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LEVEL FLOTATION STANDARDS ANALYSIS RESEARCH AND DEVELOPMENT REPORT

PHASE II - SPECIAL PROBLEMS



NOVEMBER 1975

FINAL REPORT

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**U. S. DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD**

Office of Research and Development
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Previous work in problem definition, standards analysis, and general requirements for a level flotation standard, indicated that several specific areas need additional data/analysis in order to resolve applicability and/or cost/feasibility of level flotation requirements in those areas.

The objective of the study reported herein was to provide information that would assist in finalizing a level flotation standard. This report provides data that will be useful in defining longitudinal and transverse limits for test weight placement for compliance testing purposes. A study of the rough water requirements of small boats which discusses problems encountered in a wave environment is presented. Recommendations for incorporating the data obtained are also presented as part of this report.

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METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures			Approximate Conversions from Metric Measures			
Symbol	When You Know	Multiply by	To Find	Symbol	When You Know	
LENGTH						
m	meters	39.37	inches	in	inches	
cm	centimeters	2.54	centimeters	cm	centimeters	
mm	millimeters	25.4	millimeters	mm	millimeters	
km	kilometers	0.621371	kilometers	km	kilometers	
AREA						
m ²	square meters	1.19599	square meters	m ²	square meters	
ft ²	square feet	0.092903	square feet	ft ²	square feet	
yd ²	square yards	0.846349	square yards	yd ²	square yards	
ac	acres	0.404686	acres	ac	acres	
MASS (weight)						
kg	kilograms	2.20462	kilograms	kg	kilograms	
g	grams	0.001	grams	g	grams	
lb	pounds	0.453592	pounds	lb	pounds	
oz	ounces	0.0283495	ounces	oz	ounces	
ton	metric tons	1.10231	metric tons	ton	metric tons	
VOLUME						
m ³	cubic meters	35.3147	cubic meters	m ³	cubic meters	
l	liters	1.05669	liters	l	liters	
ml	milliliters	0.033814	milliliters	ml	milliliters	
gal	gallons	0.264179	gallons	gal	gallons	
qt	quarts	0.946353	quarts	qt	quarts	
pt	pints	0.473176	pints	pt	pints	
cu ft	cubic feet	0.0283168	cubic feet	cu ft	cubic feet	
cu yd	cubic yards	0.764555	cubic yards	cu yd	cubic yards	
TEMPERATURE (exact)						
°C	Fahrenheit temperature	5/9 (F - 32)	Fahrenheit temperature	°C	Fahrenheit temperature	
°F	Celsius temperature	9/5 (C + 32)	Celsius temperature	°F	Celsius temperature	

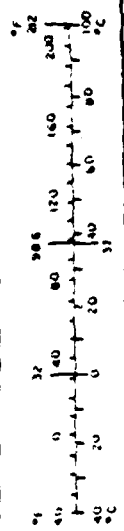


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LEVEL FLOTATION STANDARDS ANALYSIS
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1.0 INTRODUCTORY SUMMARY

Figure 1-1 presents an overview of the objectives of the level flotation project. References 1 and 2 document previous work that has been performed in the level flotation area. In brief, Reference 1 contains a literature search of various flotation standards, practices and recommendations of various countries. It critically compares three flotation standards; the present federal standard, an industry recommended standard and a proposed standard formulated from a study of the other standards. It also documents initial proof testing which indicates that more testing was needed to establish requirements for a level flotation standard. Reference 2 continued research and analysis to obtain information/data needed to qualify a need for level flotation and define requirements for a level flotation standard. The work presented in this report deals with several problems (discussed below) that were not resolved in the earlier work.

As new and different equipment is made available, old tables of recommended test weights become obsolete. Section 2.0 provides data on swamped outboard motors and controls that can be used to compile an updated weight table that can be used with a level flotation standard.

There had been concern that SK boats would not be able to meet a level flotation standard without undue hardship and costs. Section 3.0 demonstrates how two boats of this type can be fitted to meet a level flotation standard without excess difficulty.

Section 4.0 discusses the problems of water absorption of foam; particularly, seat foam. Recommendations for a timed submergence are given for compliance testing considerations.

One of the basic problems of establishing a level flotation standard is in defining an attitude that is both safe and readily attainable. Sections 5.0 and 6.0 discuss the longitudinal trim requirements and the transverse stability requirement.

¹ Cockburn, J. A. and Michalopoulos, C. A., Flotation Standards Analysis Research and Development Report, Wyle Laboratories, June 1973.

² Sautkulis, C., Bowman, J., and Chadwick, T., Phase I Final Report - Level Flotation Standards Analysis Research and Development Report, Wyle Laboratories, May, 1975.

Throughout the development of the level flotation standard, the Coast Guard was concerned with making the public and industry aware of the benefits associated with, and research going into the formulation of a level flotation standard. Part of this program was a level flotation demonstration held in Austin, Texas, for members of BSAC and anyone else that was interested. Section 7.0 of this report contains a literature handout that was prepared for this demonstration. This handout describes the test boat characteristics and procedures employed for the demonstration.

A set of experiments involving novice boaters in a swamping situation which were performed under this task which did not work out as planned are presented in section 8.0. These experiments do, however, provide useful input to another ongoing task (Boater Education) and will be used to full advantage.

Experiments designed to determine any special problems which self-bailing boats might have are presented in section 9.0. Unless accident data indicate otherwise, these boats should be treated like other boats with respect to a level flotation standard.

Section 10.0 points out that small boats of 500 lbs or less persons capacity may require 62-50 flotation (as opposed to 50-50 flotation for other boats) in rough water. This should only be required if their exposure rate in this type of condition deems it necessary.

The findings in this report in conjunction with work performed in References 1 and 2, plus input from the Research and Development Center in Groton, Connecticut, combined with work performed by personnel at USCG Headquarters should lead the Coast Guard to form a safe and equitable level flotation standard.

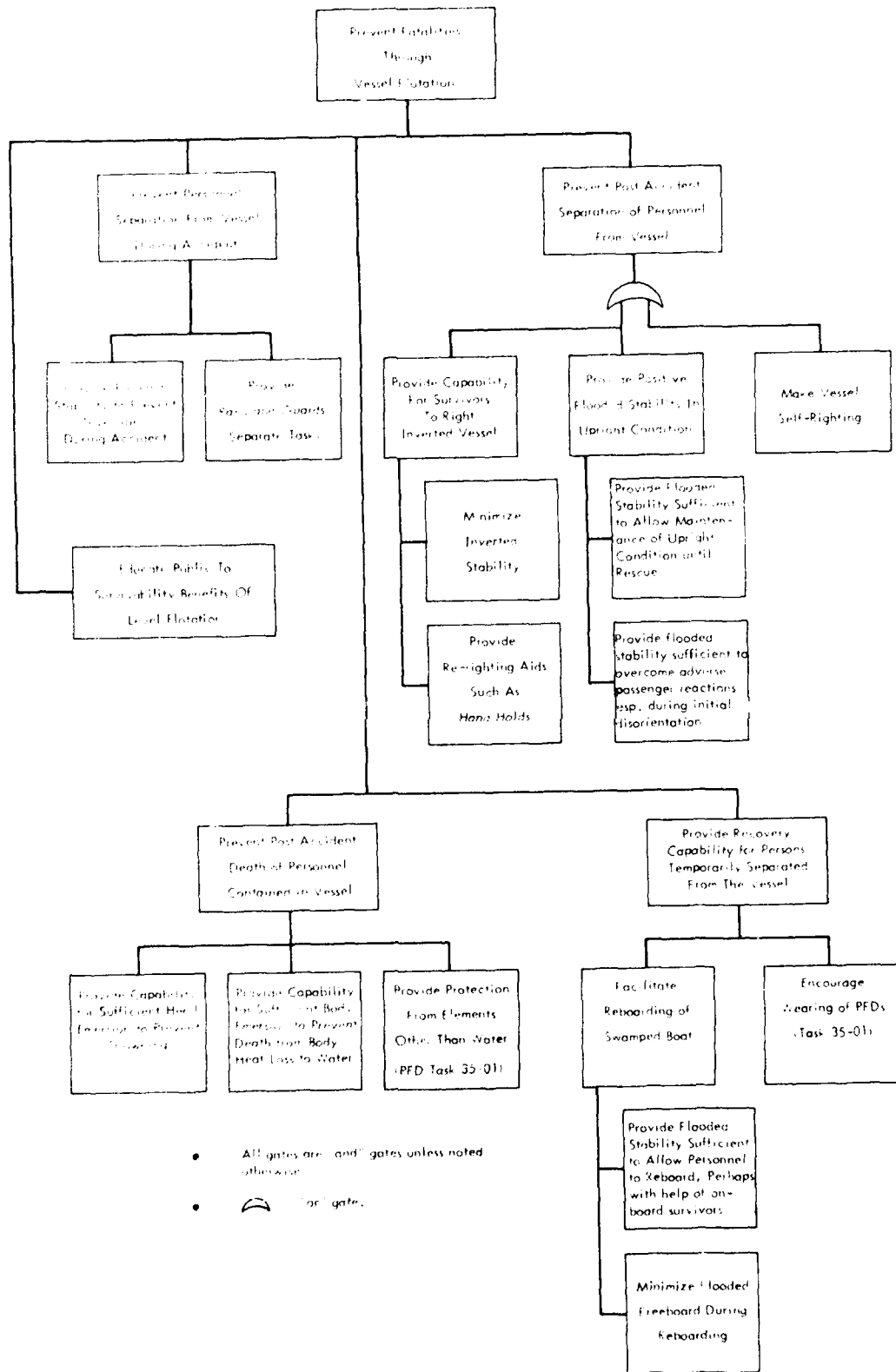


Figure 1-1. Objectives Tree for Level Flotation Standard

2.0 SWAMPED MACHINERY WEIGHT DETERMINATIONS

Reference 2 suggests that the swamped machinery weight table to be used for flotation amount determination should be updated. The data presented in this section can be used in conjunction with data on other engines to aid in updating the table of swamped machinery weight.

2.1 Test Description

Swamped engine weights were determined as follows:

The engine was fastened to an overhead crane with a load cell in series with the crane and was lifted and the dry weight recorded. The engine was then lowered into a tank of fresh water until the water level was at the top of the mounting bracket (see Appendix A, Figure A1-A11). This weight was recorded as the swamped weight of the engine. To facilitate attaching the crane, the covers on most engines had to be removed; therefore, to obtain the actual swamped weight, the weight of the engine covers was added to the weight read from the load cell. The 135 hp Evinrude and the 130 hp Chrysler had power tilt gear (see Figures A12 and A13) and were tested with it attached.

The battery and control weights were determined in a similar manner. These items were completely submerged during the submerged weight determination. Figure A14 shows one of the controls used.

2.2 Swamped Machinery Weight Results

Since the values obtained must be used in conjunction with other values to update the Swamped Machinery Weight Table, the results are presented in tabular form.

Table 2-1 presents the results of the swamped engine weight determination.

TABLE 2-1. SWAMPED ENGINE WEIGHT DETERMINATION

Make	Year	HP	Dry Weight	Swamped Weight	Swamped Wt./Dry Wt.
Evinrude	1974	2	26	23	.885
Evinrude	1972	4	36	31	.861
Evinrude	1974	6	52	45	.865
Evinrude	1974	9.9	72	61	.847
Evinrude	1975	15	73	62	.849
Evinrude	1972	25	84	75	.893
Evinrude	1972	65	210	179	.852
Evinrude	1973	85	271	237	.875
Evinrude	1974	135	302	259	.858
Chrysler	1974	35	154	136	.883
Chrysler	1973	130	267	232	.869

Average Swamped Wt./Dry Weight = .867

Table 2-2 presents the results of the swamped control and battery weights.

TABLE 2-2. SWAMPED CONTROL AND BATTERY WEIGHTS

Item	Dry Weight (lb.)	Submerged Weight (lb.)
Controls	8.5	4.5
Controls	10	5
Controls	16	11
12V Battery (Unknown)	39	19
12V Battery (Deka)	64	40
12V Battery (Die Hard)	52	35
12V Battery (Delco)	46	25

3.0 SK BOAT FLOTATION FEASIBILITY DEMONSTRATION

At the beginning of Phase II of flotation development, it was believed that SK and jet boats would be required to meet the standard. Later developments through work performed at USCG Headquarters, Washington, D. C. indicated that there was not sufficient need to warrant their compliance with the proposed level flotation standard.

The results presented here are those of an initial feasibility study using a typical SK boat and a typical jet boat. This study shows that it is feasible, without too much difficulty, to install level flotation in these types of boats.

Figures 3-1 through 3-3 show the SK boat used for this feasibility study and Figures 3-4 and 3-5 show the jet drive boat used.

Flotation was installed to meet the modified 50 - 50 level flotation requirement. Figure 3-6 shows the SK boat in the test tank with the required percent of the persons capacity weight. Person capacity is 750 pounds. Modified 50 - 50 level flotation required 50 percent of the first 600 pounds (300 pounds) plus 25 percent of the remaining weight (37.5 pounds). The proposed standard then requires 50 percent of this weight (168.75 pounds) to be supported at the side. Figure 3-7 shows the boat in this condition. An additional 15 pounds side load caused the boat to attain an attitude as shown in Figure 3-8.

Figures 3-9 and 3-10 show the flotation arrangement of the SK boat. Manufacturer installed flotation was present in the gunwales throughout the length of the passenger carrying area.

Figures 3-11 and 3-12 show the arrangement of the flotation in the jet drive boat that was used in the flotation demonstration at Naples, Florida, January 27-30, 1975.

Figures 3-13 and 3-14 are diagrams with flotation modifications indicated. Table 3-1 contains the amount and location of each flotation modification made.



Figure 3-1. SK Boat (front view)



Figure 3-2. SK Boat (stern view)

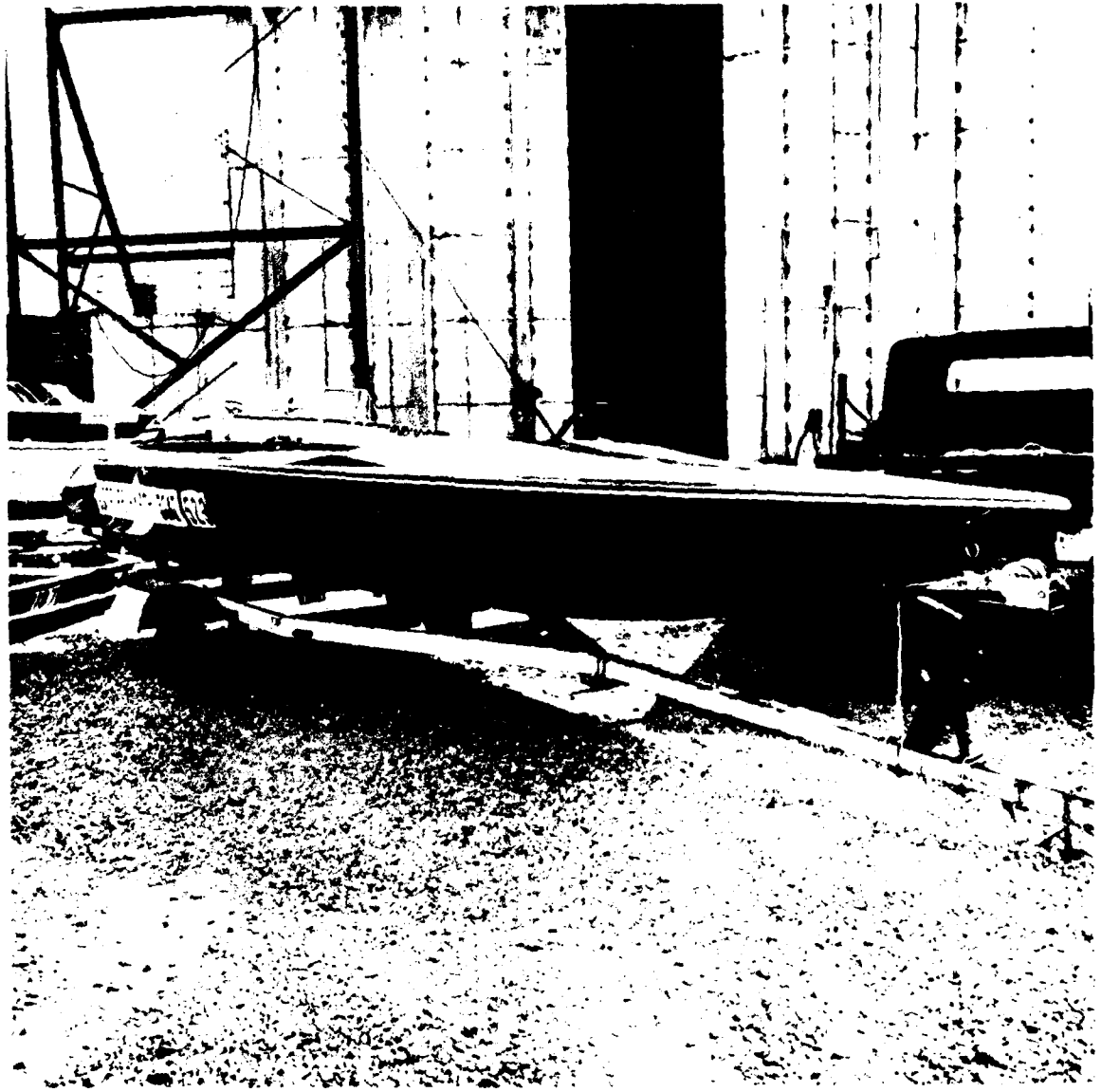


Figure 3-3. SK Boat (side view)



Figure 3-4. Jet Drive Boat (stern view)

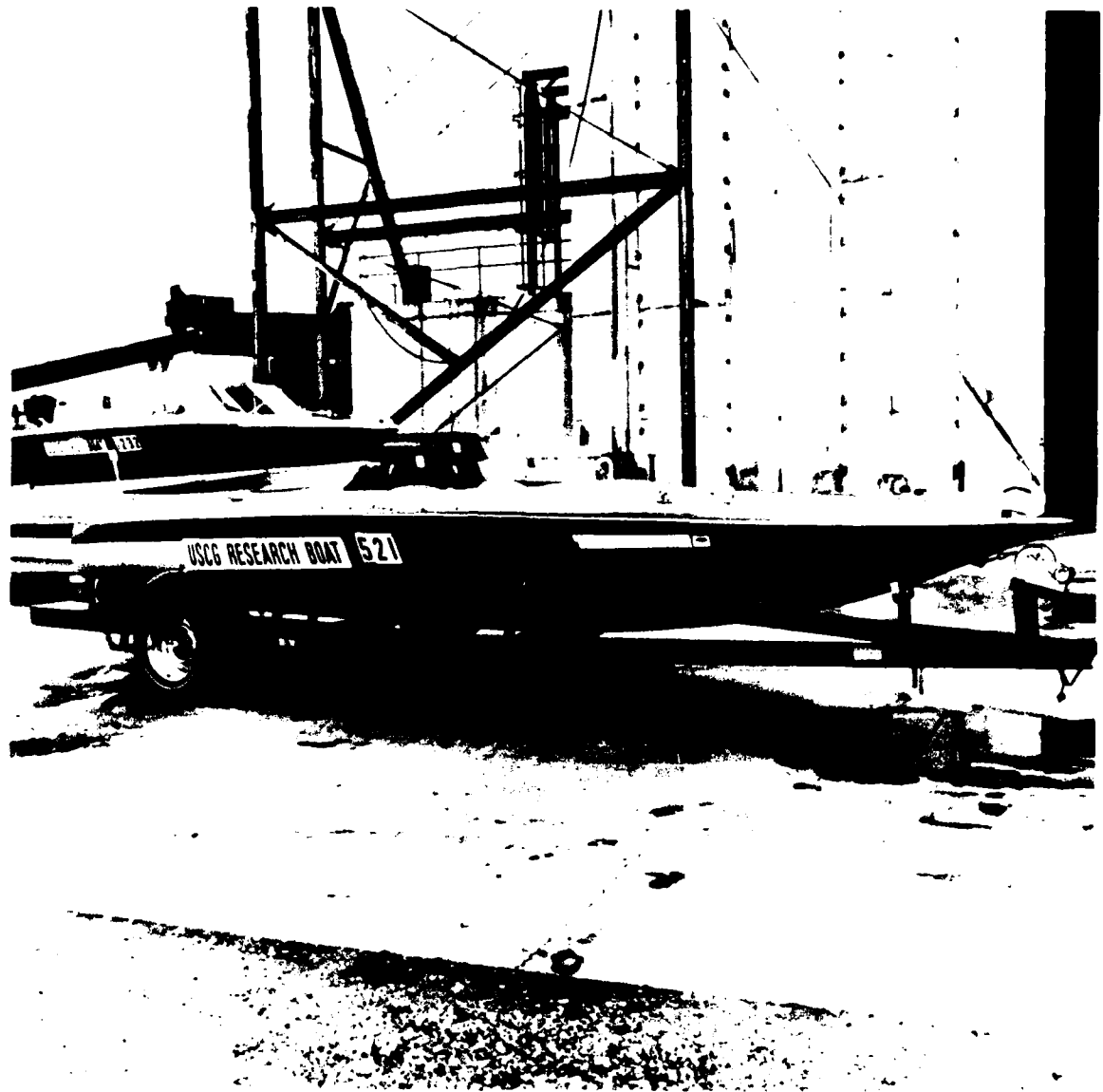


Figure 3-5. Jet Drive Boat (side view)

