


Figure 10- Hendry '25' Capsizing Before Rerighting: Refer to Table III(2) (Jim Givens Photograph)

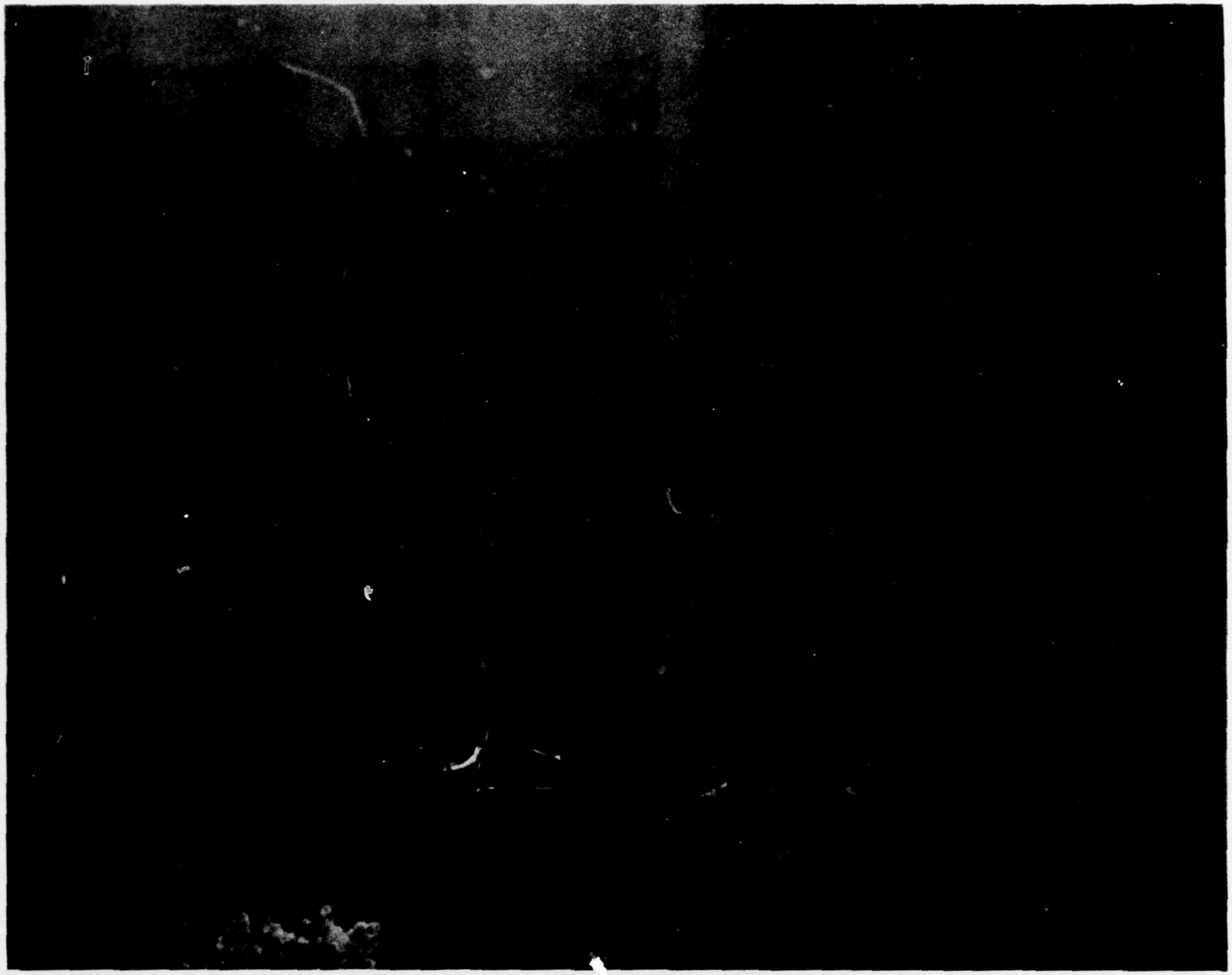


Figure 11- Hendry '25' Capsizing Before Rerighting: Refer to Table III(2) (Jim Givens Photograph)