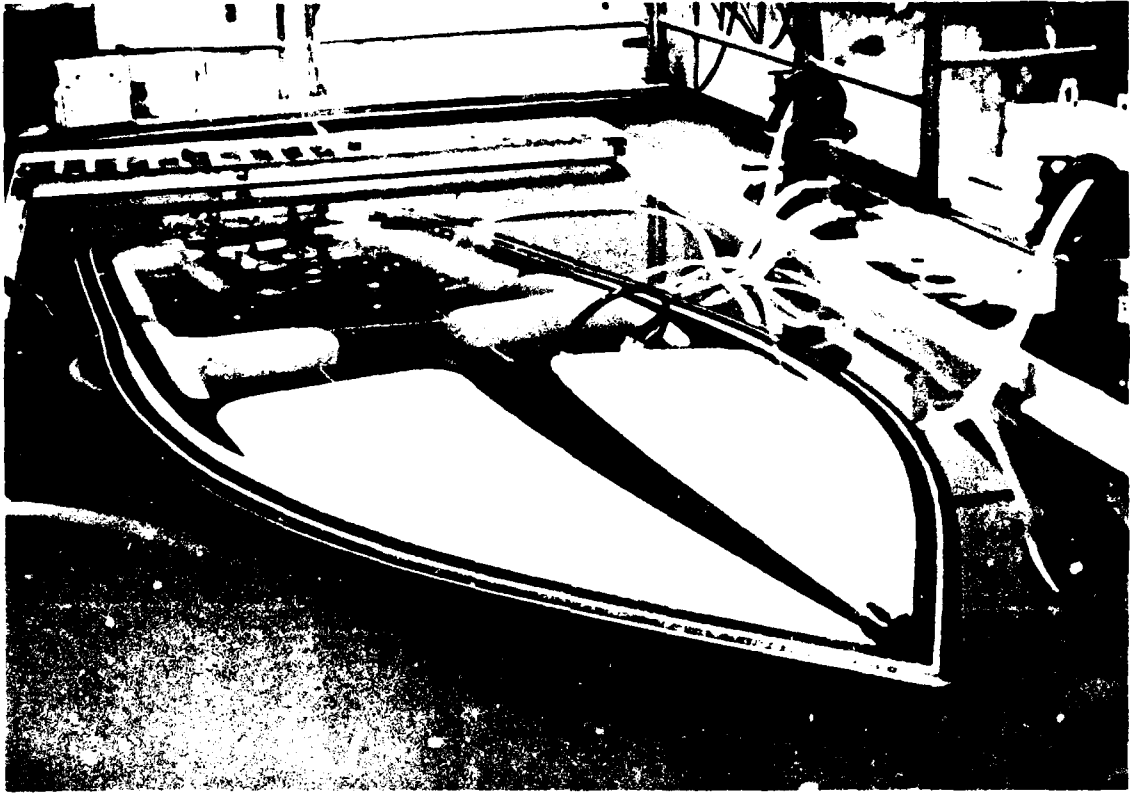


Figure 3-6. SK Boat - 50-50 Level Flotation

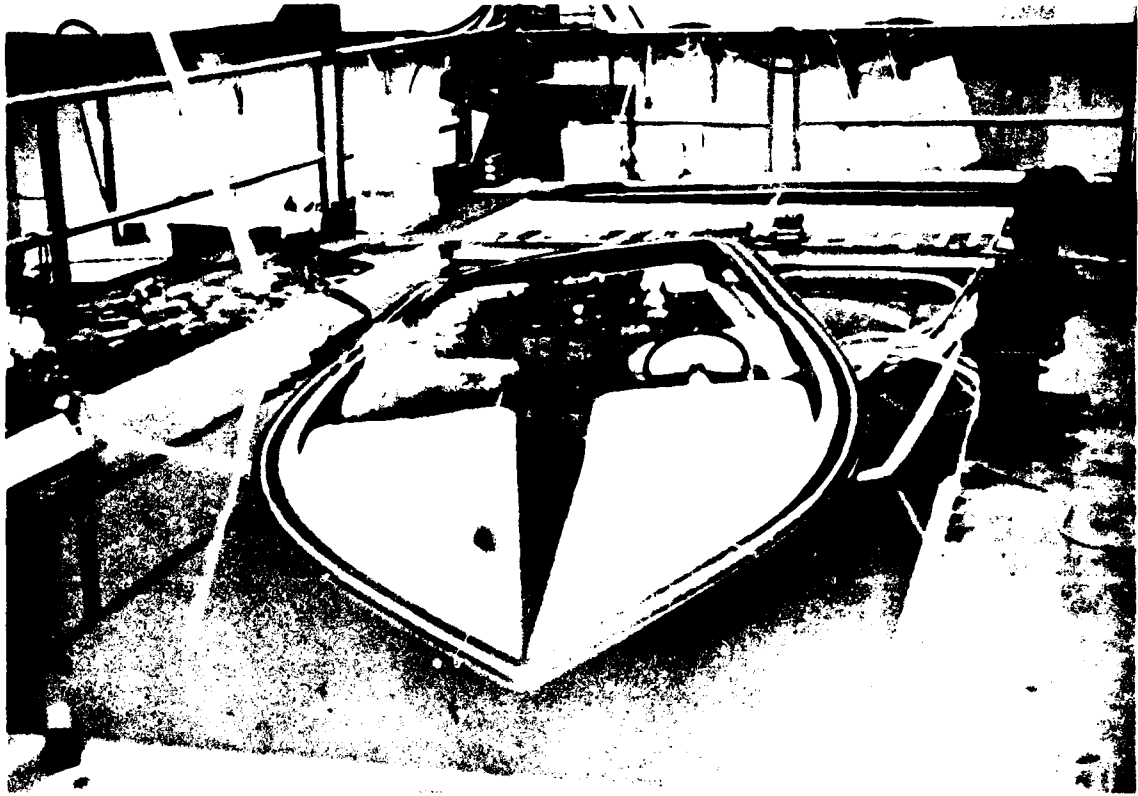


Figure 3-7. SK Boat - Side Load Test

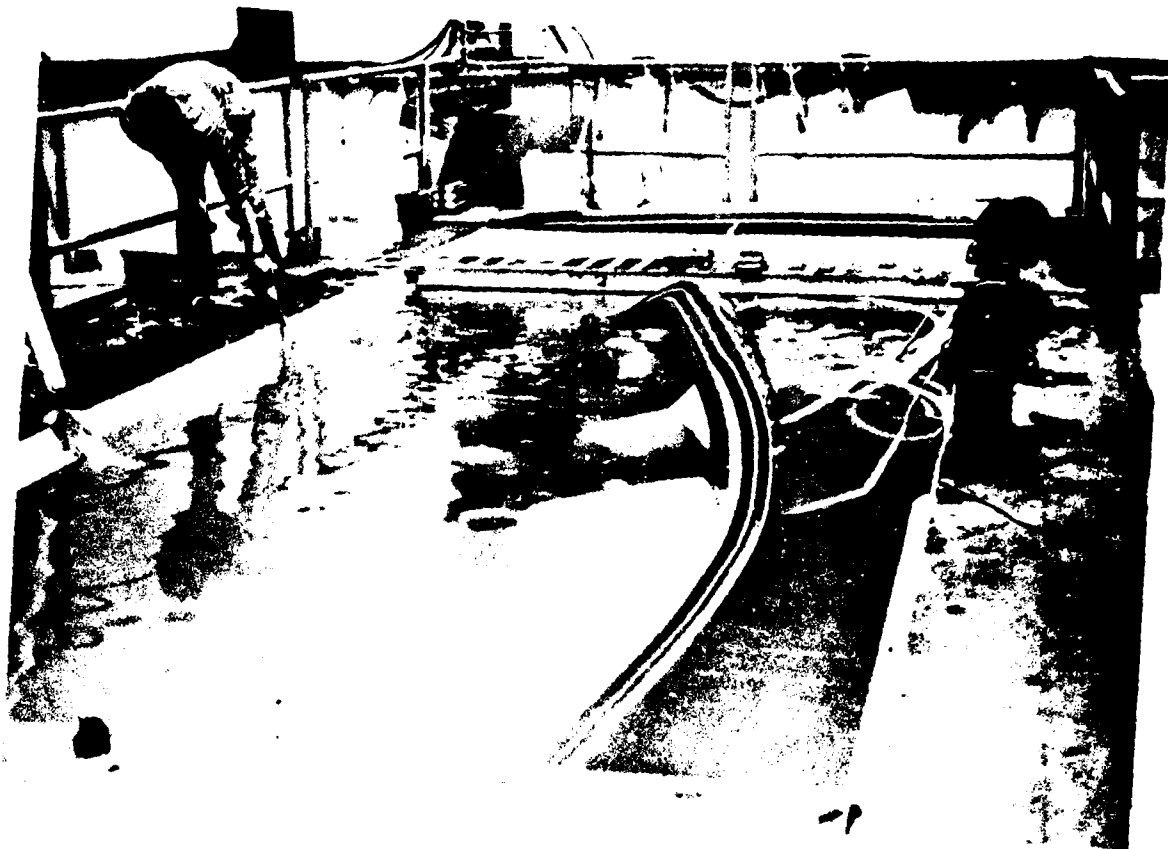


Figure 3-8. SK Boat With Additional Side Load Weight

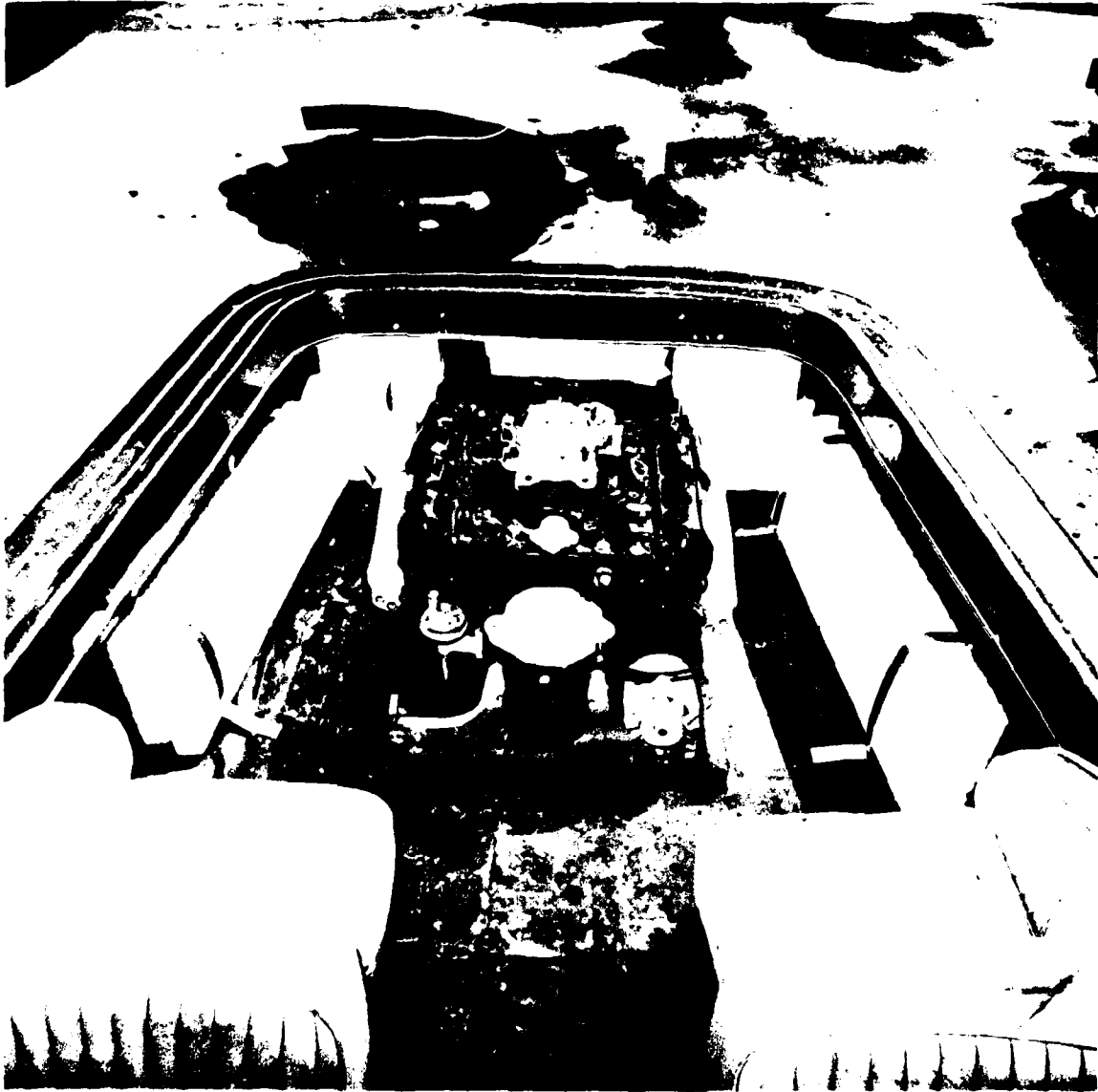


Figure 3-9. SK Boat Flotation Arrangement

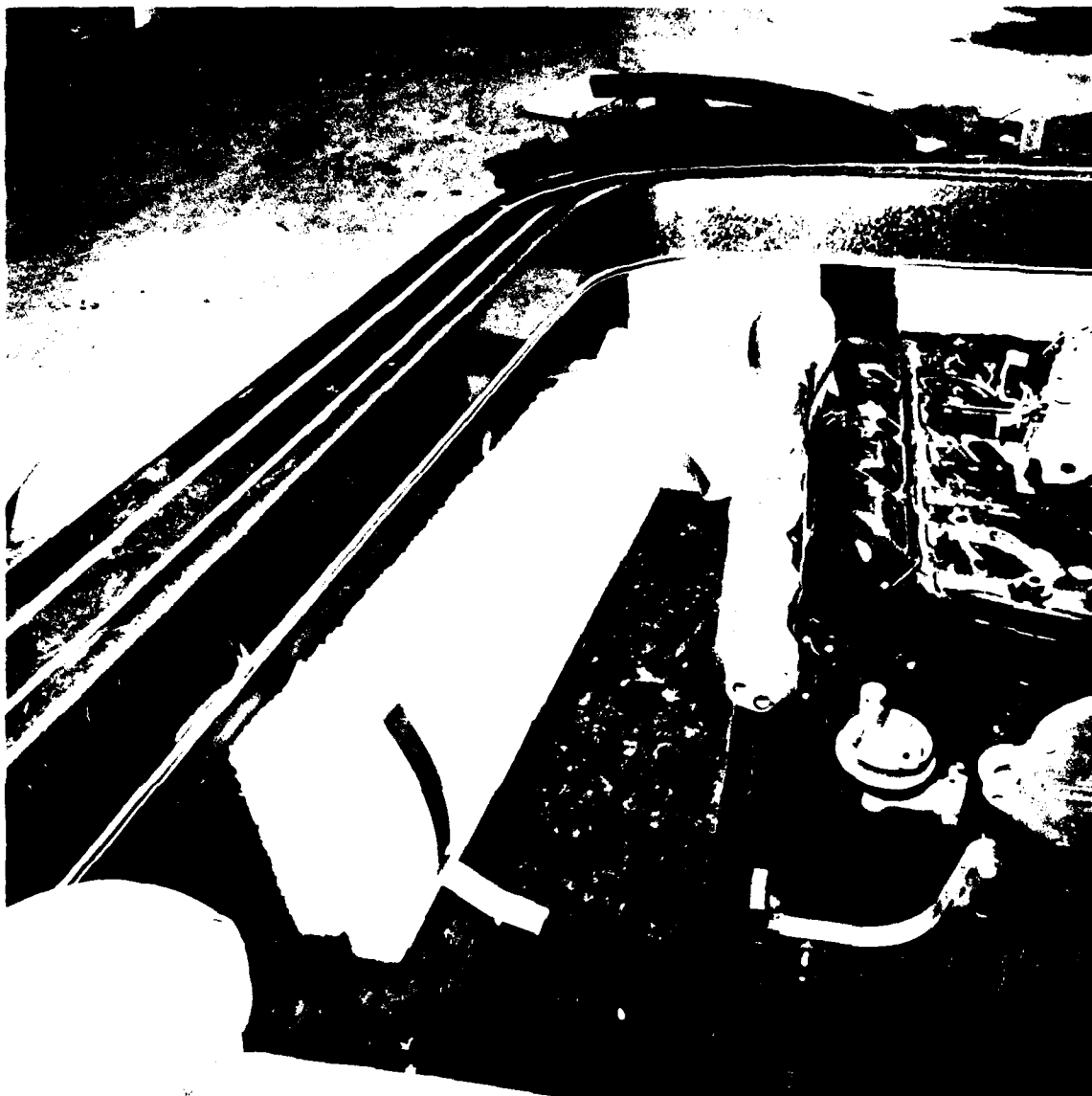


Figure 3-10. SK Boat Flotation Arrangement

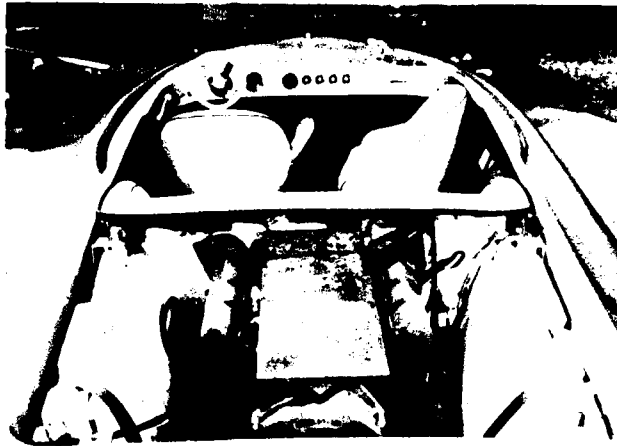


Figure 3-11. Jet Boat Flotation Arrangement

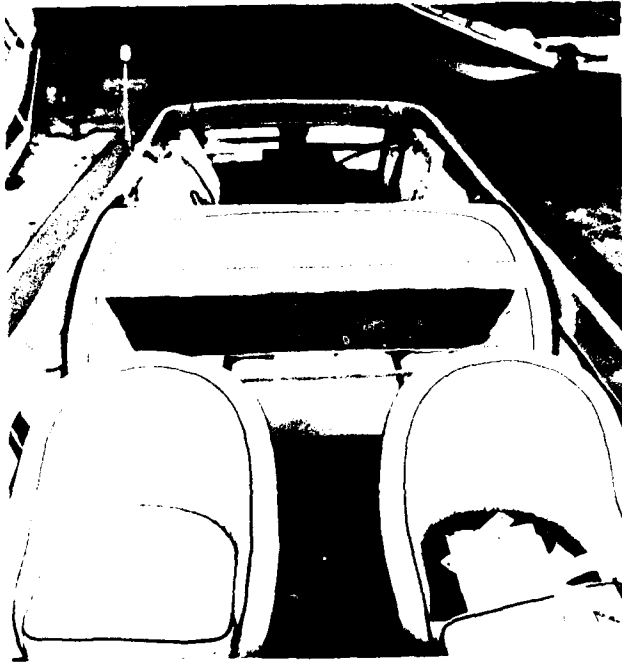


Figure 3-12. Jet Boat Flotation Arrangement

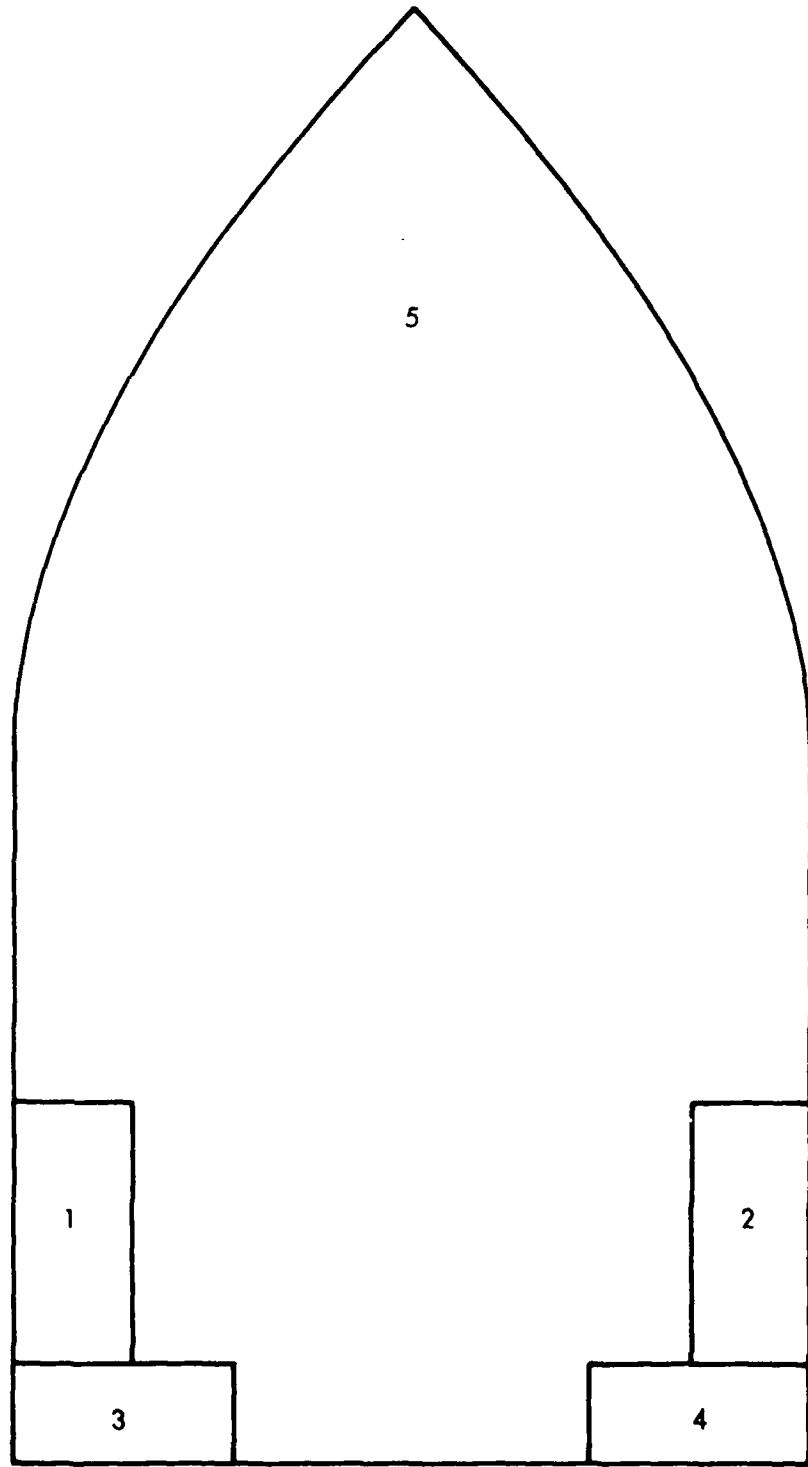


Figure 3-13. Diagram of Flotation Modification (SK Boat)

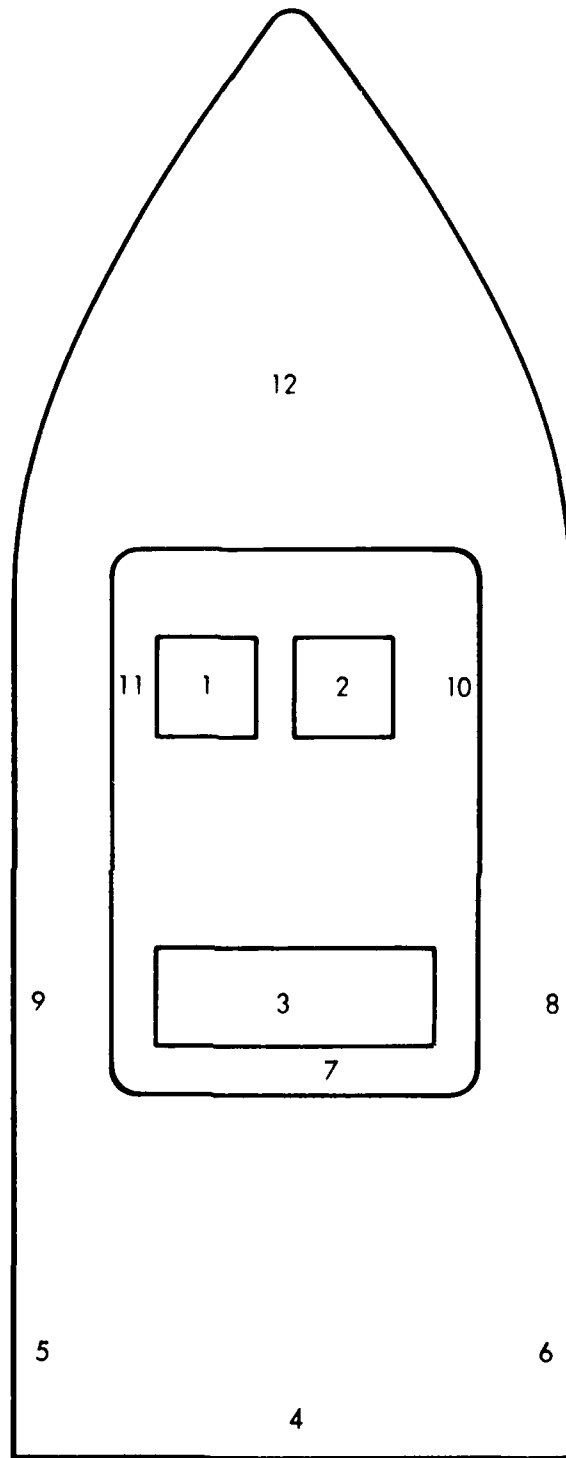


Figure 3-14. Diagram of Flotation Modification (Jet Boat)

TABLE 3-1. FLOTATION MODIFICATION

Location	Distance From Bow	Distance From C	Cu. In. Foam	lb. Buoyancy
SK Boat				
1	176 in.	27 in.	1520	53.13
2	176 in.	27 in.	1520	53.13
3	204 in.	18 in.	1871	65.40
4	204 in.	18 in.	1871	65.40
5	24 in.	(Removed From "As manufactured" boat)		-200
Jet Boat				
1	117 in.	14 in.	775.75	27.11
2	117 in.	14 in.	422.32	14.76
3	154 in.	0 in.	2035.5	71.15
4	216 in.	0 in.	563	19.68
5	192 in.	24 in.	7327.5	256.12
6	192 in.	24 in.	8496	296.97
7	168 in.	0 in.	2016	70.47
8	156 in.	34 in.	1123	39.43
9	156 in.	34 in.	1128	39.43
10	122 in.	34 in.	756	26.42
11	122 in.	34 in.	756	26.42
12	68 in.	0 in.	5548.5	193.94

4.0 FOAM ABSORPTION CONSIDERATIONS

One area of concern regarding the characteristics of flotation material is that of water absorption. It was felt that if a boat just met the minimum requirements when it was first submerged, it may not meet the minimum requirements after being submerged for a period of time, particularly if open cell foam is used such as that found in many boat seats. To aid in deciding what should be done regarding this problem, the water absorption characteristics of this seat foam was investigated.

Three seats were used for this investigation. Two of the seats were relatively new and the third was a couple of years old and had been exposed to much weather and submerged many times during other experiments. This older seat was used to see how the characteristics may have changed with age and use.

Tables 4-1, 4-2, and 4-3 present the results of the three seat tests. The seats used as felt to be representative of those that would provide buoyancy in many production boats. Looking at Tables 4-1 through 4-3, you can see that the seats do lose buoyancy by remaining submerged. However, if you look at the loss of buoyancy that occurs when the seats are walked on, you can see that this is a significant reduction. Just leaving the seats submerged in water does not give a true indication of the loss in buoyancy that would occur if the seats were submerged and people were moving about on them. This could present a problem for compliance testing for a flotation standard. If the loss in buoyancy with people moving about on the seats is to be effected, a test procedure must be developed to do this. It may be rationalized that people sitting on the seats do not have the same effect on buoyancy as people walking on the seats, and that the seat can be submerged for compliance testing purposes without "walking on the seats."

If seat foam is permitted to be used to meet the flotation requirement, another problem may be encountered; that of having the seats pull out from their fastenings. A test for strength of fastenings may also have to be developed.

To see what effect loss of buoyancy due to submergence had on an entire boat, an 18 ft jet drive boat was tested. Table 4-4 shows these results.

TABLE 4-1. NEW SEAT SUBMERGENCE TESTS

Time Submerged	Submerged Fixture Wt (lb)	Submerged Fixture and Seat Wt (lb)	Seat Buoyancy (lb)
Initially Submerged	105	7	98
Submerged for 1 hr	105	48	57
Submerged for 2 hr	105	51	54
Submerged for 4 hr	105	54	51
Submerged for 4 hr and walking on submerged seat for 10 min.	105	70	35
Submerged for 6 hr and walking on submerged seat for 10 min.	105	72	33
Submerged for 22 hr	105	74	31
Submerged for 24 hr and walking on seat for 10 min.	105	77	28

TABLE 4-2. NEW SEAT SUBMERGENCE TESTS

Time Submerged	Submerged Fixture Wt (lb)	Submerged Fixture and Seat Wt (lb)	Seat Buoyancy (lb)
Initially	105	12	93
Submerged for 15 min.	105	31	74
Submerged for 16 hr	105	58	47
Submerged for 19 hr	105	62	43
Submerged for 19 hr and walked on for 10 min.	105	75	30
Submerged for 21 hr	105	76	29

TABLE 4-3. OLD SEAT SUBMERGENCE TESTS

Time Submerged	Submerged Fixture Wt (lb)	Submerged Fixture and Seat Wt (lb)	Seat Buoyancy (lb)
Initially	103	45	58
Submerged for 15 min.	103	64	39
Submerged for 16 hr	103	67	36
Submerged for 16 hr and walking on seat for 10 min.	103	85	18
Submerged for 18 hr	103	87	16

TABLE 4-4. 18 FT JET BOAT SUBMERGENCE TESTS

Time	Net Buoyancy
Initially	475
Sub 4 hr	332
Sub 16 hr	268
Sub 16 hr and walked on seats	240

From Table 4-4, it can be seen that the reduction in buoyancy due to walking on the seats is a small percentage of the total reduction in buoyancy caused by the boat being submerged for an extended period of time.

5.0 LONGITUDINAL TRIM CONSIDERATIONS

5.1 Objective

The objective of the work covered in this section was to investigate and analyze any trim problems which may be associated with level flotation.

5.2 Trim Problems Associated With Level Flotation

There were several areas which needed consideration during the development of the level flotation standard. One area of concern was the trim attitude of a flooded boat with no passenger load on board. If a boat met the standard criteria in the full load condition, would that mean it would also provide a safety platform in the partially loaded or no passenger load condition? A boat in the no passenger load condition must still float with an attitude that would allow passengers in the water to board it.

Another area of concern was that of the maximum trim a boat should have both in the full passenger load and no passenger load flooded condition. This would have to be a subjective determination based on results of flotation testing.

A third area of importance was the longitudinal limits for test weights for compliance testing purposes. Reasonable longitudinal limits needed to be set for test weight placement in order to insure that in a real life situation passengers could be supported in areas that they could readily occupy.

5.3 Experiments

Several experiments were conducted to provide data to help in answering the trim questions.

5.3.1 Trim in the Light Flooded Condition

These experiments were performed in order to investigate the possible trim a boat might have in the no passenger load flooded condition. These experiments were performed as follow:

Three boats were equipped with flotation to meet a modified 50-50 flotation requirement. This modified requirement is that the boat support, on centerline, 50% of the first 600 lbs of passenger load and 25% of the remainder of the passenger load. The transverse stability requirement is that it support 50% of the centerline load at the side. The three boats used are boats 516, 1219 and 1187 (Figures 5-1, 5-2, and 5-3, respectively). Characteristics of these boats are shown in Table 5-1.

The flotation material in each boat was adjusted so that the boat floated in a "level" attitude when the test weights were placed at a predetermined position. "Level" for these experiments was taken as possible minimum conditions for the proposed standard. The predetermined positions of the test weights varied from midlength of the passenger carrying area, to 10%, 20% or 30% forward of the midlength. In the case of boat 516 which had two passenger compartments, the test weights for each compartment were divided in the same ratio as the lengths of each compartment to each other.

For some experiments, the flotation material in the boat was not relocated to obtain a "level" attitude when the test weights were moved to various locations. Instead, a test fixture (Figure 5-4) was fabricated to simulate the effect of shifting flotation material. If the weights in the two baskets are the same, the net vertical force on the boat is 0 (neglecting friction in the pulleys). These two forces, however, apply a couple to the boat enabling it to be trimmed to any desired attitude without changing the weight/buoyancy relationship of the boat.

The test weights were initially placed on centerline at the midlength of the passenger carrying area or areas. The required machinery weight was also placed on the boat in its proper location. The quantity of test weights used initially was that required by the modified 50-50 flotation standard; i.e., 50% of the first 600 pounds plus 25% of the remainder of the passenger load.

Each boat was leveled by shifting flotation material or with the leveling fixture and the drafts fore and aft recorded. Weights were then removed in increments and the resulting draft changes recorded. The attitude of the boat with all passenger load weights removed was also recorded.

The weights were then replaced in the boat on centerline, but at a different longitudinal position; 10%, 20% or 30% forward of midlength of the passenger compartment. The weights were again removed in increments and drafts fore and aft recorded (see Section 5.4.1).

5.3.2 Longitudinal Position of Test Weights

Since the level flotation standard would specify an attitude in which the boat must float, it must also specify area limits for test weights. Ideally, test weights should be placed only in areas that real people could be expected to occupy in a swamping situation. This would require defining areas that people could occupy. This could prove to be difficult and very time consuming, especially when compliance testing. An alternative to this is subjectively choosing a longitudinal limit that appears to be satisfactory.

Based on experience gained during the development of a level flotation standard, it was believed that $\pm 20\%$ of passenger area length about midlength of passenger area was a suitable limit for placement of test weights. It appears to be very difficult to fit occupants in the boat forward of the 20% mark, say at the 30% mark. In order to substantiate the subjective choice of $\pm 20\%$, the following determination was made.

Most boats would probably lean toward the forward limit for passenger load to obtain a level attitude. This is due to the heavy engine weight aft. If test weights were permitted to have their LCG at 20% forward of the midlength of the passenger carrying area, this would mean that in a real swamping situation half the people must be forward of the 20% mark in order to obtain a level attitude. In order to determine if this indeed were possible, a sample of 18 boats was used for the determination. For each of these boats (see Table 5-2), the persons capacity in pounds was determined. The person capacity in pounds was then divided by 150 to obtain the number of people at 150 pounds the boat would support. Half of this number of people then must be able to get forward of the 20% forward mark in each of these boats. The required number of people (Table 5-2) boarded each boat and attempted to locate themselves in the required position. Results are presented in Section 5.4.2.

5.4 Results and Analysis of Trim Experiments

Following are the results of several experiments designed to aid in establishing trim criteria for a level flotation standard.

5.4.1 Results of Experiments to Determine Trim in the Light Flooded Condition

Tables 5-3 through 5-9 contain the results of the experiments designed to determine possible trim in the light, flooded condition. The results of each boat will be discussed separately.

Boat 516 was initially equipped with flotation to support a passenger load of 1280 pounds to the modified 50-50 requirement. This is a net load of 470 pounds. From the time of the original test determining the quantity of flotation present to the time of the first experiment (approximately two hours), the boat lost buoyancy due to water absorption resulting in its being able to support only 450 pounds.

As seen in Table 5-3, the boat was trimmed so that the aft end was approximately 12 inches below the surface of the water with the forward end approximately at the surface of the water. (This was being considered as a possible minimum level attitude for the proposed standard.) The test weights were at the midlength of the passenger carrying areas for this experiment. When all passenger weights were removed, the total trim of the boat was just over 13 inches. This is very little change from the initial trim of approximately 12 inches.

The next two experiments with boat 516 utilized the leveling apparatus to bring the boat to the desired trim when the passenger load weight was placed 20% and then 30% forward of midlength on the centerline (as opposed to at the midlength as in the first experiment).

The boat had lost an additional ten pounds of buoyancy due to water absorption (additional submergence time about two hours) for the 20% forward experiment and an additional ten pounds prior to the 30% forward experiment (total immersion time approximately seven hours). As seen in Tables 5-4 and 5-5, the change in trim from the fully loaded condition to the no passenger load condition increased in the latter experiments. In the case where the weights were 20% forward, the trim went from about 13 inches down by the stern to about 15 inches down by the stern, and in the case where the weights were 30% forward, the trim went from

about 11-1/2 inches down by the stern in the fully loaded condition to just over 20 inches in the no passenger load condition. For this boat, the submergence of the aft end was always the greatest in the fully loaded condition and the boat never trimmed to what could be considered a severe attitude.

From these experiments, it shows that this boat does not trim excessively in the no passenger load condition even when the flotation was located such that it requires the passenger load to be 30% forward of midlength to obtain minimum acceptable trim conditions in the full load condition. At the time of these tests, it was felt that 30% forward of midlength could possibly be the physical limit for locating the weights to obtain the desired trim attitude in the fully loaded condition.

Tables 5-6, 5-7 and 5-8 contain the results of experiments on boat 1219. Table 5-6 shows that when the test weights are at the midlength of the passenger carrying area, the boat changed trim slightly from the full passenger load to the no passenger load condition. It went from just over five inches down by the stern to seven inches down by the bow.

The next two experiments with boat 1219 had the same location of the test weights (30% forward of midlength); however, they differed in initial trim. Table 5-7 shows the trim in the full load condition to be about five inches down by the stern while the initial trim for the experiments shown in Table 5-8 is about 16 inches down by the stern with the submergence at the aft end being about 13 inches.

For both experiments going from the fully loaded condition to the no passenger load condition did not result in severe trim. Again, these experiments indicate that severe trim in the light condition would not be a problem.

The last boat used in these trim experiments was a small, lightweight johnboat. Table 5-9 shows the results of this experiment which are quite different from the results of the previous two boats.

The flotation material was adjusted so that the boat floated approximately level when the passenger load weight was located 10% forward of midlength. As the weights were removed, the boat trimmed down by the stern as was expected. This trim, however, became excessive as the passenger load weight in the boat became relatively small. When the last increment of passenger load weight was removed, the boat assumed an almost vertical stern down position. This is an unacceptably severe trim attitude. It would be very difficult to board this boat from the water in order to take advantage of the flotation with which it is equipped.

5.4.2 Results of Longitudinal Limits of Test Weights Determination

Appendix B contains photos of the 18 boats used in the determination. Each boat contains half the number of people that it would have if fully loaded. (In some cases rounding off the calculations caused more than half the total number of people to be in the boat as can be found in Table 5-2). Each of these boats had two tape marks on the side of the boat. (Boats with multiple passenger areas have two tape marks per passenger area.) The tape mark aft marks the midlength of the passenger carrying area. The tape mark forward marks the spot that is 20% of the passenger length forward of the midlength of the passenger area. As can be seen from the photos in Appendix B, the 20% forward mark appears to be the limit in front of which half the number of persons for these boats can fit.

5.5 Conclusions and Recommendations

Based on the results of the longitudinal trim experiments, it can be concluded that a no passenger load, flooded trim condition needs to be specified in the level flotation standard. This trim, as well as the full load trim, will be subjective determinations based on experience gained through flotation testing. The limits that are being recommended here are:

- For the full load condition - One end of the boat must be at or above the surface of the water. The other end must not be more than 12 inches below the surface of the water.
- For the no passenger load condition - Same as full load condition.

It is felt that test weights that are used during testing for compliance should be allowed to be placed such that their center of gravity is anywhere between 20% of the passenger area length forward of midlength of the passenger area and 20% of the passenger area length aft of midlength of the passenger area.

TABLE 5-1. CHARACTERISTICS OF TEST BOATS

Boat Number	Length (ft)	Beam (ft)	Capacity Plate Values		
			Maximum HP	Person Cap.	Maximum Weight
516	15.91	6.12	85	1050	1500
1219	16.49	6.63	120	750	1245
1187	14.05	4.0	10	400	540

TABLE 5-2. BOATS USED FOR LONGITUDINAL WEIGHT DISTRIBUTION STUDY

Boat No.	Persons Capacity		1/2 P.C. No. People	Passenger Area Length (inches)	0.5L (in.)	0.2L (in.)
	Lb	Lb/150				
241	428	2.9	2	140	70	28
435	940	6.3	3	194	97	39
436	1000	6.7	4	196	98	39
524	450	3.0	2	138	69	28
1104	600	4.0	2	92	46	18
1202	680	4.5	3	152	76	30
1267	665	4.4	2	161	81	32
1269	1400	9.3	5	82	41	16
1272	750	5.0	3	164	82	33
1273	560	3.7	2	106	53	21
1278	900	6.0	3	98	49	20
1281	600	4.0	2	126	63	25
1282	300	5.3	3	83	42	17
1283	1200	8.0	4	104/55	53/28	21/11
1286	1200	8.0	4	112/48	56/24	22/10
1287	400	2.7	2	161	81	32
1289	675	4.5	3	167	84	33
1291	750	5.0	3	116	58	23

TABLE 5-3. LONGITUDINAL STABILITY DATA SHEET

Boat Number 516
 Location of Passenger Load Midlength

Total Passengers' Weight Present	Draft	
	Fore	Aft
495	+ 1/4"	- 11-9/16"
445	+ 1-1/2"	- 3-1/8"
395	+ 1-1/4"	0
345	+ 1-1/8"	+ 1"
295	+ 1-1/4"	+ 1-3/4"
245		
195	+ 1-1/2"	+ 3-7/10"
145		
95		
45		
0	+ 9"	+ 4-3/8"

TABLE 5-4. LONGITUDINAL STABILITY DATA SHEET

Boat Number 516
 Location of Passenger Load 20% Fwd

Total Passengers' Weight Present	Draft	
	Fore	Aft
495	+ 1/2"	- 12-3/4"
445	+ 1/4"	- 1-3/4"
395	+ 1-1/2"	- 1/4"
345	+ 1-1/4"	- 1"
295	- 3"	+ 2-1/8"
245		
195		
145		
95		
45		
0	- 12"	+ 2-3/4"

TABLE 5-5. LONGITUDINAL STABILITY DATA SHEET

Boat Number 516
 Location of Passenger Load 30% Fwd

Total Passengers' Weight Present	Draft	
	Fore	Aft
465	+ 3/4"	- 10-7/8"
415	+ 2"	- 4-1/4"
365	+ 2-1/2"	- 1-1/4"
315	+ 4"	- 1"
265	+ 5-1/4"	- 3/4"
215	+ 8"	- 1-3/4"
165	+ 11-3/4"	- 2-7/8"
115	+ 13-1/2"	- 3"
65	+ 15-1/4"	- 3-1/6"
15		
0	+ 17-1/4"	+ 3"

TABLE 5.6 LONGITUDINAL STABILITY DATA SHEET

Boat Number 1219
 Location of Passenger Load Midlength

Total Passengers' Weight Present	Draft	
	Fore	Aft
395	0	- 5-1/4"
345	- 1/4"	- 1/2"
295	- 1/4"	+ 1-3/4"
245	- 1/4"	- 2-5/8"
195	- 1/8"	- 3-1/4"
145	0	+ 4"
95	- 1/2"	- 4-7/8"
45	0	+ 6-1/8"
0	- 1/4"	- 6-3/4"

TABLE 5-7. LONGITUDINAL STABILITY DATA SHEET

Boat Number 1219
 Location of Passenger Load 30% Fwd

Total Passengers' Weight Present	Draft	
	Fore	Aft
395	- 1/4"	- 4-7/8"
345	+ 1/4"	- 3-8/10"
295	+ 1"	- 3-1/2"
245	+ 2"	0
195	+ 3"	+ 9/10"
145	+ 3-1/2"	+ 1-3/10"
95	+ 5-1/2"	+ 1-1/2"
45	+ 8-1/2"	+ 1-6/10"
0	+ 14"	+ 1-1/4"

TABLE 5-8. LONGITUDINAL STABILITY DATA SHEET

Boat Number 1219
 Location of Passenger Load 30% Fwd

Total Passengers' Weight Present	Draft	
	Fore	Aft
395	+ 3"	- 13-1/8"
345	+ 3-1/4"	- 12-3/8"
295	+ 4"	- 11"
245	+ 5"	- 9-3/8"
195	+ 6"	- 6-1/4"
145	+ 5"	+ 1/8"
95	+ 5-1/2"	+ 1"
45	+ 8"	- 9/10"
0	+ 12-3/8"	- 8/10"

TABLE 5-9. LONGITUDINAL STABILITY DATA SHEET

Boat Number 1187
 Location of Passenger Load 10% Fwd

Total Passengers' Weight Present	Draft	
	Fore	Aft
155	- 2-3/4"	+ 1-1/2"
130	+ 3-1/2"	+ 1-3/4"
105	+ 9"	+ 1/2"
80	+ 15-1/2"	- 1/2"
55	+ 23"	- 5-1/4"
30	Sunk by the stern	

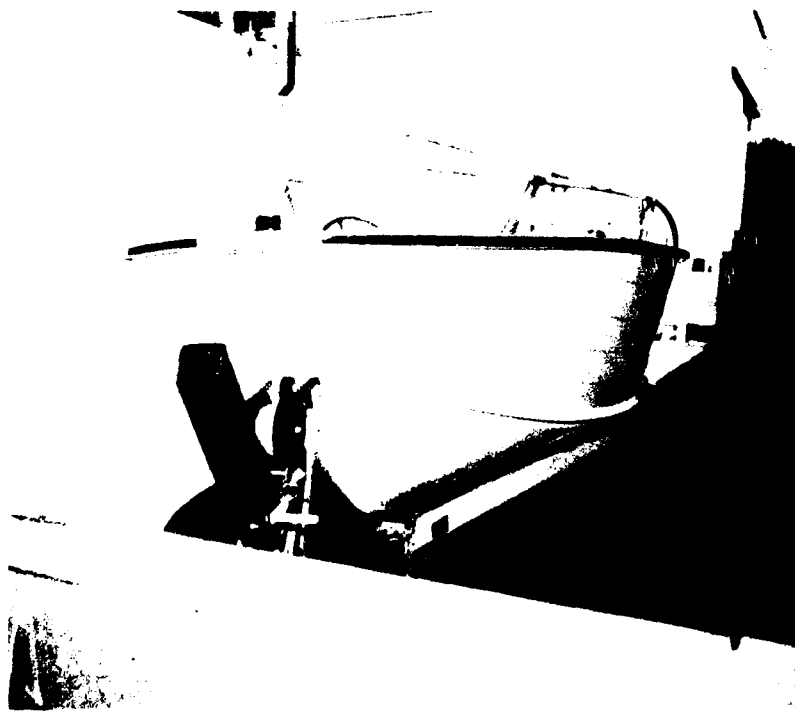
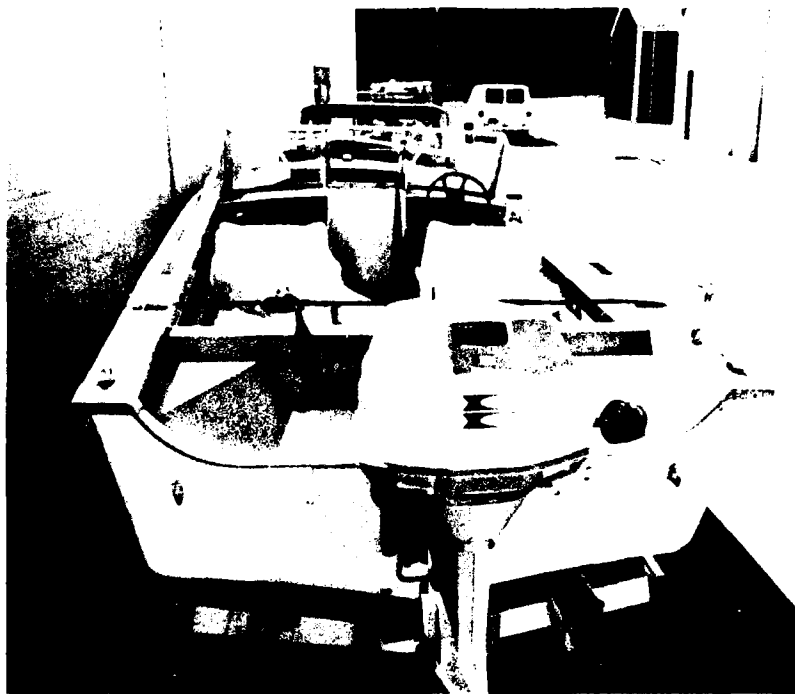


Figure 5-1. Boat Used in Trim Experiments

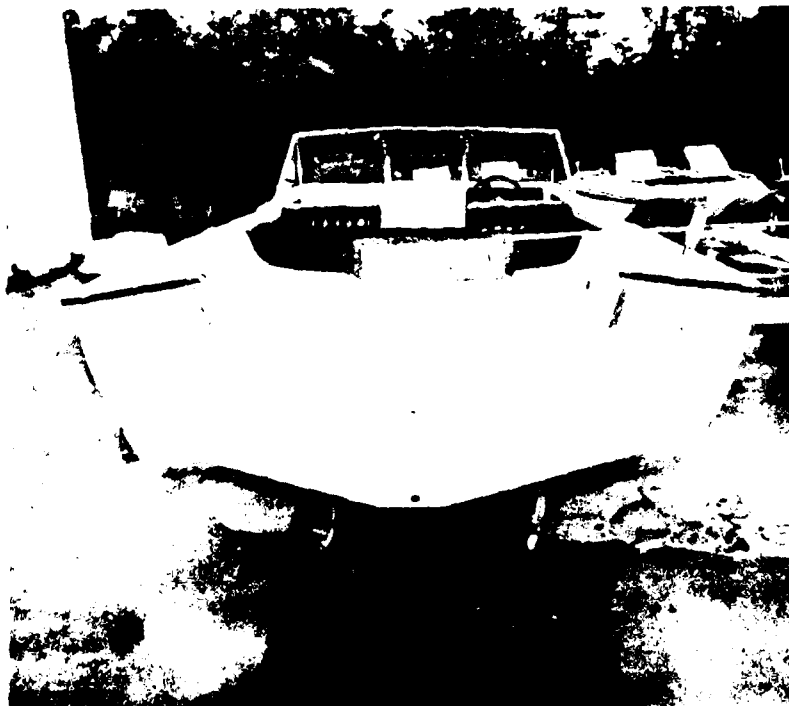
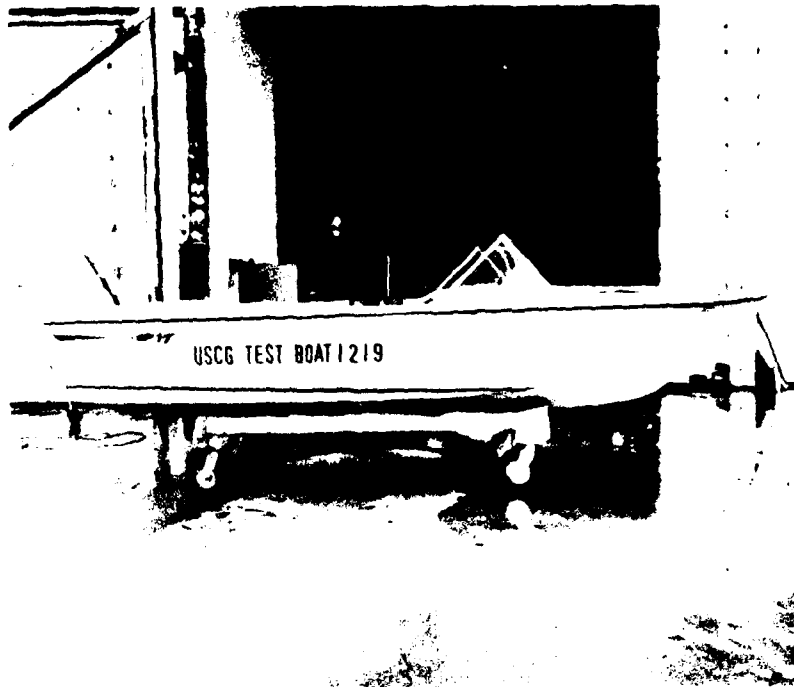


Figure 5-2. Boat Used in Trim Experiments



Figure 5-3. Boat Used in Trim Experiments

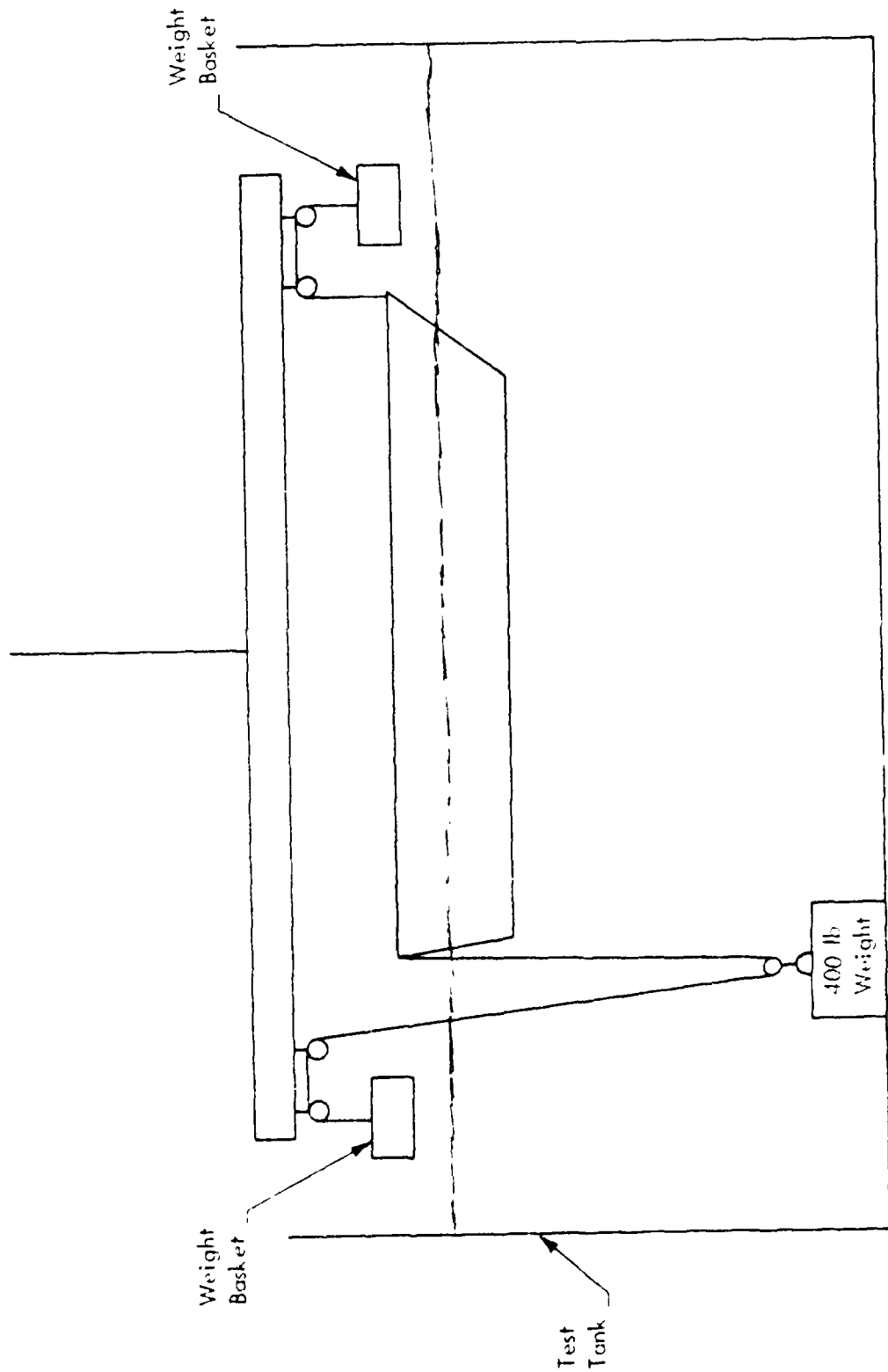


Figure 5-4. Leveling Apparatus

6.0 TRANSVERSE STABILITY CONSIDERATIONS

It has been determined through Reference 1 and 2 that a certain amount of transverse stability is a desirable feature of level flotation. A level flotation standard would have to specify the required amount of stability and a method of measuring this stability.

Based on Phase I and Phase II of the developmental testing, a desirable amount of transverse stability has been determined subjectively (see Section 10.0 for Rough Water Requirements). An objective measure of this stability has also been determined. A boat will have the desirable stability if the flotation is arranged such that the boat does not exceed a 30° heel angle when half of the weight being supported on centerline for the flotation test is moved to the lowest outboard perimeter and the remaining half of the weight is removed. The subjective determination of the desired stability was based on the boat's motion in waves and allowing a certain amount of persons motion in the boat.

The area of concern here is the location of the test weights for compliance testing purposes. Throughout the developmental testing, stability measurements were taken placing the test weights so that their center of gravity was approximately four inches off the cockpit sole and approximately four inches inboard of the outside extremity of the passenger carrying area. Longitudinal distribution of test weights was generally a fairly uniform distribution throughout the passenger carrying area.

If the no passenger load flooded condition trim requirements are met, it would be relatively easy to arrange the flotation material so the test weight would have a reasonable longitudinal distribution. Since the side load transverse stability test is a measure of the stability of the flooded boat and not an approximation of what all the people in the boat can actually do as is the centerline total flotation test, some leeway in the distribution of test weights should be allowed.

The longitudinal distribution proposed in the USCG Level Flotation regulation dated September 5, 1975, appears to be acceptable. This distribution says that the center of gravity of the test weights for the transverse stability test must be within $\pm 35\%$ of the passenger area length about the midlength of the passenger area. It also states that the test weights must be distributed along at least 30% of the length of the passenger carrying area.

7.0 FLOTATION DEMONSTRATION FOR BSAC

One of the requirements for Subtask II of the flotation development was to equip four boats with level flotation to be used in a demonstration for a BSAC meeting in Austin, Texas. Weather conditions in Texas at the time of the meeting did not permit all four boats to be used in the demonstration; however, following is the handout document that was prepared for this demonstration.

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AUSTIN FLOTATION DEMONSTRATION
BOATING SAFETY ADVISORY COUNCIL
TECHNICAL NOTES

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29, 30 May 1975

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Prepared for

DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD
Office of Research and Development
Washington, D.C. 20590

AUSTIN FLOTATION DEMONSTRATION

7.1 Introductory Summary

The demonstration on 29 May 1975, will reflect the latest views on the proposed Level Flotation Standard. Four boats will be used for this demonstration. Two of these boats are runabout types, one being a bowrider and the other a single passenger area boat. Both are equipped with inboard engines and one has a jet drive unit attached. The other has no propulsion unit attached; however, the weight of the engine has been modified to simulate the total weight of an engine and jet drive unit. The bowrider boat (Model V 187) has a Persons Capacity of 1200 lb and the single passenger area runabout has a Persons Capacity of 900 lb. Flotation for each boat was determined according to the flotation curve contained in Figure 7-1. From the curve, the flotation amount for the 1200 lb capacity boat is 30/50 and the flotation amount for the 900 lb capacity boat is 35/50.

The 900 lb capacity boat is equipped with quick release mechanisms on the seats so the seats can be removed to show the effect of loss of buoyancy of the seats due to water absorption or failure of the seat fastenings.

The other two boats to be used in the demonstration are johnboats. These will be used to demonstrate the flotation characteristics of boats on the other end of the boat spectrum, that is, small and lightweight craft. One of these boats is equipped with 50/50 flotation for a Persons Capacity of 400 lb. This is believed to provide sufficient stability in calm water. To demonstrate how this boat with 50/50 flotation reacts in rough water (9 to 18 inch waves) the other johnboat is equipped with flotation such that, in calm water, it will simulate the rough water stability characteristics of the 50/50 flotation system.

7.2 Flotation Characteristics of Demonstration Boats

Since each boat was received with flotation material installed by the manufacturer, the flotation characteristics of each boat had to be determined in order to decide what modifications needed to be made to obtain the Coast Guard proposed Level Flotation system.

7.2.1 Glastron Model V 174, 900 lb Persons Capacity

This boat (Figure 7-2) was received on loan from the Glastron Boat Company to be used for flotation research. The boat did not have an engine when it was received; therefore, a dummy engine weight had to be installed. The weight of the engine that is generally installed in this boat was obtained from the Glastron Boat Company. A scrap engine was obtained from a local scrap yard and weight was added to bring the total to the required weight. The total machinery weight in this boat is 644 lb dry (521 lb submerged).

Initial flotation tests on this boat showed that it had enough flotation to support, in addition to the machinery weight, a weight of 811 lb on centerline and a side load weight of 274 lb (centerline and side load tests were independent). This amount of flotation was far in excess of that required by the proposed Level Flotation Standard. In order to obtain the flotation amount that would be required by the proposed standard, flotation material had to be removed from the boat. After several iterations of calculations and tank testing the desired characteristics were obtained. As shown on the flotation curve (Figure 7-1), a boat with a 900 lb Persons Capacity will be required to have 35/50 flotation. This means that it will be required to support 35 percent of the Persons Capacity on centerline and 50 percent of that amount at the side of the boat without the boat losing stability.

Referring again to Figure 7-1, a 900 lb Persons Capacity boat is allowed to use "seat foam" (open cell foam) to make up the difference between 25/50 (Curve "A") and 35/50 (Curve "B") flotation. This particular boat does not have enough open cell foam installed to provide that much flotation. During the test the seats will be removed, and the boat will then have approximately 27/40 flotation.

7.2.2 Glastron Model V 187, 1200 lb Persons Capacity

This boat (Figure 7-3) was also received on loan from the Glastron Boat Company for flotation research. As with the V 174, a scrap engine and additional weight were added to simulate the missing engine and outdrive. The total machinery weight in this boat is 775 lb dry and 590 lb submerged.

Initial tests on this boat indicated that, as delivered, in addition to the machinery weight, it could support 240 lb on centerline and 191 lb at the side. According to Figure 7-1, this boat would be equipped with 30,50 flotation, meaning that it would be required to support 378 lb on centerline and 189 lb at the side. Therefore, additional foam was added until the boat met the 30,50 criteria.

During the demonstration, the boat's flooded capability will be demonstrated with a full 1200 lb persons load, and with a 756 lb persons load. The 756 lb load equals the passenger load which the boat will support with the occupants 50 percent out of the water. With a 750 lb load, the boat supports the people as if the boat was rated for 750 lb and had a 50,50 flotation system.

7.3 Fisher Model Swift 14, 400 lb Persons Capacity

This boat has a manufacturer's posted Persons Capacity of 400 lb, and a posted maximum horsepower of 10. The posted Maximum Weight Capacity of 540 lb exactly equals the Persons Capacity plus the maximum motor weight for a 10 hp engine. The flotation installed supports 51 percent of the Persons Capacity and 58 percent of that can be moved to the edge of the passenger carrying area without the vessel exceeding a 30° heel limitation. The stability (at 58 percent) exceeds our 50 percent design criteria due to the manner in which the manufacturer installs his level flotation option. Photographs of this boat are shown in Figure 7-4.

During the tests we will capsize the boat with one person on board. You will note that the boat doesn't capsize until the occupant attempts to reboard it over the side.

It is our experience that johnboats with one person on board rarely capsize or swamp during the initial accident. After the boat is swamped, two persons will demonstrate the transverse and longitudinal stability characteristics of the 51,58 flotation system.

During our testing in choppy water (9 to 18 inch chop) on the Tennessee River, we noticed that lightweight boats showed dramatic decreases in flooded stability in waves. This was somewhat surprising, as similar tests with larger boats in up to 6 ft to 8 ft breaking waves indicated that the flooded, level flotation, boats responded to the waves by heaving

rather than rolling, and thus showed little decrease in stability as compared to calm water. In order to give you some idea of the magnitude of the stability problem with the lightweight boats, we have set up an identical Fisher to simulate the stability characteristics of 50/50 flotation in rough water. This second boat is actually set up to ~50/15, and the stability it demonstrates for you in calm water is close to that which 50/50 gives in choppy water.

7.4 Persons Submergence and Percent of Weight Supported

Table 7-1 contains the results of tests conducted on three male and three female subjects in fresh water. It provides data on the percent of a person's height submerged versus their net weight. "Net weight" is expressed as a percentage of their dry weight, and it equals the buoyancy the flotation would have to provide for them.

To summarize the Table:

- a) The 50 percent net weight point is about at a person's waist.
- b) The 25 percent net weight point is in the area of the armpits.
- c) The variance of the test values over the six subjects was relatively small, and approximately 67 percent of the test values were within 5 percent of the test means.

TABLE 7-1. PARTIALLY SUBMERGED NET WEIGHT TESTS

Subject No.	Dry Weight (lbs)	Height (in.)	Submergence as Percent of Subject Height		
			At 75 Percent of Dry Weight	At 50 Percent of Dry Weight	At 25 Percent of Dry Weight
M1	156	71	39.2	60.1	74.1
M2	169	77	46.8	63.6	76.6
M3	210	68	52.9	52.5	76.5
F1	103	63	47.2	64.6	80.3
F2	120	66	43.9	59.1	78.0
F3	151	70	42.9	55.7	72.9
Average, \bar{x}	151.5	69	45.5	61.1	76.4
Standard Deviation, σ			4.2	3.0	2.4
σ/\bar{x}			0.09	0.05	0.03

M = Male
F = Female

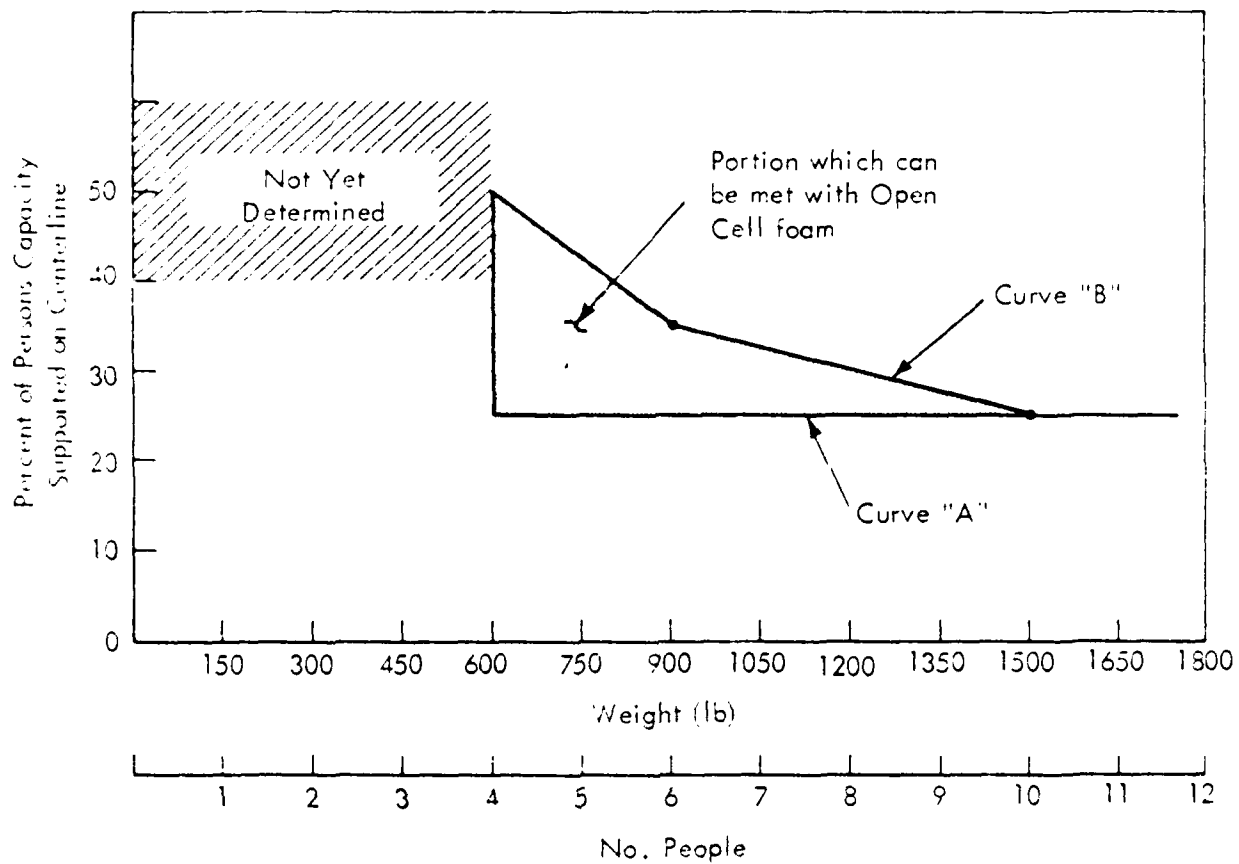


Figure 7-1. Proposed Level Flotation Requirement Curve



Figure 7-2(a). Glastron Model V 174, Side View Figure 7-2(b). Glastron Model V 174, Stem View

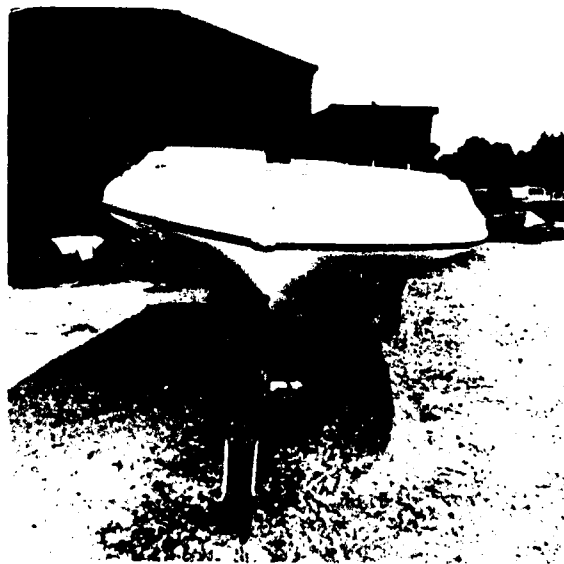


Figure 7-2(c). Glastron Model V 174, Front View

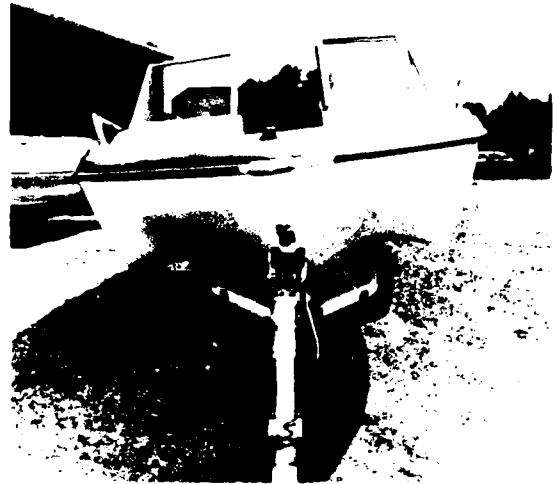


Figure 7-3(a). Glastron Model V 187, Side View Figure 7-3(b). Glastron Model V 187, Bow View



Figure 7-3(c). Glastron Model V 187, Stern View



Figure 7-4(a). Fisher Marine Swift 14, Side View Figure 7-4(b). Fisher Marine Swift 14, Stern View



Figure 7-4(c). Fisher Marine Swift 14, Bow View

3.0 PERSON'S ACTIONS/BOAT REACTIONS STUDY

One of the main considerations throughout the level flotation development has been with documenting the relative merits of different levels of level flotation. The following presentation documents one attempt at establishing these relative merits.

It was realized during flotation tests utilizing people that had not been involved in this type of test before, that the action of these people as the boat first swamped was quite different from people who were quite accustomed to performing flotation tests. With this in mind, a series of experiments was designed that would use inexperienced subjects. It was hoped that differences in boat reactions (with boats having different flotation amounts) caused by persons' actions could be ascertained from these experiments.

Several pilot experiments were performed which utilized subjects from Wyle. These subjects did not know that the boat was going to swamp, but were told they would be performing another task. In these pilot tests, a Wyle employee was used to instigate the swamping, which proved to be a downfall of these experiments. The Wyle subjects knew the Wyle swamping instigator, and as soon as the boat began swamping, figured out what was going on and this resulted in actions that would not be representative of what someone would do if he found himself in a swamping boat.

The experiments which proved most significant (even though most of the significance was not directly related to the relative merits of level flotation) were those that used subjects from a local college.

These experiments were performed as follow:

The subjects were briefed on a task which they believed was the object of the experiment. They were told they would be taken to a boat anchored offshore where they would be looking along the shore line for visual distress signals.

They were taken to the anchored boat and given data sheets on which they were to record their visual distress signal information. Once the subjects were in the anchored boat, the director of the experiments actuated a release on the boat that would cause it to begin to swamp within approximately two minutes through a trap door located beneath one of the bench seats. The experiment director in the boat then "disappeared" around a point of land and the rest of the shore crew also disappeared. A safety boat was present, but the subjects did not know it was part of the experiments. The actions of the subjects in the boat as it began to swamp were recorded on movie film from a hidden camera.

From the limited number of experiments conducted, no definite conclusions can be made about the two different flotation types tested. These tests did indicate that in order for the occupants to take advantage of level flotation, they must be educated in some manner to do so.

Wyle is presently performing a task with the objective being to find out what level of education should accompany a level flotation standard in order to take full advantage of the flotation provided. The results of the previous mentioned experiments will be used in this analysis as a control sample of experiments.

9.0 SELF-BAILING BOAT CONSIDERATIONS

9.1 Discussion of the Problem

During Phase I of the development of the level flotation standard, thought was given to possible peculiarities of self-bailing boats. For the purpose of this discussion, a self-bailing boat is a boat which is constructed such that the cockpit deck is above the surface of the water when the boat is loaded to its maximum weight capacity and the cockpit is in free communication with the water. Boats of this type generally have double bottoms that are foam filled, so that even if punctured they will not lose buoyancy.

Any flotation standard that would be considered would require support of a weight that was less than the maximum weight capacity of the boat. This is due to the buoyancy of machinery, gear and people as they are fully or partially submerged in the water in a swamped boat.

Due to the nature of the construction, these self-bailing boats would never be swamped, i.e., full of water, if sufficient time were allowed for them to come to equilibrium. Therefore, these boats would pass any flotation standard which required support of a weight which was less than the maximum weight capacity of the boat.

Consideration was given to the transient condition which may exist before all water which is taken on board may drain out. This condition could come about from taking a wave over the bow, side or transom of the boat, partially or completely filling the boat with water. In this condition, the added weight of all the water may produce very undesirable reactions to the boat.

Several tests/experiments were performed on a sample of these self-bailing boats to determine if indeed they would prove to be extremely unsafe in the transient condition of being filled with water.

9.2 Tests/Experiments Performed

In order to determine if self-bailing boats presented any peculiar problems when flooded, a sample of six boats from three manufacturers was subjected to a set of tests/experiments. Only five of these turned out to be self-bailing by the definition used in Section 9.1.

The tests/experiments were performed as follows:

For the first three boats, weight was added to each boat until a just float condition was reached. For this test, test weight location was adjusted so that the boat remained level as it swamped. The transverse stability of each boat was subjectively checked at several loading increments by pushing down on one side of the boat and noting how "tender" it felt. The second part of the experiment performed on two of the first three boats consisted of loading weight along one side of the boat until it reached an angle of approximately 30° . The transverse stability of the boats in this condition was again subjectively checked.

The experiments with the other two boats were slightly different. These two boats were loaded with weights and allowed to flood until the water level was at the transom height (see Figures 9-1 and 9-2). It was felt that measuring the total flotation in these boats would not contribute to their evaluation. Figures 9-3 and 9-4 show one of the boats in the side load evaluation. The weight used was placed at the extreme outboard side of the boat. Water was then pumped into the boat until it flowed out over the transom. The boat reached a heel angle of approximately 30° with the weight and water. As the water was allowed to drain out through the self-bailing scuppers, the heel angle was reduced. With the boat at 30° and full of water, the "reserve stability" was subjectively checked.

9.3 Results and Conclusions

Table 9-1 shows the results of the tests/experiments performed on the five self-bailing boats. The side load value for Boat 434 was not determined because it was felt that it would not have added to the evaluation.

As can be seen from Table 2-1, all the boats contain flotation in an amount that far exceeds that required by the proposed standard. In addition, the stability of all boats was subjectively rated as acceptable.

Unless an analysis of accident data indicates otherwise, it is the opinion of the author that self-hailing boats need not be subject to a special flotation standard, but should be regulated under the proposed Level Flotation Standard.

TABLE 9. 1. CHARACTERISTICS OF SELF-BAILING BOATS

Boat Number	Manufacturer	Length	Horsepower	Max. Wt.	Max. Persons Capacity	Flotation Tests		Flotation Required By Proposed Standard	Stability
						Centerline	Side Load		
432	Boston Whaler	13 ft	40	839	827	948	384	430	Acceptable
433	Boston Whaler	16 ft	100	1154	1154	2051	528	593	Acceptable
434	Boston Whaler	21 ft	200	1598	1598	3788	-	663	Acceptable
435	Robalo	19 ft	150	1615	940	4129	731	649	Acceptable
436	Robalo	20 ft	190	1565	1000	4090	780	656	Acceptable

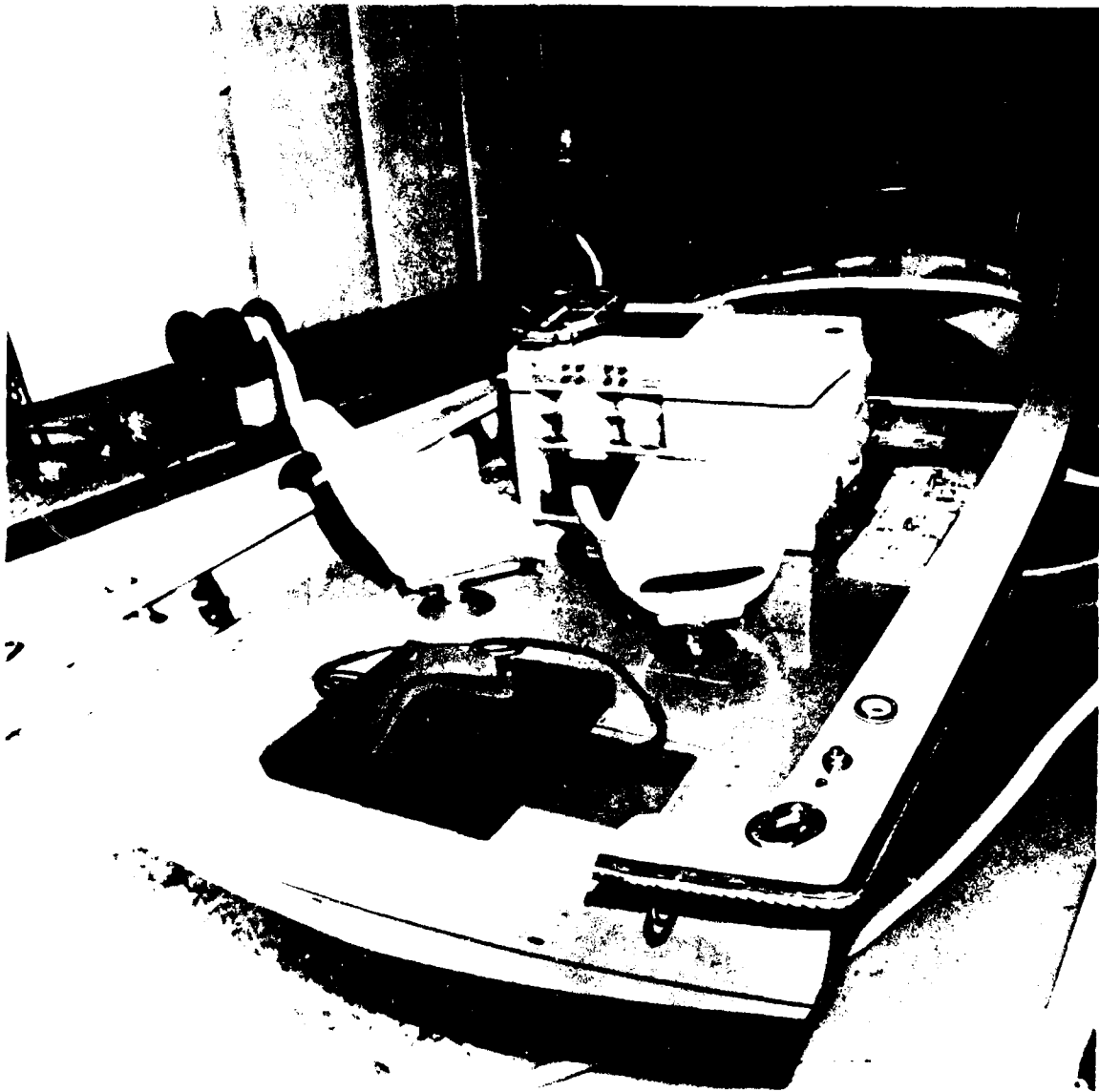


Figure 2-1. Self-Bailing Boat, Centerline Test

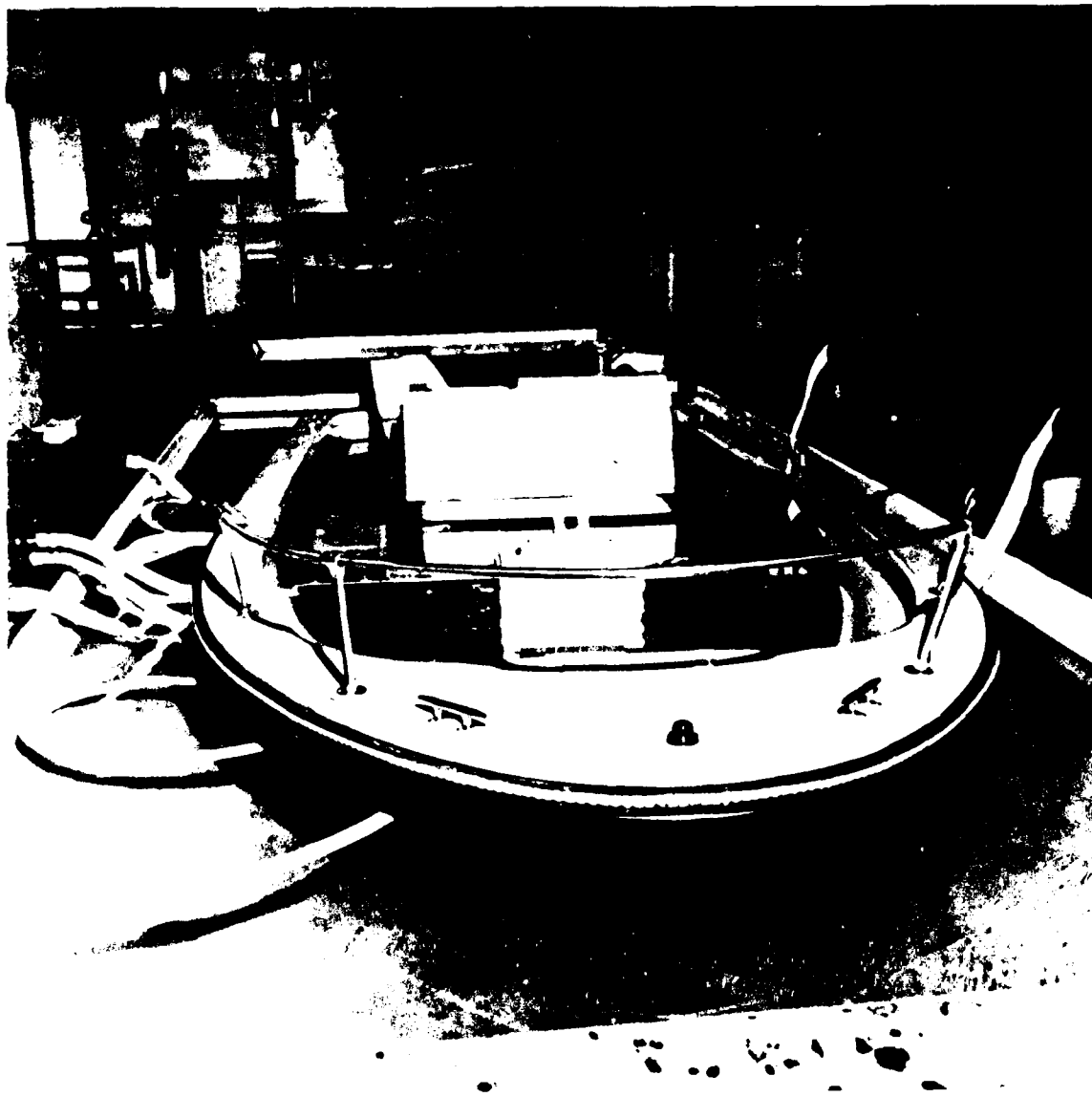


Figure 9-2. Self-Bailing Boat, Centerline Test

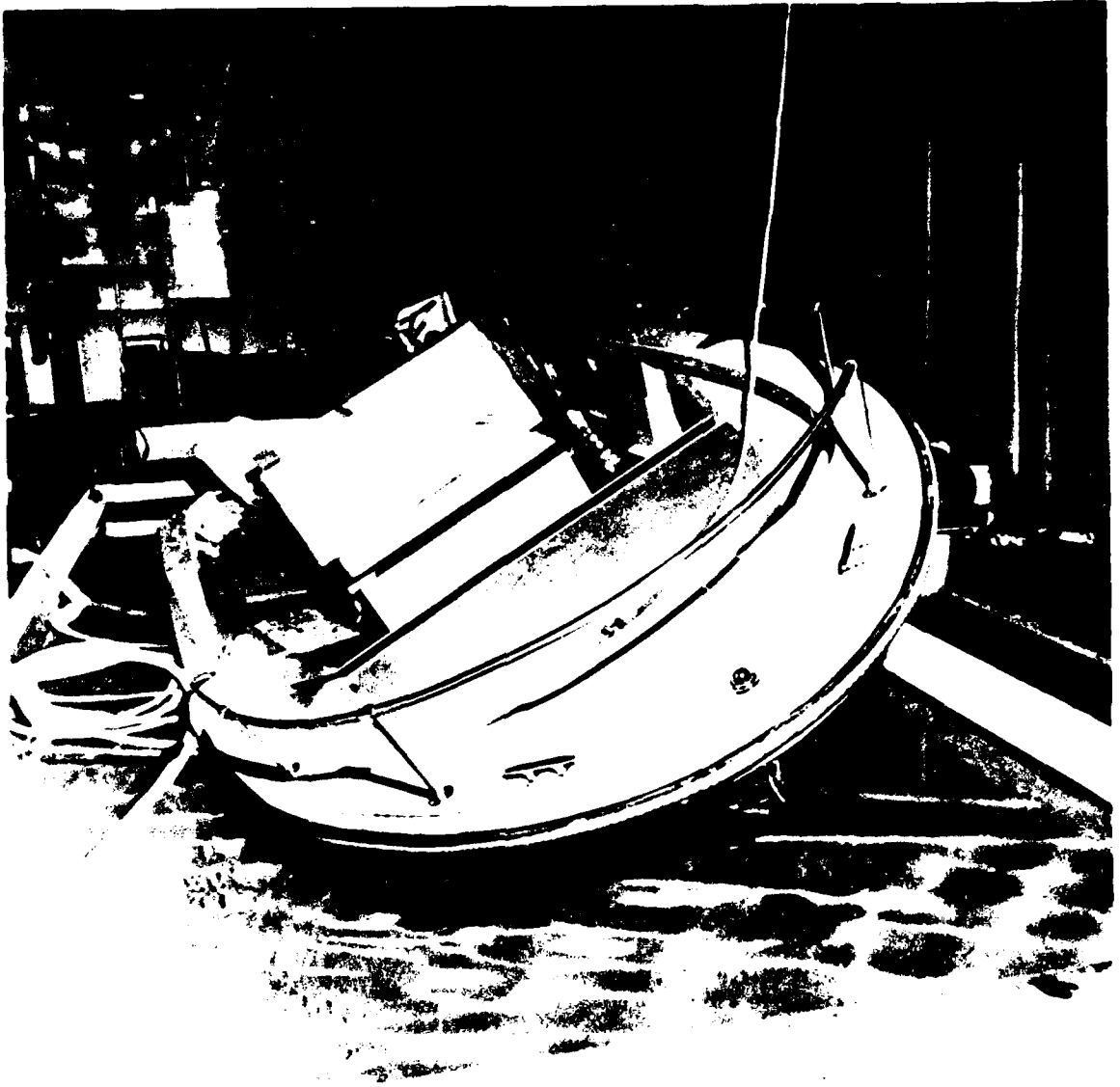


Figure 9-3. Self-Bailing Boat, Side Load Test

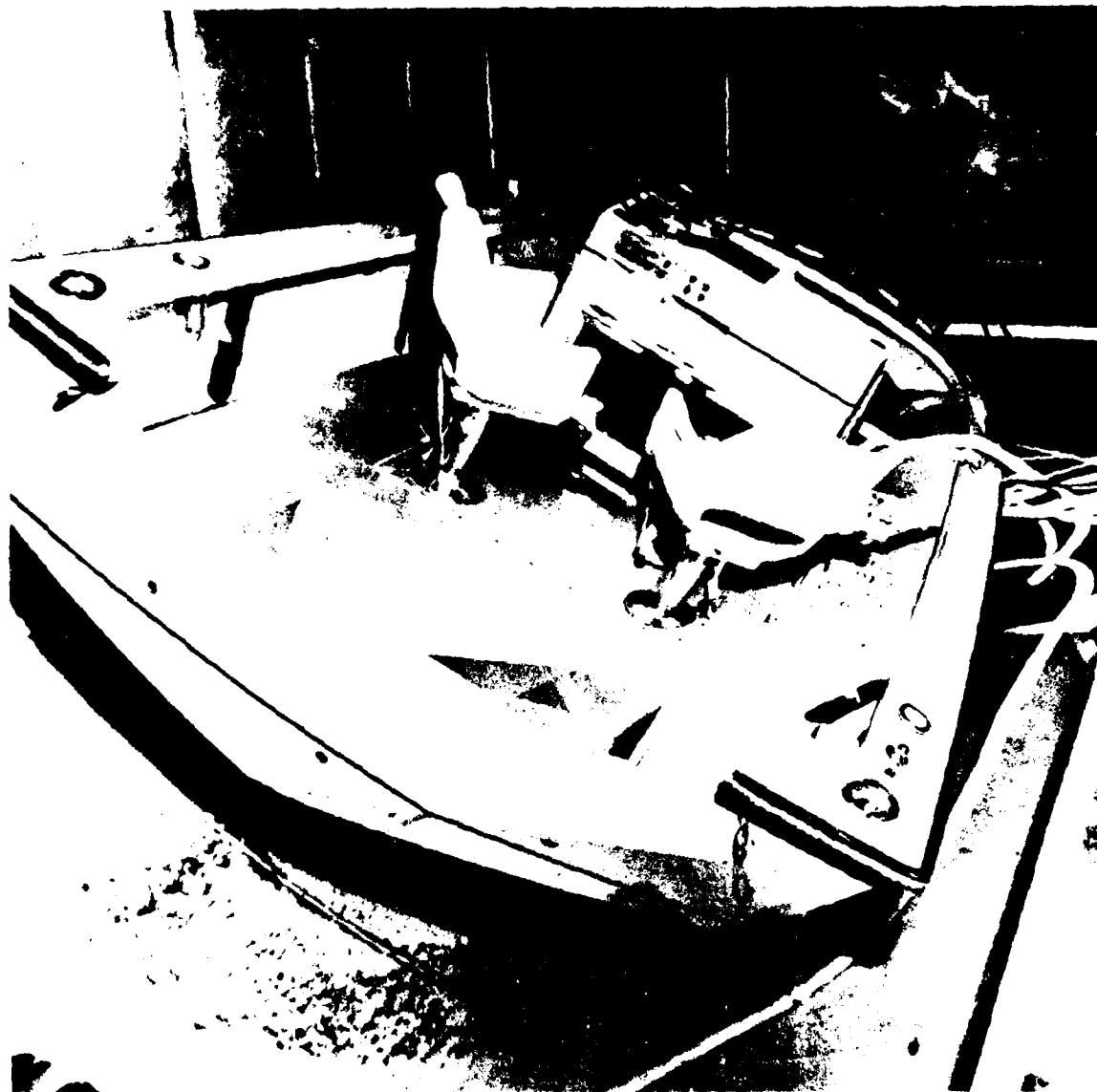


Figure 9-4. Self-Bailing Boat, Side Load Test

10.0 ROUGH WATER EVALUATION

Limited testing of boats equipped with a form of level flotation was performed in waves in Phase I development of the level flotation standard. This testing involved several experiments which subjected the swamped boats to the wakes of passing vessels. An additional test in rough water was performed by the Coast Guard R and D Center, Groton, Connecticut. These experiments utilized a 16 ft runabout equipped with 50-50 level flotation. These experiments were performed in extreme conditions of five to six foot waves. The boat did not exhibit any peculiar characteristics in these conditions and, in fact, it performed quite well.

During the Phase II effort, it was felt that additional rough water evaluation should be conducted. These experiments were initially designed to utilize a range of boats in a range of wave conditions (6 in. to 14 in. wave heights).

The initial experiments indicated that a stability problem with small, lightweight boats existed in waves of approximately two feet height. Further, experiments in open water and in a controlled wave environment as discussed in this section enabled the problem to be better defined.

10.1 Preliminary Open-Water Evaluation

The first rough water experiments performed in Phase II development of a level flotation standard utilized two boats, a 16 ft aluminum runabout (Figure 10-1) and a 14 ft lightweight aluminum flat bottom boat (Figure 10-2). See Table 10-1 for the characteristics of these two boats (516 and 1187, respectively).

Flotation in each boat was adjusted so it would provide 50-50 flotation for the passenger load that was used in the experiments. Boat 516 had a passenger load of 700 pounds and boat 1187 had a passenger load of 375 pounds. The experiments were conducted on the Tennessee River near Huntsville, Alabama, with wave heights estimated at 14 in. to 16 in. The 16 ft runabout felt quite stable and was rated acceptable. The johnboat on the other hand felt extremely unstable and much effort was required to keep it upright. These experiments indicated that 50-50 flotation may not be sufficient in some cases. The flotation in boat 1187 was modified so that it gave 75-50 support of the passenger load. This modification was tested under approximately the same conditions and was found to be more stable than the 50-50 configuration.

(Movie film of all of these experiments was submitted to USCG Headquarters in May, 1975.) The results of these initial experiments led to the decision to test a variety of boat/flotation combinations in a controlled wave environment.

10.2 Wave Tank Evaluation

Coast Guard Headquarters leased the Navy Wave Tank at NSRDC for two days to be used for rough water evaluation of flotation. Before the actual testing was performed at NSRDC, additional open water testing needed to be performed in order to narrow the range of testing to be performed at the wave tank.

10.2.1 Preliminary Evaluations

Testing at NSRDC was limited due to cost and time availability restraints. It was, therefore, important to reduce the range of testing needed by further experiments in open water. All testing was not performed in open water due to the varying test conditions and infrequency of rough weather at the particular time of year on the Tennessee River near Huntsville, Alabama.

Several preliminary experiments were performed. The purpose of these experiments was three-fold. First, to determine if round bottomed boats exhibited similar stability characteristics for the same flotation arrangement and same general size of boat as flat bottomed boats exhibit.

Second, to establish an upper limit of size of boat that needed to be tested at NSRDC. The earlier tests with the 16 ft runabout indicates that 50-50 flotation was sufficient for it. This meant that there was some point at which 50-50 flotation became satisfactory. There were several experiments designed to determine this point.

The third objective of these preliminary experiments was to try to establish a "continuous measure" of the stability of swamped boats in rough water. This "continuous measure" was developed along the same procedure as the side load test for the static stability determination of flooded boats.

10.2.1.1 Preliminary Experiments — The first of these preliminary experiments used three round/V-bottomed aluminum boats. Figures 10-3, 10-4, and 10-5 are photos of these boats numbered 225, 120, and 1202, respectively, and their characteristics are shown in Table 10-1. For the purpose of these experiments, these boats were equipped with 50-50 level flotation for persons capacities of 400 lbs, 600 lbs, and 800 lbs for boats 225, 1202 and 1200, respectively. These boats were subjectively evaluated on the Tennessee River in waves up to 8 in. high.

The next series of experiments utilized two boats. Figures 10-6 and 10-7 are photos of boats 524 and 244, respectively. Characteristics of these boats are shown in Table 10-1. Boat 524 was set up with 50-50 flotation for a persons capacity of 450 pounds. Boat 244, which was a 15 ft flat bottomed aluminum boat, was used as if it were a bass boat. This experiment was designed to determine if the limiting parameters for 50-50 flotation being acceptable was boat/machinery weight or persons capacity.

This flat bottomed boat had weight added to approximate the weight of a similar size bass boat and the maximum horsepower for it was calculated assuming it had a 21 in. high transom instead of 15 in. as it actually had. These two boats were subjectively evaluated on the Tennessee River in waves of 12 to 14 in. height.

The next set of experiments attempted to establish a "continuous measure" of the stability of swamped boats in rough water. This continuous measure was an attempt at putting a number on a given boat/flotation condition that could be compared to the subjective rating of that boat. These tests utilized boat 1137 (Figure 10-2, Table 10-1).

The first of these continuous measure experiments utilized a sliding steel weight with a counter floating foam dummy. Figure 10-8. The reasoning behind this arrangement was as follows. The weight could be moved off centerline in increments producing a heeling moment. The foam dummy was designed to have the same pounds per inch immersion as a person, based on the swamped people experiments in Section 7.0. This was an attempt to approximate the change in heeling moment the boat would experience due to the heeling and wave effects on a real person in a boat. This configuration was tested on the Tennessee River and movie film is available on request.

The next two attempts at establishing a continuous measure involved adding a heeling moment to the boat with no compensation from a floating dummy. The first involved fastening two baskets to the gunwale of the boat, one forward and one aft. Weight was then dropped into the baskets in increments until a capsize condition was reached.

The second experiment involved placing weight in increments in the boat on the bottom along one side, again adding weight until a capsize condition was reached.

10.2.1.2 Preliminary Results — The results of the experiments using the three round bottomed boats with persons capacities of 400 lbs, 600 lbs and 800 lbs will be discussed first. The boat that was set up for the 400 lb persons capacity reacted very similar to the flat bottomed boat of 400 lb persons capacity; i.e., fairly unstable. The boat that was set up for 600 lb persons capacity felt fairly stable, but not as stable as the boat set up for 800 lb persons capacity which felt very stable. All boats were evaluated with a full load of people on board.

The experiments using boats 524 and 244 indicated that the persons capacity was the limiting factor for size of boat. It must be remembered that there is a direct relationship between size of boat and persons capacity. Both of these boats were set up for a 450 lb persons capacity. Even though they were both heavy boats with relatively heavy machinery, with flotation to compensate, they still felt somewhat unstable in the 12 in. to 14 in. waves in which they were evaluated.

During the continuous measure tests, it was found that the foam dummy used for the first set of experiments provided too much counter flotation to the heeling weights. The boat did not capsize even when all of the weights were moved as far outboard as they could be moved.

The baskets, to which weight was added, that were fastened to the gunwales of the boat appeared to be sensitive to a difference of five pounds in the baskets that resulted in the boat going from a fairly stable attitude to a capsize condition.

The test which seemed most promising was the one that involved placing weights inside the boat on the bottom along one side. Drawbacks to this method included maintaining accuracy in placing the tests weights while in a wave environment. The other major drawback was

losing the weights if the boat capsized. This was remedied by placing a board to catch the weights along the top of the gunwale.

To summarize the preliminary evaluation results:

- Six hundred pounds persons capacity should be the upper limit for the size of the boats to be tested in the wave tank at NSRDC.
- Placing weights inside the boat should be used as the continuous measure test.

10.2.2 Wave Tank Test Boats

There were four basic hulls that were used for the evaluation in the wave tank at NSRDC. In all there were 18 configurations evaluated.

Figures 10-9, 10-10, 10-11 and 10-12 are photos of the four hull types that were used. Table 10-2 shows the characteristics of the 18 boats evaluated with boats that were variations of the same hull being designated with the same class number. This sample is believed to be representative of small boats with persons capacities of 600 lbs and less. Class 5 is the same as Class 3 with 30 lbs of weight added to simulate a heavier boat. The flotation conditions used covered a range of total flotation amount and stability characteristics.

10.2.3 Wave Tank Test Plan

Original plans were for four different types of evaluations/experiments. The first of these were "ease of attitude maintenance" tests which utilized experienced test subjects. For these tests, each boat was to be loaded with the persons capacity for which it was set up. It would then be evaluated by the occupants in two wave conditions.

The second test which was the continuous measure test was to be conducted in the same wave conditions. The third set of tests again utilized the experienced test subjects in evaluating re-righting and re-boarding the swamped boats.

The last set of experiments were originally planned as pilots for the persons action tests discussed in Section 8.0 of this report. Due to scheduling of the wave tank, the persons action tests discussed in Section 8.0 were completed before these tests. Plans were to continue with these tests to get added data on ease of attitude maintenance from inexperienced test subjects.

Tables 10-3 and 10-4 show two tentative schedules that were developed. As discussed in the next section, only two types of tests were conducted, the "ease of attitude maintenance" tests with the experienced test subjects and the tests using the inexperienced test subjects.

10.2.4 Wave Tank Experiments

The main reason for performing only the "ease of attitude maintenance" tests and the inexperienced people tests was the lack of time caused by several malfunctions of the wave makers. The first continuous measure tests indicated that the test was very time consuming and showed little promise of good results. It was, therefore, decided that in the interest of obtaining the most useful data, those tests would not be further attempted.

The "ease of attitude maintenance" tests were performed as follows:

The boat being evaluated was loaded with the persons capacity for which it was set up. The people evaluating these boats had experience in working in swamped boats. The boat with people was then subjected to a wave environment. The occupants and an on-shore observer rated the boat from 1 to 5 according to the rating scale shown in Table 10-5. Data was recorded on the form shown in Figure 10-13. Two wave heights were used for each boat flotation condition.

The inexperienced people tests involved placing people who had not previously participated in any flotation work in a boat and allowing water to flood through a trap door in the bottom while subjecting the boat to a wave environment. All subjects were interviewed as soon as the test was over.

Eleven 1200 ft rolls of video tape and approximately 300 ft of color movie film was taken of all of these tests and is available upon request.

10.2.5 Wave Tank Results

The inexperienced people tests added to the data of Section 8.0 of this report. This data will be used as part of an ongoing task to determine the level of education needed to accompany the level flotation standard in order to take full advantage of the flotation. All of these results will be incorporated into the final report of that task.

Table 10-6 shows the results of the ease of attitude maintenance tests. The boat number (e.g., 232 1-50/50) is interpreted as follows:

The first three digits (232) is the hull number used for inventory purposes only. The next digit (1) is the class of boat as specified in Table 10-2. The next four digits (50/50) indicate the flotation arrangement of the boat. The first number before the slash (/) indicates the total flotation present as a percent of the persons capacity, and the number after the slash indicates the weight that can be supported at the side without the boat losing stability expressed as a percent of the total amount of flotation present.

The average rating for each wave height is the average taken from the occupants and the observers' ratings during the tests.

Figures 10-14 and 10-15 are graphs of the data in Table 10-6. These are plots of ratings with respect to persons capacity for different flotation amounts. From these graphs, it appears that more data points are needed before one can justify fitting any curves through the points. It was for this reason that it was decided to continue the rough water evaluations. Time scheduling of the wave tank at NSRDC made it difficult to return there, so an open water site was chosen for the additional evaluations.

10.3 Open Water Evaluations

The site that was chosen for the open water evaluations was a seaway off the west coast of Florida near Ft. Myers Beach. This site was chosen for two reasons. First, the conditions that normally exist there were what was needed for the testing. The wind would blow gently

in the morning increasing throughout the day. This wind produced low waves early in the day with the waves gradually building throughout the day. The second reason for choosing this site was the availability of shore and support facilities provided by a concerned member of the boating industry.

Several additional tests were performed on the Tennessee River after returning to Huntsville, Alabama. This was to take advantage of an unexpected windy day and to gather more data. Since these tests were basically the same as those performed at Ft. Myers Beach, they will be incorporated in this section as if they had been conducted there.

10.3.1 Open Water Test Boats

The boats used were basically the same as those used in the wave tank evaluations. Certain boats were selected for use based on the data that was still needed. Table 10-7 is a list of the boats used for the open water evaluations.

10.3.2 Open Water Experiments

The open water experiments were conducted in a similar manner to those conducted in the wave tank at NSRDC. Each boat was loaded with the persons capacity for the flotation condition for which it was set up and then evaluated in a wave environment. In addition to "ease of attitude maintenance" or stability as it will be called throughout the rest of this discussion, each boat/flotation combination was rated in two other areas. These two areas were re-righting and re-boarding.

The method of rating used at these tests was somewhat different than the method used for the wave tank tests at NSRDC. For these tests, a boat that was considered acceptable was chosen and its ratings were defined. This boat was then used as a reference boat and the other boats were compared to it. This was boat 4-40/50 and its ratings were defined as 5-4-4 for stability, re-righting and re-boarding. Figure 10-16 shows typical open water evaluations.

10.3.3 Open Water Results

Tables 10-8 and 10-9 show the results of the open water evaluations. The stability rating is plotted as a function of persons capacity for the various flotation conditions in Figure 10-17 and 10-18. These values will be combined with the results of the wave tank tests from Section 10.2.5 and will be discussed in Section 10.4.

10.4 Rough Water Results

Before the results from the wave tank tests and the Ft. Myers tests can be combined, a correction for the different rating used must be made. Only the high wave condition results will be combined. The evaluation at the wave tank rated boat 4-40/50 at 3.75. The rating for boat 4-40/50 was defined as five for the Ft. Myers evaluation. To correct the values obtained at the Ft. Myers tests to the same scale as those performed at the wave tank, 1.25 must be subtracted from all the Ft. Myers values. Doing this, results in the values shown in Table 10-10. Combining these with values from Table 10-6 and plotting, we get Figure 10-19. Taking the values from Tables 10-10 and 10-6 and using linear regression with a least means squared fit to generate a straight line for three of the flotation conditions, results in the graph shown in Figure 10-20.

Assuming that a rating of four is the minimum acceptable rating (this is a valid assumption based on subjective evaluations), then boats with 50-50 flotation and a persons capacity less than 500 lbs would not be acceptable in rough water. This graph indicates that the minimum amount of flotation that would be acceptable in rough water for boats with a persons capacity of 500 lbs or less would be 62-50 flotation.

Before requiring boats of this size to have 62-50 flotation, a study of increased effectiveness taking into account the number of accidents in rough water should be made.

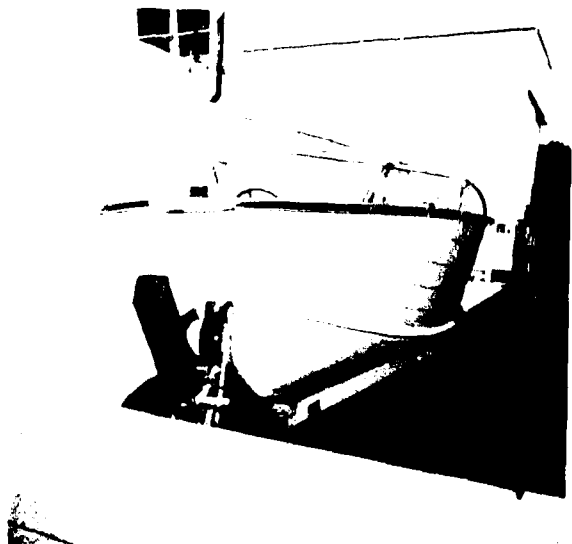
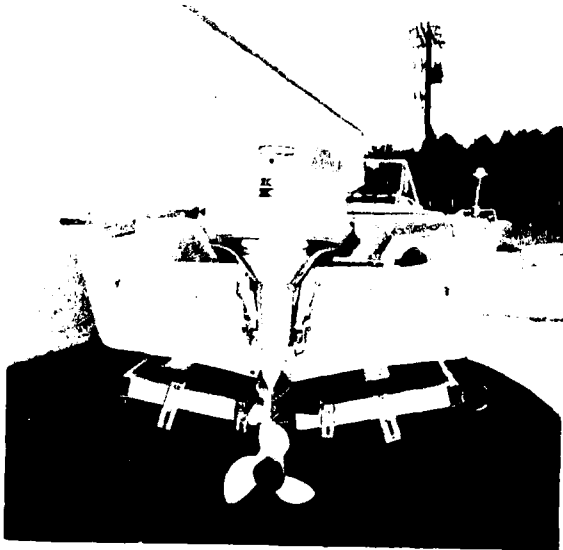
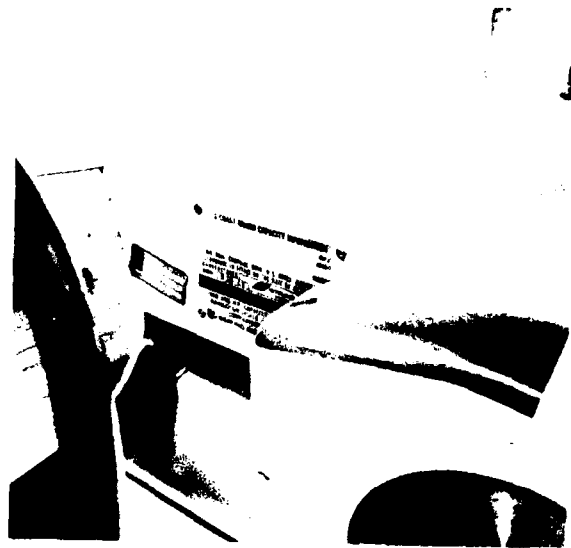
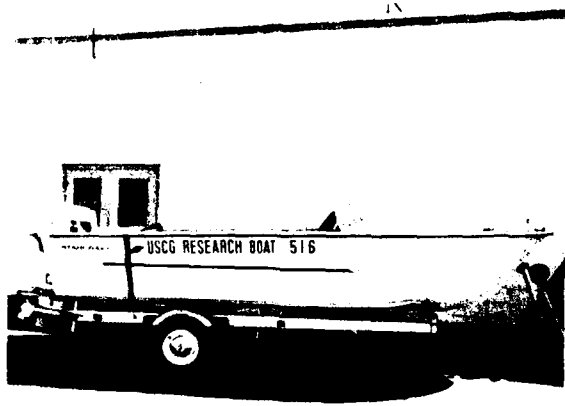


Figure 10-1. Rough Water Test Boat 516

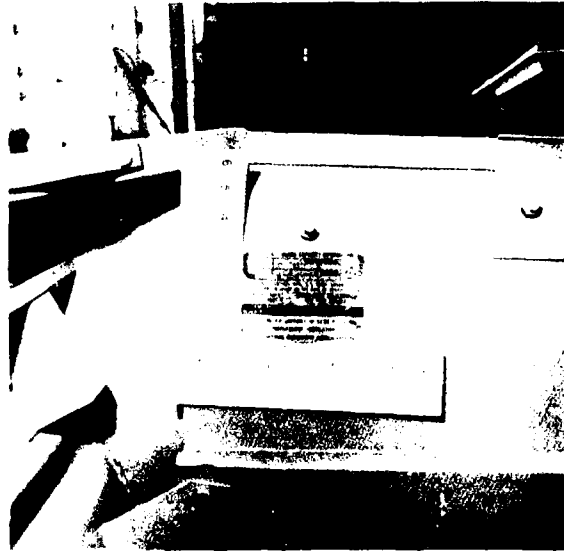


Figure 10-2. Rough Water Test Boat 1187



Figure 10-3. Rough Water Test Boat 225



Figure 10-4. Rough Water Test Boat 1200



Figure 10-5. Rough Water Test Boat 1202

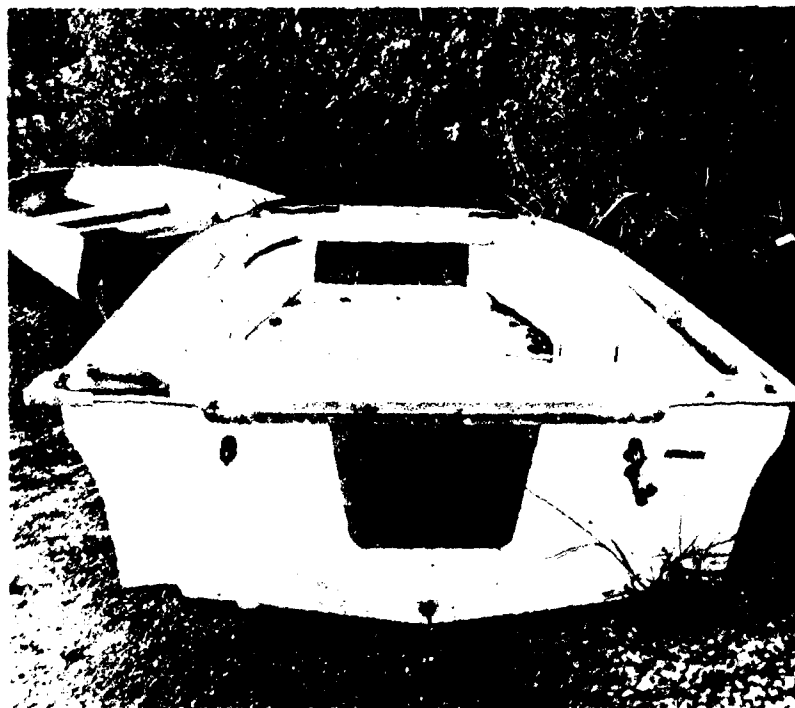
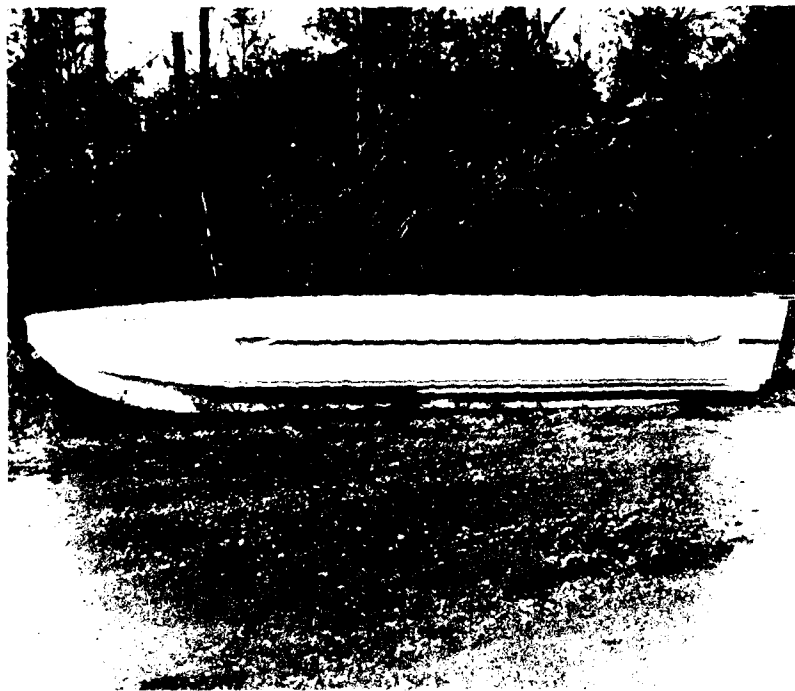


Figure 10-6. Rough Water Test Boat 524

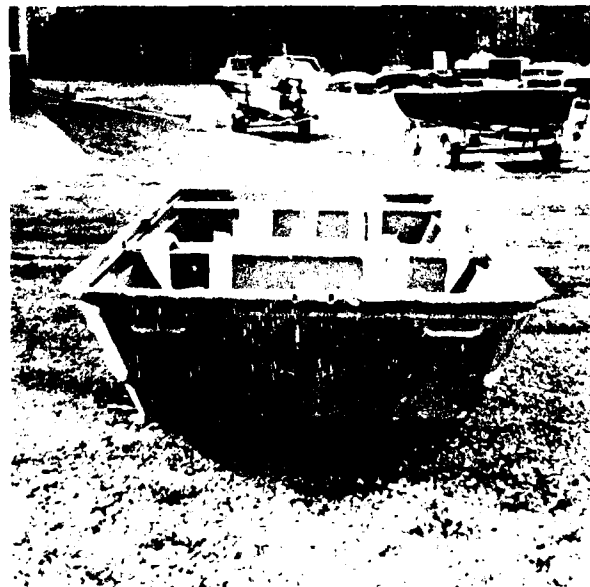


Figure 10-7. Rough Water Test Boat 244

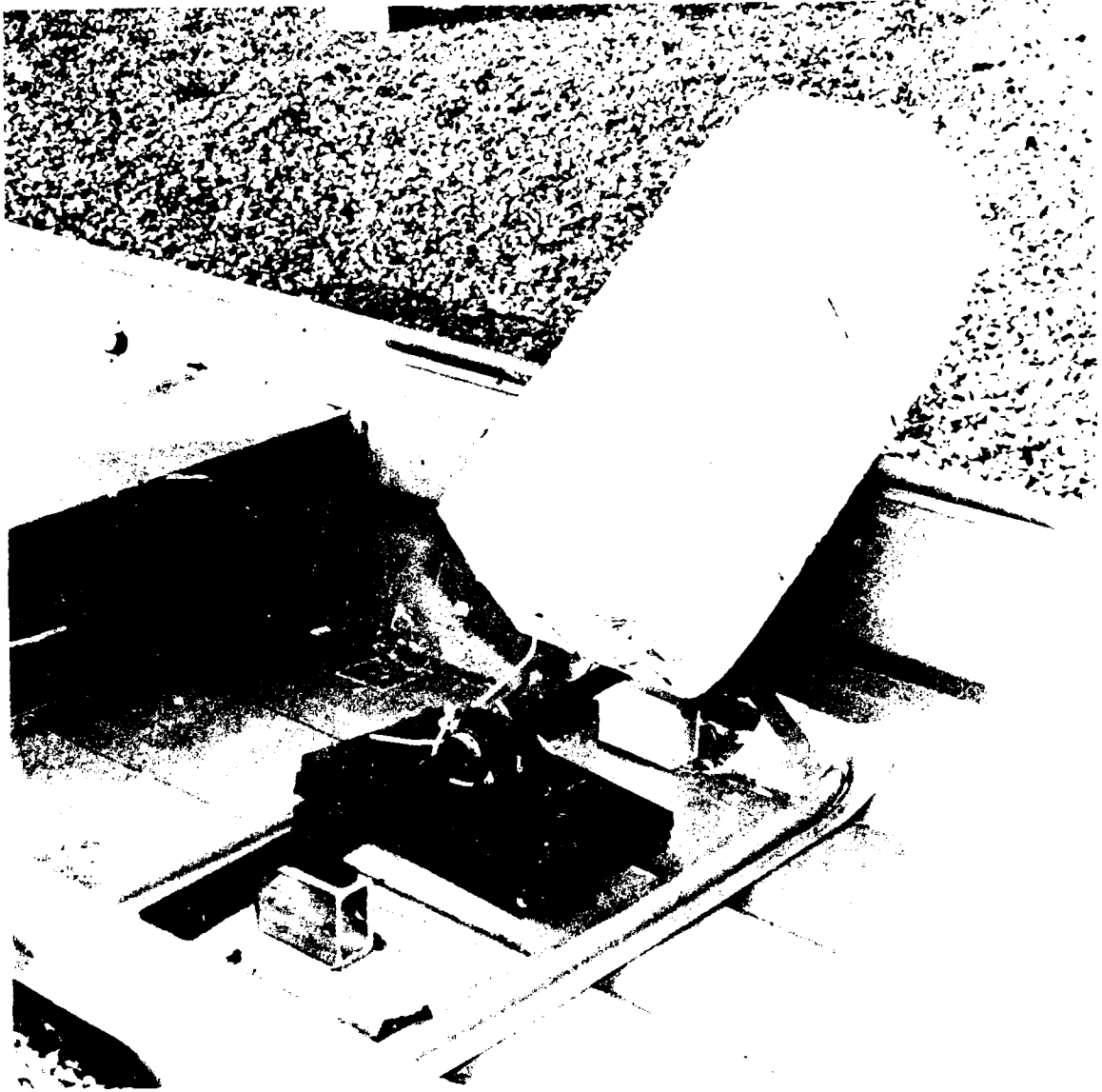


Figure 10-8. Foam Dummy Fixture

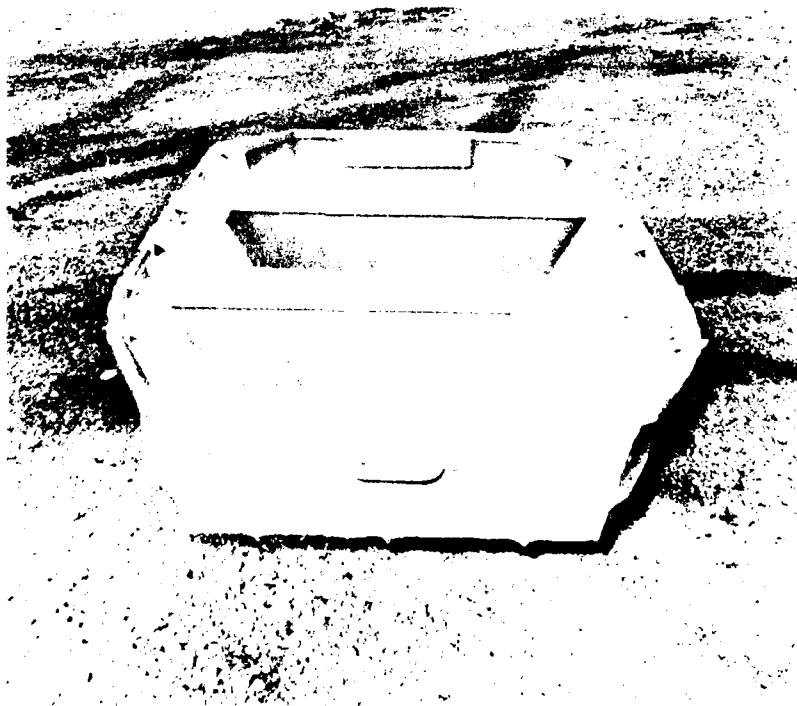


Figure 10-9. Class 1 Rough Water Test Boat

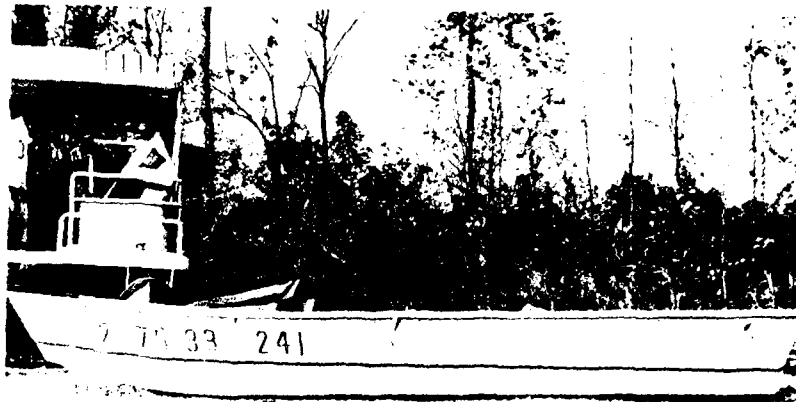


Figure 10-10. Class 2 Rough Water Test Boat

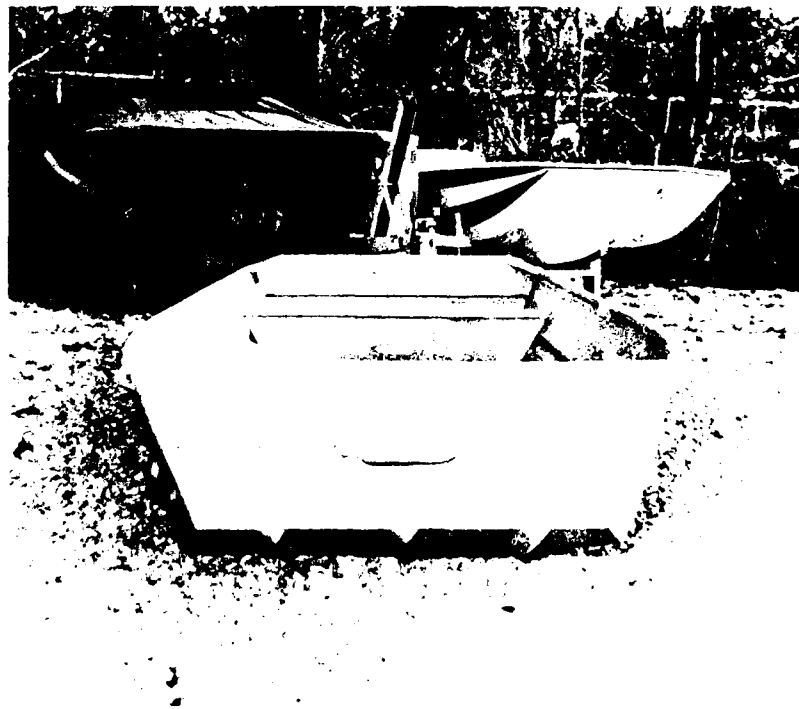
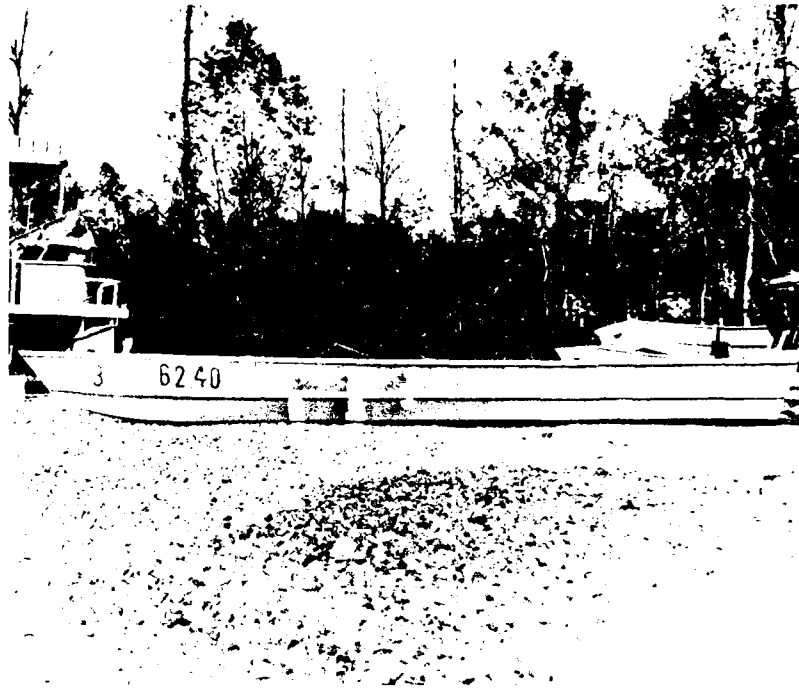


Figure 10-11. Class 3 Rough Water Test Boat

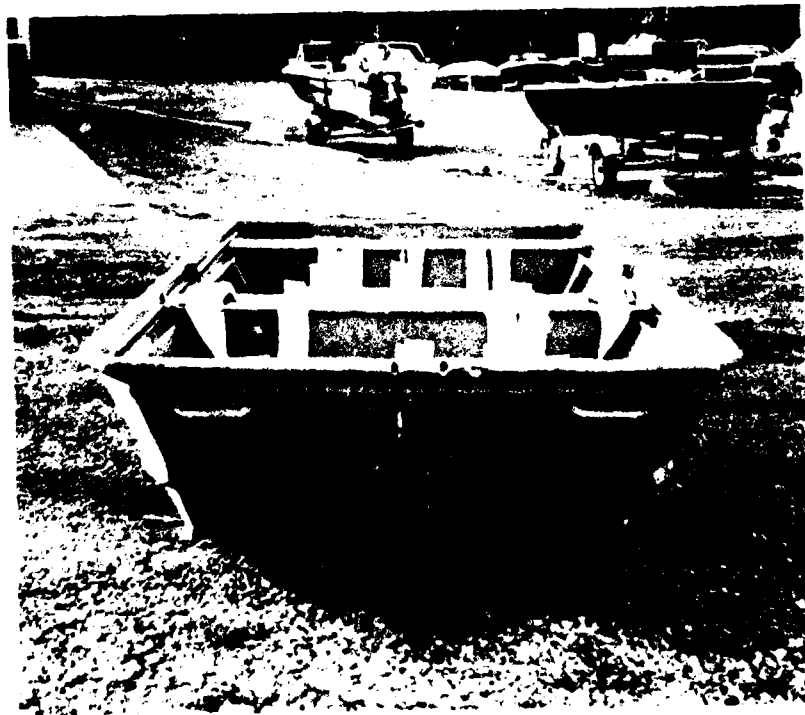
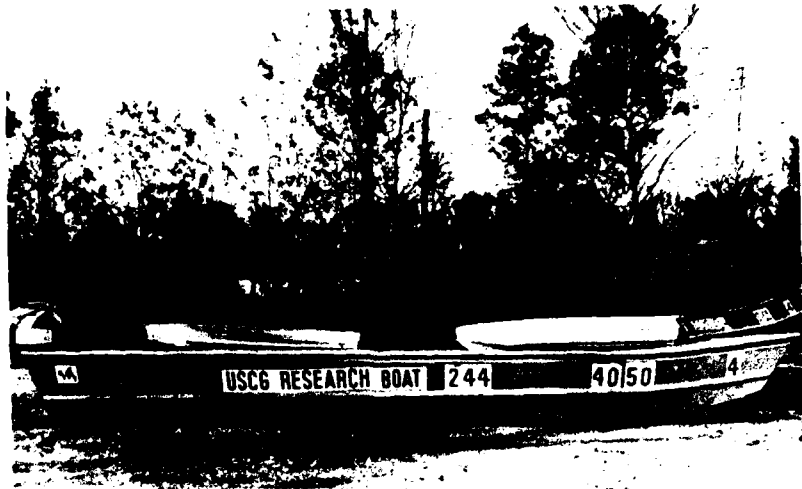


Figure 10-12. Class 4 Rough Water Test Boat

CARDEROCK FLOTATION TESTS
EXPERIENCED SUBJECT TESTS

DATE _____

TEST NO. _____

BOAT NO. _____

TIME _____ WAVE HEIGHT _____

EVALUATOR	RATING	COMMENTS

TEST NO. _____

BOAT NO. _____

TIME _____ WAVE HEIGHT _____

EVALUATOR	RATING	COMMENTS

Figure 10-13. Wave Tank Data Form

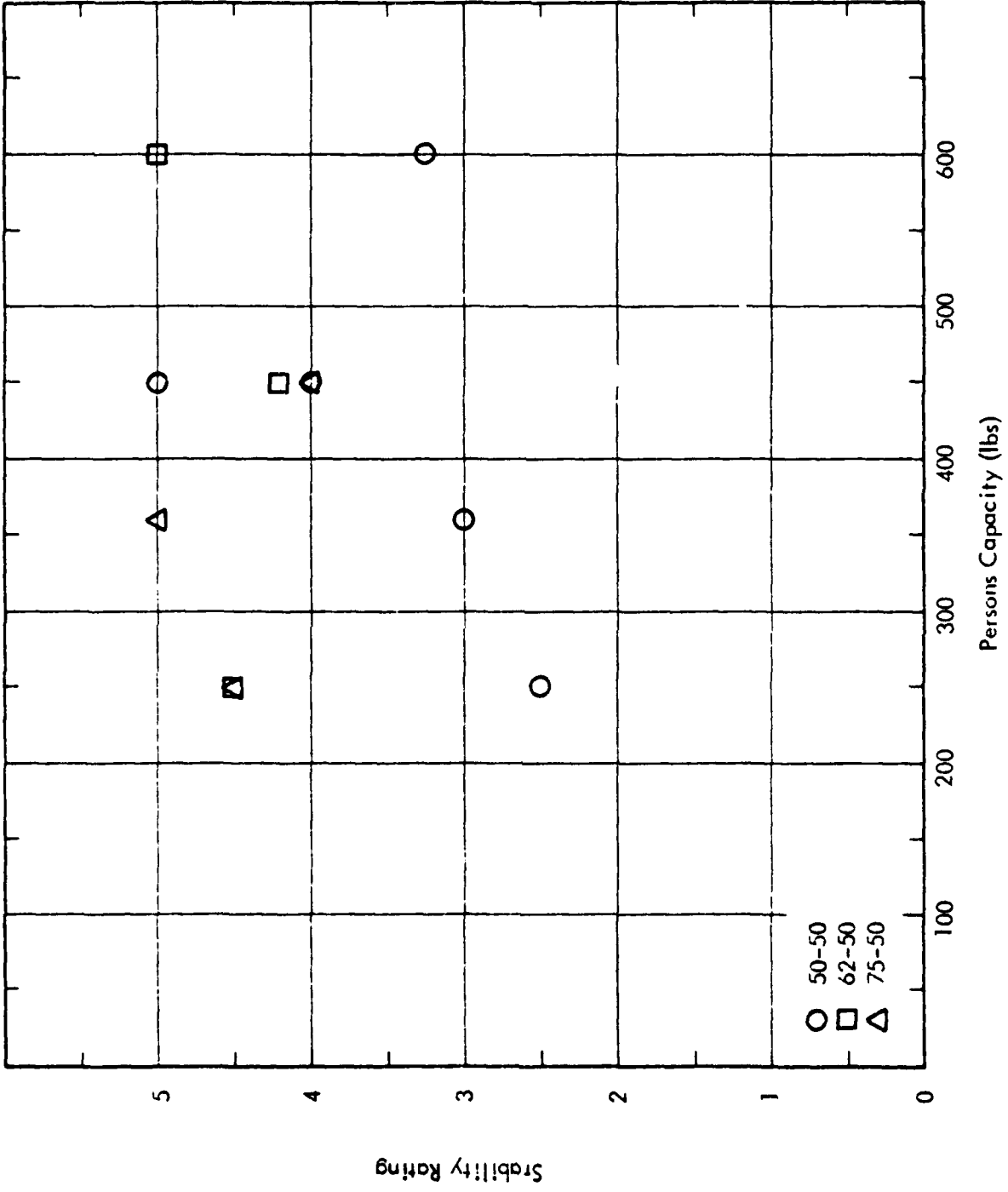


Figure 10-14. Wave Tank Data, Low Wave Height

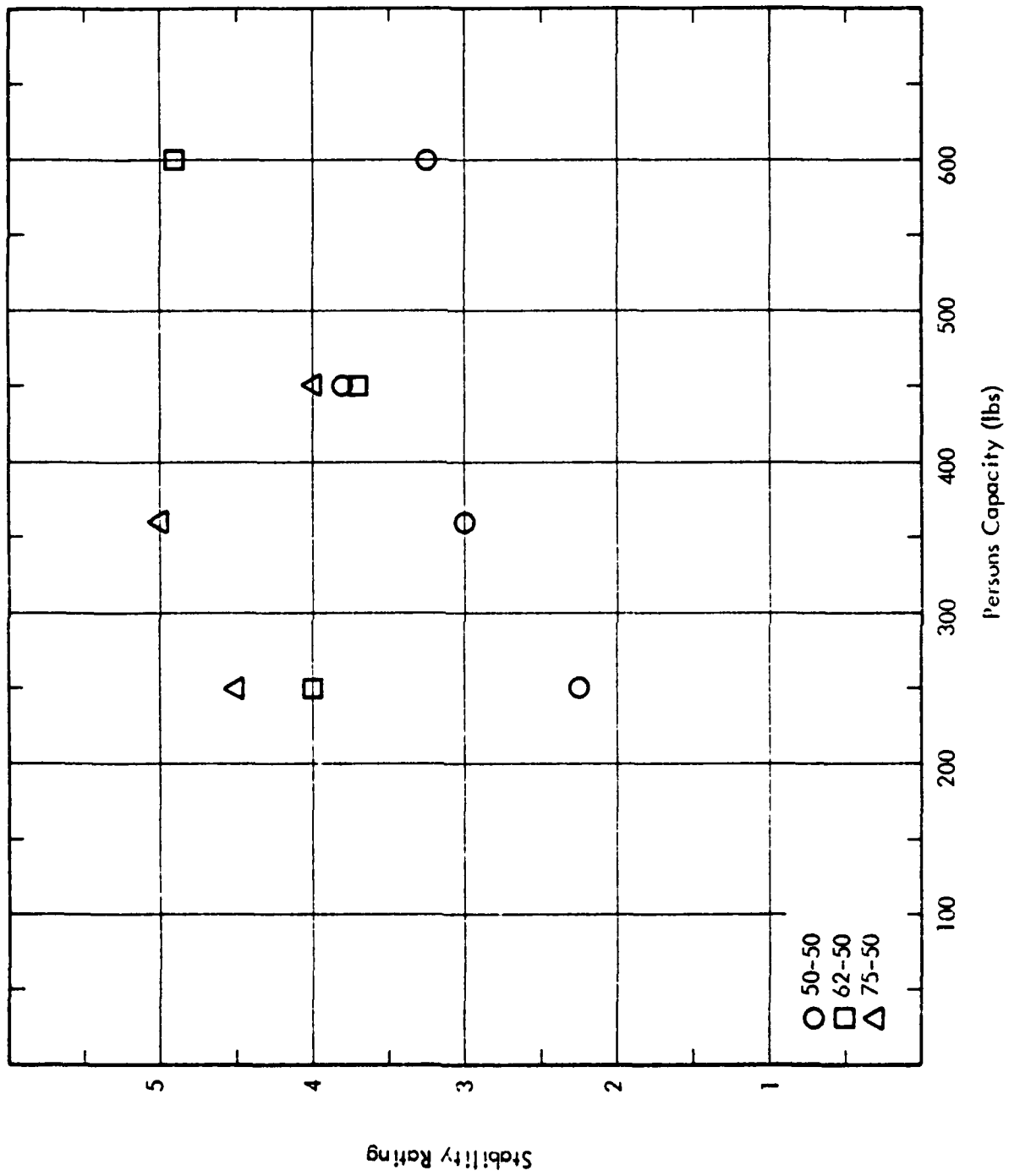


Figure 10-15. Wave Tank Data, High Wave Height



Figure 10-16. Typical Rough Water Evaluations

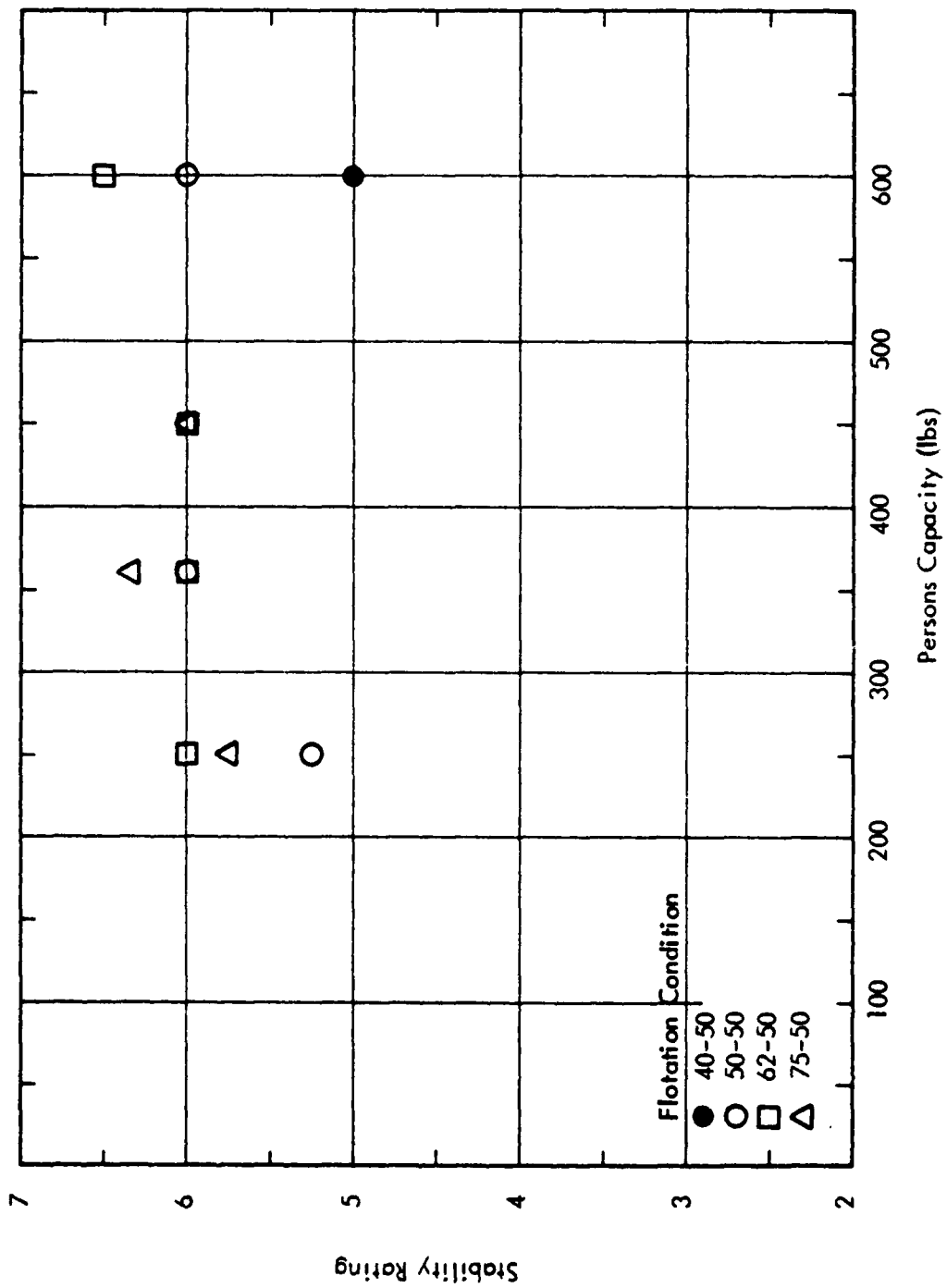


Figure 10-17. Open Water Data, Low Wave Height

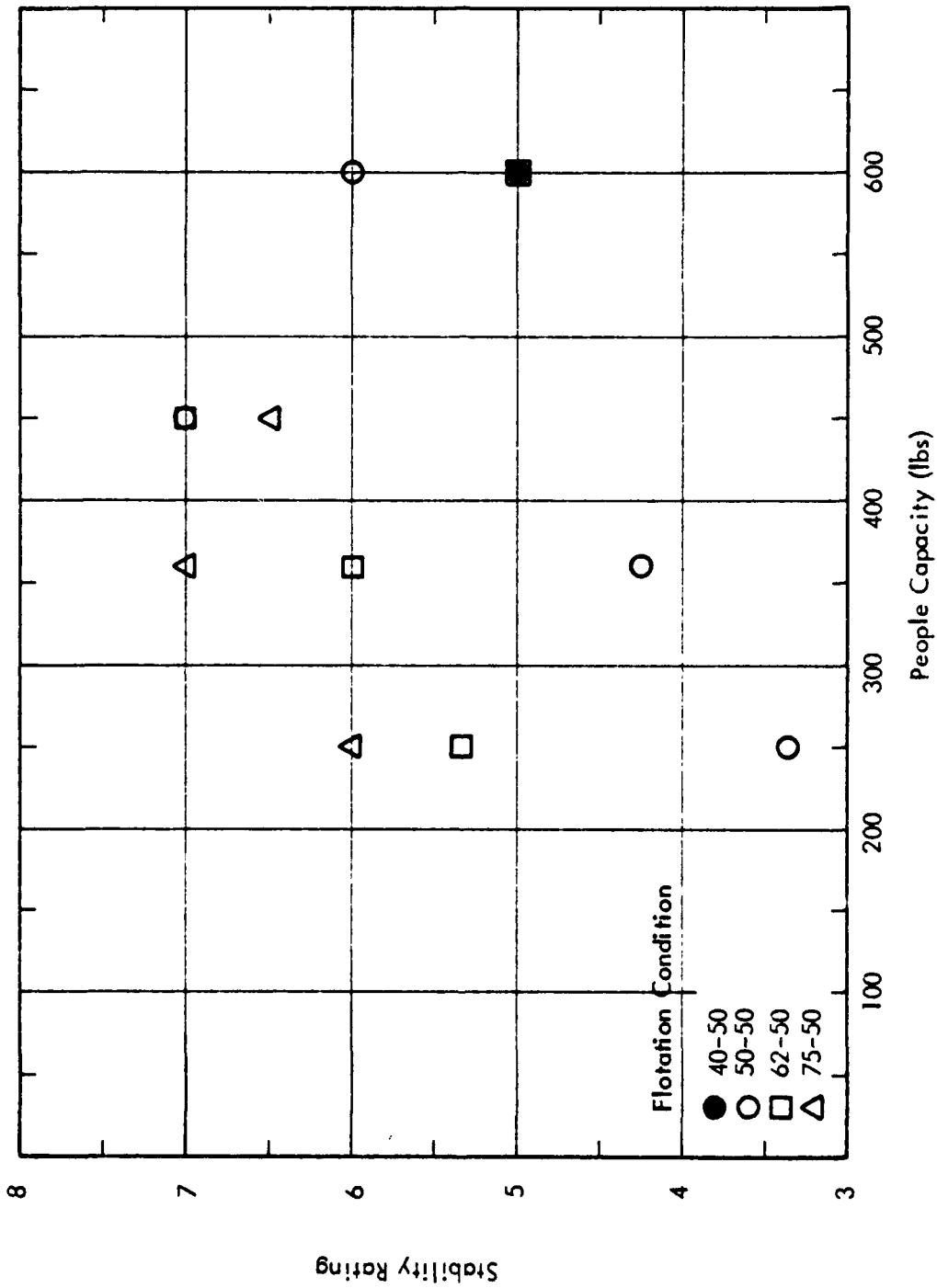


Figure 10-18. Open Water Data, High Wave Height

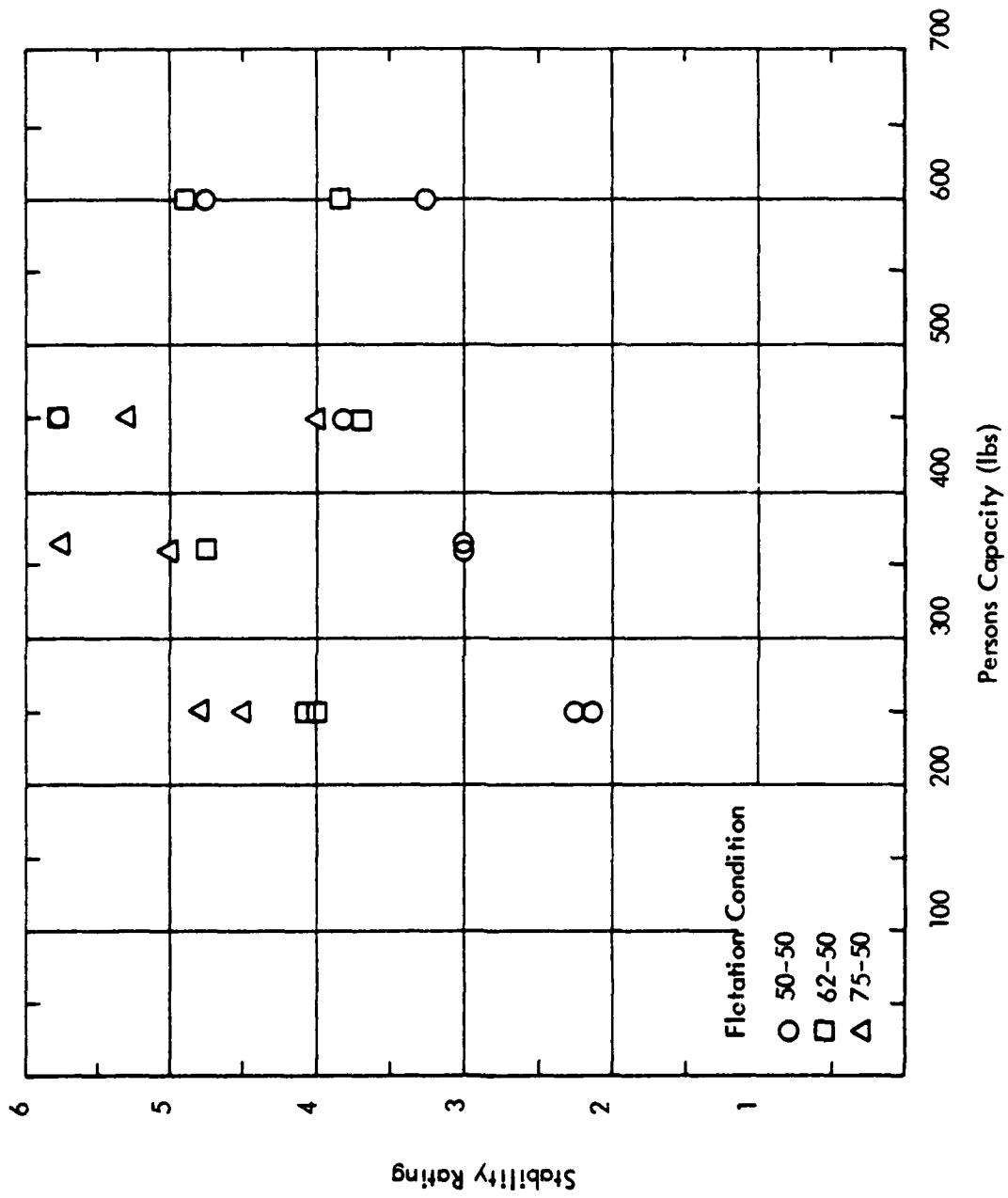


Figure 10-19. Combined Data, High Wave Height

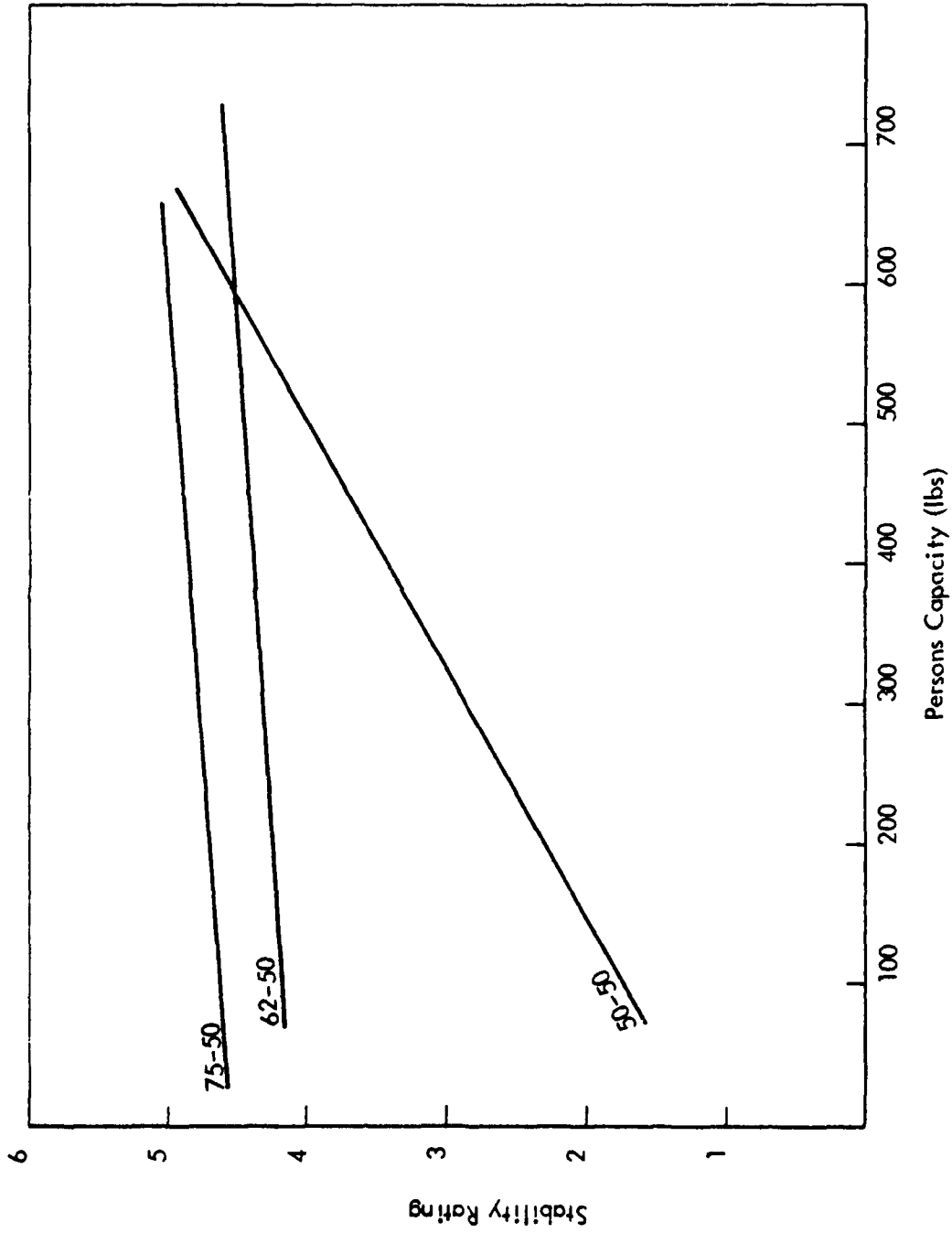


Figure 10-20. Linear Regression of Rough Water Data

TABLE 10-1. CHARACTERISTICS OF RESEARCH BOATS

Boat Number	Length (ft)	Beam (ft)	Persons Capacity
516	15.91	6.2	700
1187	14.05	4.0	375
225	11.96	4.22	400
1200	14.13	5.31	800
1202	13.70	5.28	600
524	14.83	5.0	450
244	14.96	4.83	450

TABLE 10-2. WAVE TANK TEST BOAT DESCRIPTION

Boat No.	Flotation Condition	Persons Capacity	Motor Weight	Battery Weight	Class
232	50/50	250	30	-	1
233	62.5/50	250	30	-	1
237	75/50	250	30	-	1
238	50/50	450	75	12	2
239	62.5/50	450	75	12	2
240	50/70	450	75	12	2
241	75/33	450	75	12	2
242	75/50	450	75	12	2
247	50/50	360	75	12	3
248	50/65	360	75	12	3
249	62.5/40	360	75	12	3
250	62.5/60	360	75	12	3
251	75/50	360	75	12	3
252	75/33	360	75	12	3
253	50/50	450	75	12	5
244	40/50	600	115	27.5	4
245	50/50	600	115	27.5	4
246	60/50	600	115	27.5	4

Class Description

- 1 Length - 10', Max. Beam - 45.75"
- 2 Length - 12', Max. Beam - 55.625"
- 3 Length - 14', Max. Beam - 45.625"
- 4 Length - 15', Max. Beam - 58.0"
- 5 Same hull as Class 3 with 30 lb lead added

TABLE 10-3. WAVE TANK TEST SCHEDULE

LEFT BAY				RIGHT BAY					
Test No.	Boat No.	Test Title	Wave Condition	Personnel	Test No.	Boat No.	Test Title	Wave Condition	Personnel
1	1 50/50	EP	1	McBride	1	4 40/50	EP	1	Steinfeldt Hickox Underwood
2	1 62/50	CM	1		2	4 50/50	CM	1	
3	1 62/50	CM	2		3	4 50/50	CM	2	
4	1 50/50	EP	2	McBride	4	4 40/50	EP	2	Steinfeldt Hickox Underwood
5	2 50/50	EP	2	Steinfeldt McBride	5	3 50/50	EP	2	Hickox Beck
6	1 75/50	CM	2		6	4 60/50	CM	2	
7	1 75/50	CM	1		7	4 60/50	CM	1	
8	2 50/50	EP	1	Steinfeldt McBride	8	3 50/50	EP	1	Hickox Beck
9	1 62/50	EP	1	McBride	9	4 50/50	EP	1	Steinfeldt Hickox Underwood
10	1 50/50	CM	1		10	4 40/50	CM	1	
11	1 50/50	CM	2		11	4 40/50	CM	2	
12	1 62/50	EP	2	McBride	12	4 50/50	EP	2	Steinfeldt Hickox Underwood
13	1 75/50	EP	2	McBride	13	4 60/50	EP	2	Steinfeldt Hickox Underwood
14	2 50/50	CM	2		14	3 50/50	CM	2	
15	2 50/50	CM	1		15	3 50/50	CM	1	
16	1 75/50	EP	1	McBride	16	4 60/50	EP	1	Steinfeldt Hickox Underwood
17	2 62/50	EP	1	Steinfeldt McBride	17	3 50/65	EP	1	Hickox Beck
18	2 75/50	CM	1		18	3 62/40	CM	1	
19	2 75/50	CM	2		19	3 62/40	CM	2	
20	2 62/50	EP	2	Steinfeldt McBride	20	3 50/65	EP	2	Hickox Beck

TABLE 10-3. WAVE TANK TEST SCHEDULE (concluded)

LEFT BAY				RIGHT BAY					
Test No.	Boat No.	Test Title	Wave Condition	Personnel	Test No.	Boat No.	Test Title	Wave Condition	Personnel
21	3 75 50	EP	2	Hickox Beck	21	5 50 50	EP	2	Steinfeldt McBride
22	3 62 60	CM	2		22	3 75 33	CM	2	
23	3 62 60	CM	1		23	3 75 33	CM	1	
24	3 75 50	EP	1	Hickox Beck	24	5 50 50	EP	1	Steinfeldt McBride
25	2 75 50	EP	1	Steinfeldt McBride	25	3 62 40	EP	1	Hickox Beck
26	2 62 50	CM	1		26	3 50 65	CM	1	
27	2 62 50	CM	2		27	3 50 65	CM	2	
28	2 75 50	EP	2	Steinfeldt McBride	28	3 62 40	EP	2	Hickox Beck
29	3 62 60	EP	2	Hickox Beck	29	2 75 33	EP	2	Steinfeldt McBride
30	3 75 50	CM	2		30	2 50 70	CM	2	
31	3 75 50	CM	1		31	2 50 70	CM	1	
32	3 62 60	EP	1	Hickox Beck	32	2 75 33	EP	1	Steinfeldt McBride
33	2 50 70	EP	1	Steinfeldt McBride	33	3 75 33	EP	1	Hickox Beck
34	2 75 33	CM	1		34	5 50 50	CM	1	
35	2 75 33	CM	2		35	5 50 50	CM	2	
36	2 50 70	EP	2	Steinfeldt McBride	36	3 75 33	EP	2	Hickox Beck

EP = Experienced People Tests
 CM = Continuous Measure Tests

TABLE 10-4. WAVE TANK ALTERNATE TEST SCHEDULE

LEFT BAY				RIGHT BAY					
Test No.	Boat No.	Test Title	Wave Condition	Personnel	Test No.	Boat No.	Test Title	Wave Condition	Personnel
1	1 50/50	EP	1	McBride	1	4 40/50	EP	1	Stienfeldt Hickox Underwood
2	1 62/50	CM	1		2	4 50/50	CM	1	
3	1 62/50	CM	2		3	4 50/50	CM	2	
4	1 50/50	EP	2	McBride	4	4 40/50	EP	2	Stienfeldt Hickox Underwood
5	1 50/50	EP	3	McBride	5	4 40/50	EP	3	Stienfeldt Hickox Underwood
6	1 62/50	CM	3		6	4 50/50	CM	3	
7	2 50/50	EP	2	Stienfeldt McBride	7	3 50/50	EP	2	Hickox Beck
8	1 75/50	CM	2		8	4 60/50	CM	2	
9	1 75/50	CM	1		9	4 60/50	CM	1	
10	2 50/50	EP	1	Stienfeldt McBride	10	3 50/50	EP	1	Hickox Beck
11	2 50/50	EP	3	Stienfeldt McBride	11	3 50/50	EP	3	Hickox Beck
12	1 75/50	CM	3		12	3 60/50	CM	3	
13	1 62/50	EP	1	McBride	13	4 50/50	EP	1	Stienfeldt Hickox Underwood
14	1 50/50	CM	1		14	4 40/50	CM	1	
15	1 50/50	CM	2		15	4 40/50	CM	2	
16	1 62/50	EP	2	McBride	16	4 50/50	EP	2	Stienfeldt Hickox Underwood
17	1 62/50	EP	3	McBride	17	4 50/50	EP	3	Stienfeldt Hickox Underwood
18	1 50/50	CM	3		18	4 40/50	CM	3	
19	1 75/50	EP	2	McBride	19	4 60/50	EP	2	Stienfeldt Hickox Underwood

TABLE 10-4. WAVE TANK ALTERNATE TEST SCHEDULE (continued)

LEFT BAY				RIGHT BAY					
Test No.	Boat No.	Test Title	Wave Condition	Personnel	Test No.	Boat No.	Test Title	Wave Condition	Personnel
20	2 50 50	CM	2		20	3 50 50	CM	2	
21	2 50 50	CM	1		21	3 50 50	CM	1	
22	1 75 50	EP	1	McBride	22	4 60 50	EP	1	Steinfeldt Hickox Underwood
23	1 75 50	EP	3	McBride	23	4 60 50	EP	3	Steinfeldt Hickox Underwood
24	2 50 50	CM	3		24	3 50 50	CM	3	
25	2 62 50	EP	1	Steinfeldt McBride	25	3 50 65	EP	1	Hickox Beck
26	2 75 50	CM	1		26	3 62 40	CM	1	
27	2 75 50	CM	2		27	3 62 40	CM	2	
28	2 62 50	EP	2	Steinfeldt McBride	28	3 50 65	EP	2	Hickox Beck
29	2 62 50	EP	3	Steinfeldt McBride	29	3 50 65	EP	3	Hickox Beck
30	2 75 50	CM	3		30	3 62 40	CM	3	
31	3 75 50	EP	2	Hickox Beck	31	5 50 50	EP	2	Steinfeldt McBride
32	3 62 60	CM	2		32	3 75 33	CM	2	
33	3 62 60	CM	1		33	3 75 33	CM	1	
34	3 75 50	EP	1	Hickox Beck	34	5 50 50	EP	1	Steinfeldt McBride
35	3 75 50	EP	3	Hickox Beck	35	5 50 50	EP	3	Steinfeldt McBride
36	3 62 60	CM	3		36	3 75 33	CM	3	
37	2 75 50	EP	1	Steinfeldt McBride	37	3 62 40	EP	1	Hickox Beck
38	2 62 50	CM	1		38	3 50 65	CM	1	
39	2 62 50	CM	2		39	3 50 65	CM	2	
40	2 75 50	EP	2	Steinfeldt McBride	40	3 62 40	EP	2	Hickox Beck
41	2 75 50	EP	3	Steinfeldt McBride	41	3 62 40	EP	3	Hickox Beck
42	2 62 50	CM	3		42	3 50 65	CM	3	

TABLE 10-4. WAVE TANK ALTERNATE TEST SCHEDULE (concluded)

LEFT BAY				RIGHT BAY					
Test No.	Boat No.	Test Title	Wave Condition	Personnel	Test No.	Boat No.	Test Title	Wave Condition	Personnel
43	3 62/60	EP	2	Hickox Beck	43	2 75/33	EP	2	Steinfeldt McBride
44	3 75/50	CM	2		44	2 50/70	CM	2	
45	3 75/50	CM	1		45	2 50/70	CM	1	
46	3 62/60	EP	1	Hickox Beck	46	2 75/33	EP	1	Steinfeldt McBride
47	3 62/60	EP	3	Hickox Beck	47	2 75/33	EP	3	Steinfeldt McBride
48	3 75/50	CM	3		48	2 50/70	CM	3	
49	2 50/70	EP	1	Steinfeldt McBride	49	3 75/33	EP	1	Hickox Beck
50	2 75/33	CM	1		50	5 50/50	CM	1	
51	2 75/33	CM	2		51	5 50/50	CM	2	
52	2 50/70	EP	2	Steinfeldt McBride	52	3 75/33	EP	2	Hickox Beck
53	2 50/70	EP	3	Steinfeldt McBride	53	3 75/33	EP	3	Hickox Beck
54	2 75/33	CM	3		54	5 50/50	CM	3	

EP = Experienced People Tests
 CM = Continuous Measure Tests

TABLE 10-5. RATING SCALE DESCRIPTION

Rating	Explanation
1	Boat capsizes no matter what occupants do to attempt to prevent it.
2	Boat can be maintained upright with constant effort on part of occupants.
3	Boat requires movement at frequent intervals to maintain upright condition.
4	Boat requires infrequent movement to maintain upright condition.
5	Boat can be maintained upright as long as personnel remain on centerline.

TABLE 10-6. SUMMARY OF WAVE TANK TESTS

Boat Description	Average Rating	
	Low Wave Height	High Wave Height
232 1-50/50	2.5	2.25
233 1-62/50	4.5	4
237 1-75/50	4.5	4.5
238 2-50/50	4	3.8
239 2-62/50	4.2	3.7
240 2-50/70	5	4.75
241 2-75/33	3.7	3.3
242 2-75/50	4	4
247 3-50/50	3	3
248 3-50/65	4.7	4.3
249 3-62/40	2.3	2.3
250 3-62/60	4	3.3
251 3-75/50	5	5
252 3-75/33	4	4
253 5-50/50	4	3
244 4-40/50	2.75	3.75
245 4-50/50	3.25	3.25
246 4-60/50	5	4.9

TABLE 10-7. OPEN WATER TEST BOAT DESCRIPTION

Boat No.	Flotation Condition	Persons Capacity	Motor Weight	Battery Weight	Class
232	50/50	250	30	-	1
233	62.5/50	250	30	-	1
237	75/50	250	30	-	1
238	50/50	450	75	12	2
239	62.5/50	450	75	12	2
242	75/50	450	75	12	2
247	50/50	360	75	12	3
248	53/70	360	75	12	3
249	62.5/50	360	75	12	3
250	50/65	360	75	12	3
251	75/50	360	75	12	3
252	75/33	360	75	12	3
244	40/50	600	115	27.5	4
245	50/50	600	115	27.5	4
246	60/50	600	115	27.5	4

Class Description

- 1 Length - 10', Max. Beam - 45.75"
- 2 Length - 12', Max. Beam - 55.625"
- 3 Length - 14', Max. Beam - 45.625"
- 4 Length - 15', Max. Beam - 58.0"

TABLE 10-8. OPEN WATER RESULTS, LOW WAVE HEIGHT

Boat Description	Average Rating		
	Stability	Rerighting	Reboarding
1-75-50	5.75	5.5	5.5
1-62-50	6	6	6
1-50-50	5.25	6	6
2-75-50	6	3	4
2-62-50	6	6	6
2-50-50	6	6	6
3-75-50	6.33	3.33	6.33
3-62-50	6	6	5.33
3-50-50	6	6	6
4-60-50	6.5	4.5	6.5
4-50-50	6	5	6
4-40-50	5	6	5

TABLE 10-9. OPEN WATER RESULTS, HIGH WAVE HEIGHT

Boat Description	Average Rating		
	Stability	Rerighting	Reboarding
1-75-50	6	5.5	5.5
1-62-50	5.33	4.5	5.33
1-50-50	3.37	4.25	3.5
2-75-50	6.5	2	6
2-62-50	7	3.87	7
2-50-50	7	4	7
3-75-50	7	3.75	5.5
3-62-50	6	4.5	5.5
3-50-50	4.25	4.5	3.6
4-60-50	5	4	4
4-50-50	6	3.5	6
4-40-50	5	4	4
3-50-65	5	5	5
3-53-70	6	5	6
3-75-33	5	3	2

TABLE 10-10. OPEN WATER CORRECTED DATA, HIGH WAVE HEIGHT

Boat Description	<u>Average Rating</u> Stability
1-75-50	4.75
1-62-50	4.08
1-50-50	2.12
2-75-50	5.25
2-62-50	5.75
2-50-50	5.75
3-75-50	5.75
3-62-50	4.75
3-50-50	3.0
4-60-50	3.75
4-50-50	4.75
4-40-50	3.75
3-50-65	3.75
3-53-70	4.75
3-75-33	3.75

11.0 RECOMMENDATIONS

Recommendations made in this report are based on work discussed in this report and References 1 and 2.

1. Swamped Machinery Weight

The data from this study and the study performed by the Coast Guard R & D Center and additional information that might be obtained (such as the weight of other manufacturer's engines) can be used to update the swamped machinery table for flotation requirements.

2. SK Boat Demonstration

This type of boat is presently being considered as an exemption from the level flotation standard. If thought is given to not exempting it, the work performed in this study can be used as a baseline from which to perform additional studies if they are felt to be necessary.

3. Foam Absorption Considerations

It is economically infeasible to eliminate all entrapped air from open cell foam used in many of today's boats during a compliance test. Based on the findings of this study and engineering judgment, it appears that if a boat is left submerged for approximately 16 hrs before being flotation tested, the remaining buoyancy will be a good indication of the useful flotation provided by the boat.

4. Longitudinal Trim Requirements

The maximum submergence of one end of the boat in the full load and no passenger load test condition should be between 6 and 12 inches. For compliance test purposes, the test weight placement should be restricted to an area that is approximately 20% of the passenger area length about the midlength of the passenger area.

5. Transverse Stability Considerations

Location of test weights should be restricted as follows:

- | | |
|-----|---|
| VCG | - Four inches above cockpit sole. |
| TCG | - Four inches inboard of outer extremity at the location of test weights. |

LCG - Approximately 35% of passenger length about midlength of passenger area.

Weight

Distribution - At least 30% of length of passenger area.

6. Person Action/Boat Reaction Study

This data can be used as part of the study to determine the level of education needed to accompany the level flotation standard.

7. Self-Bailing Boat Considerations

Testing has indicated that no special problems exist with these boats. They should comply with the level flotation standard unless a study of accident data indicates otherwise.

8. Rough Water Evaluations

These evaluations indicate that a boat with a persons capacity of 500 lbs or less should have 62-50 flotation for adequate stability in rough water. A study to determine the added safety afforded by this, based on the number of swampings in rough water with this size boat, should be conducted before requiring boats of this size to have that amount of flotation.

APPENDIX A
PHOTOGRAPHS FOR
SUBMITTED MACHINERY DETERMINATIONS (SECTION 2.0)

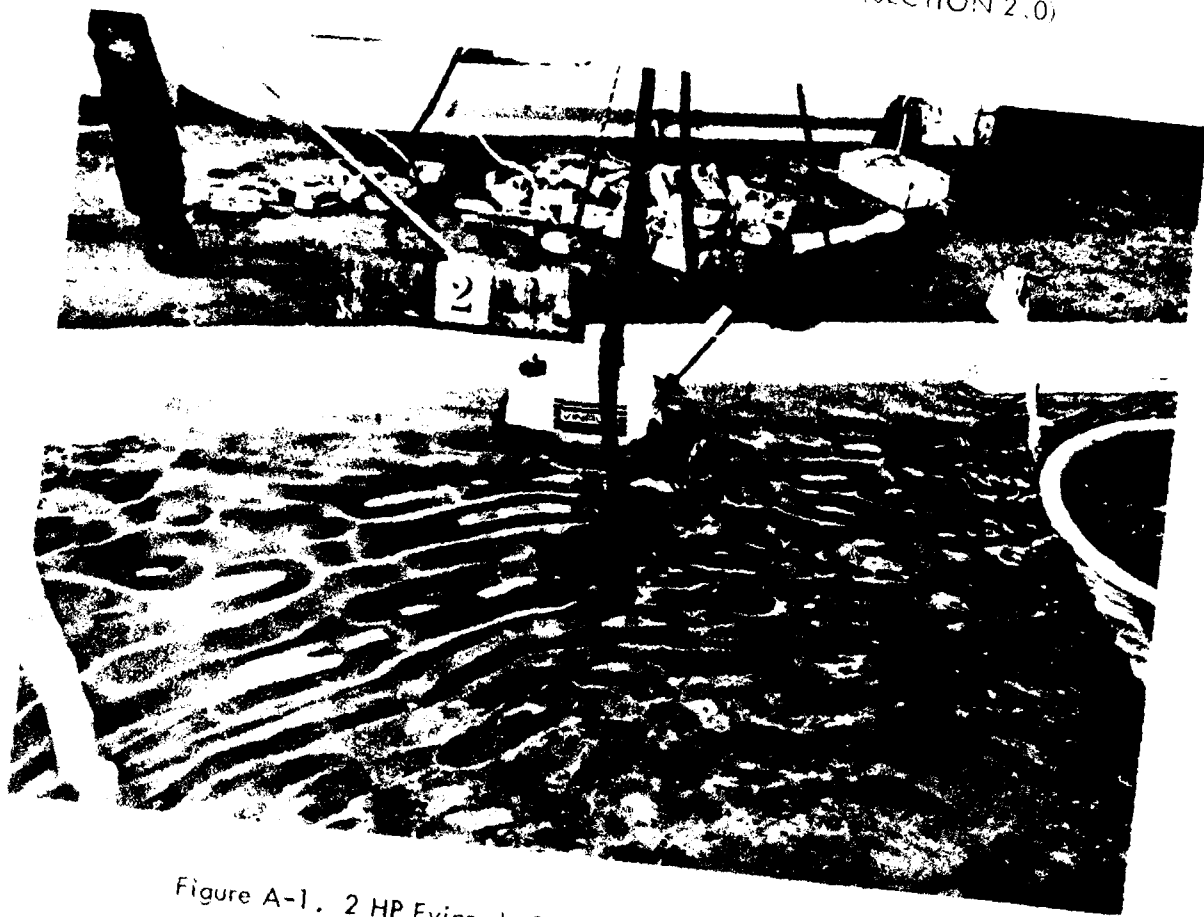


Figure A-1. 2 HP Evinrude Submerged To Mounting Bracket



Figure A-2. 4 HP Evinrude Submerged To Mounting Bracket

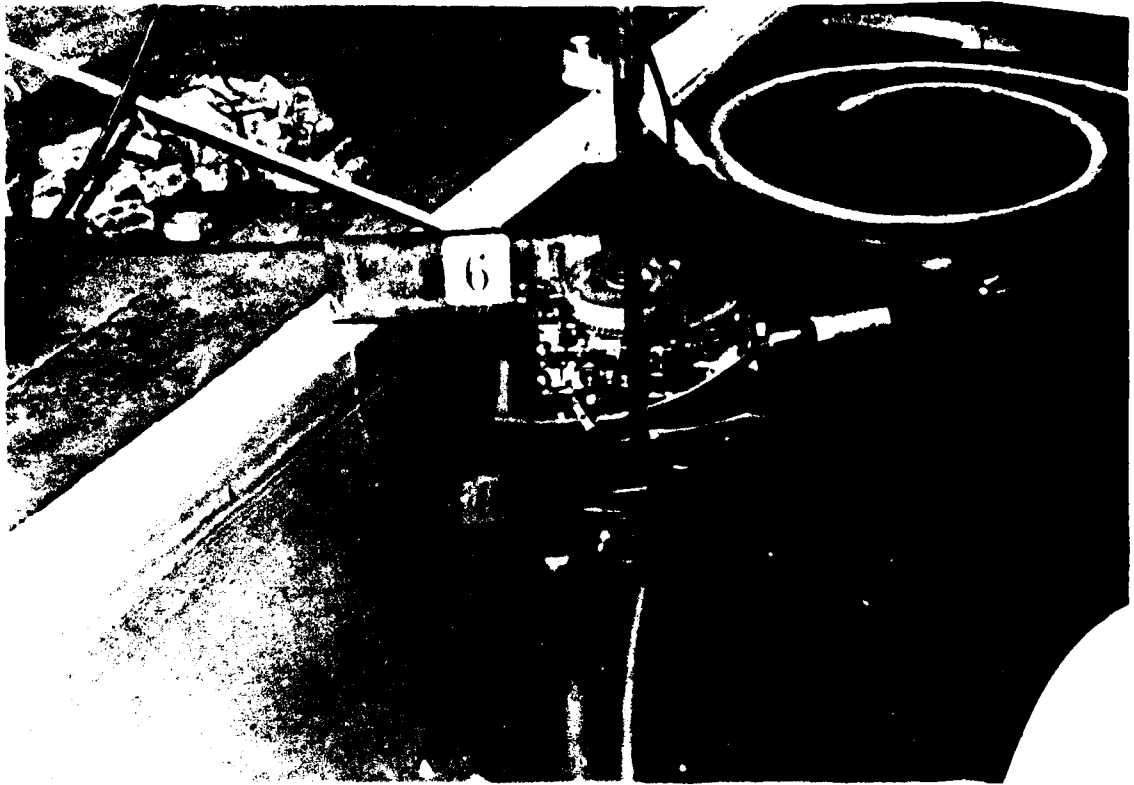


Figure A-3. 6 HP Evinrude Submerged To Mounting Bracket

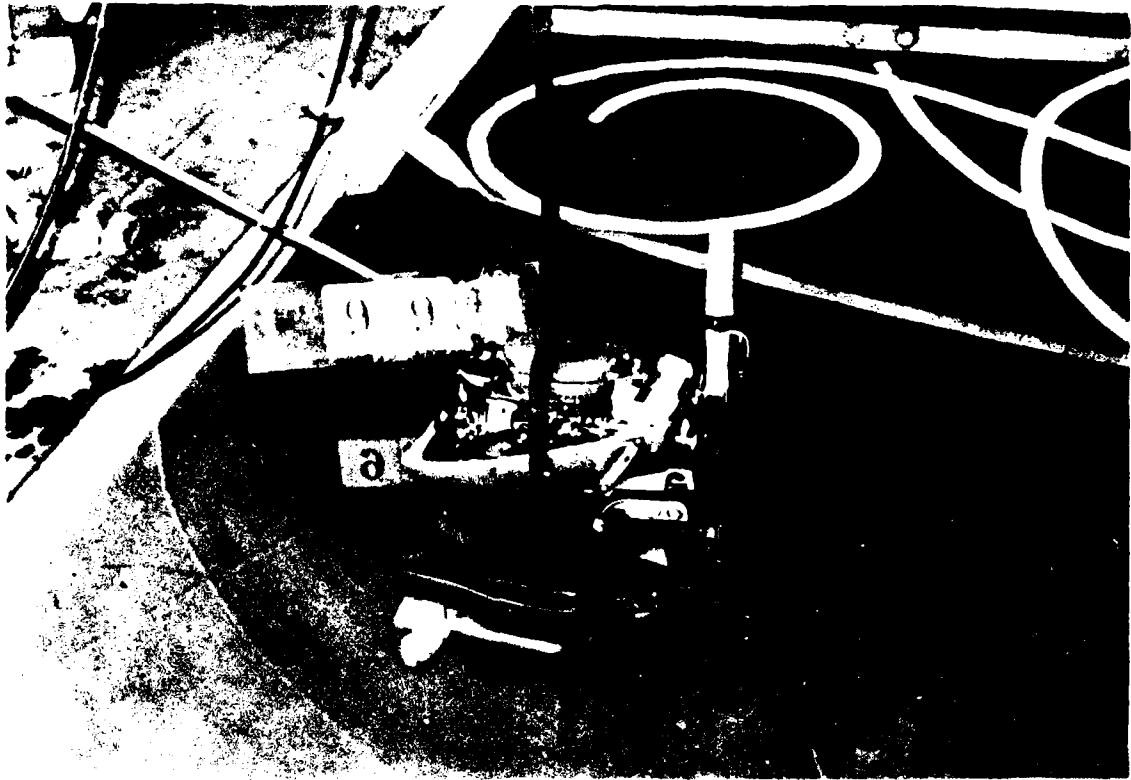


Figure A-4. 9.9 HP Evinrude Submerged To Mounting Bracket

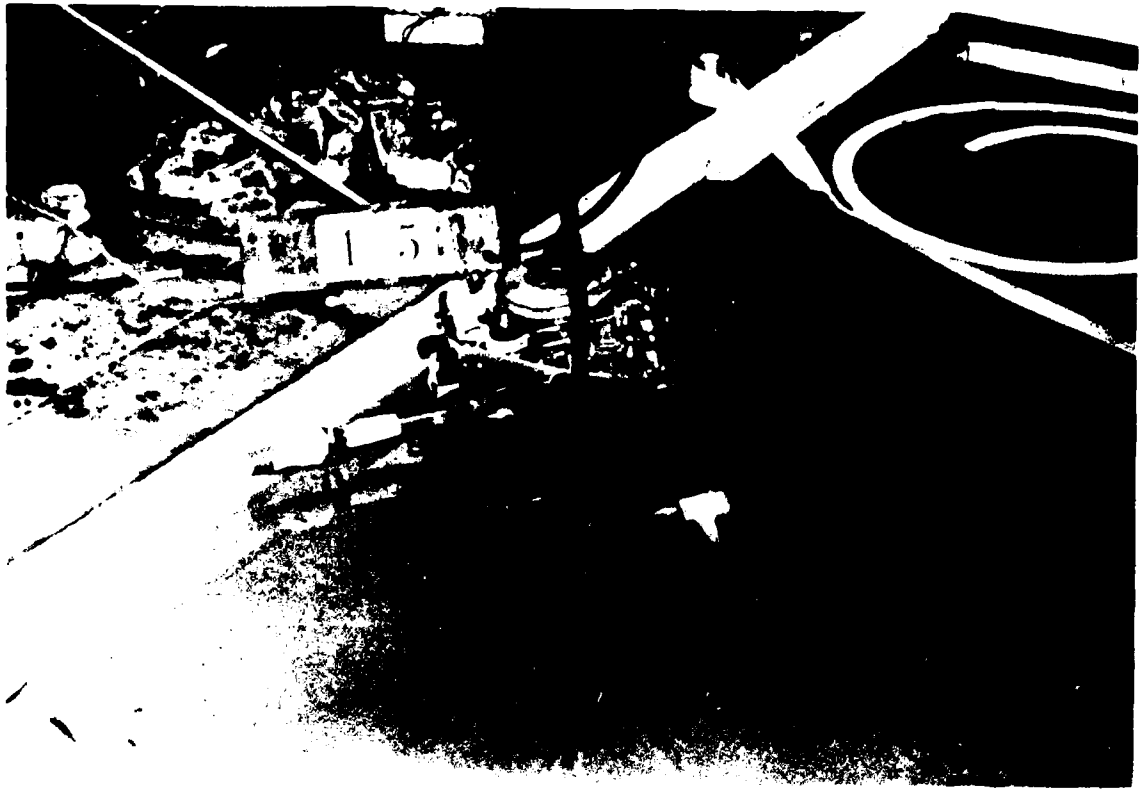


Figure A-5. 15 HP Evinrude Submerged To Mounting Bracket

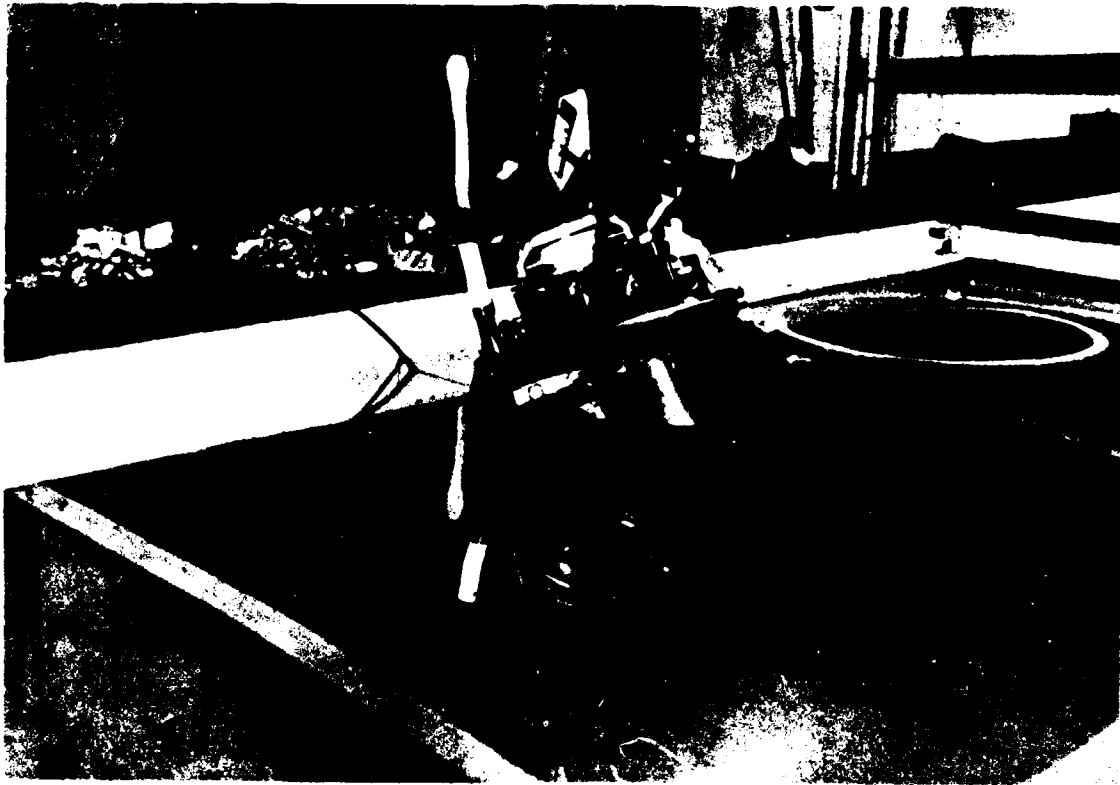


Figure A-6. 25 HP Evinrude Submerged To Mounting Bracket

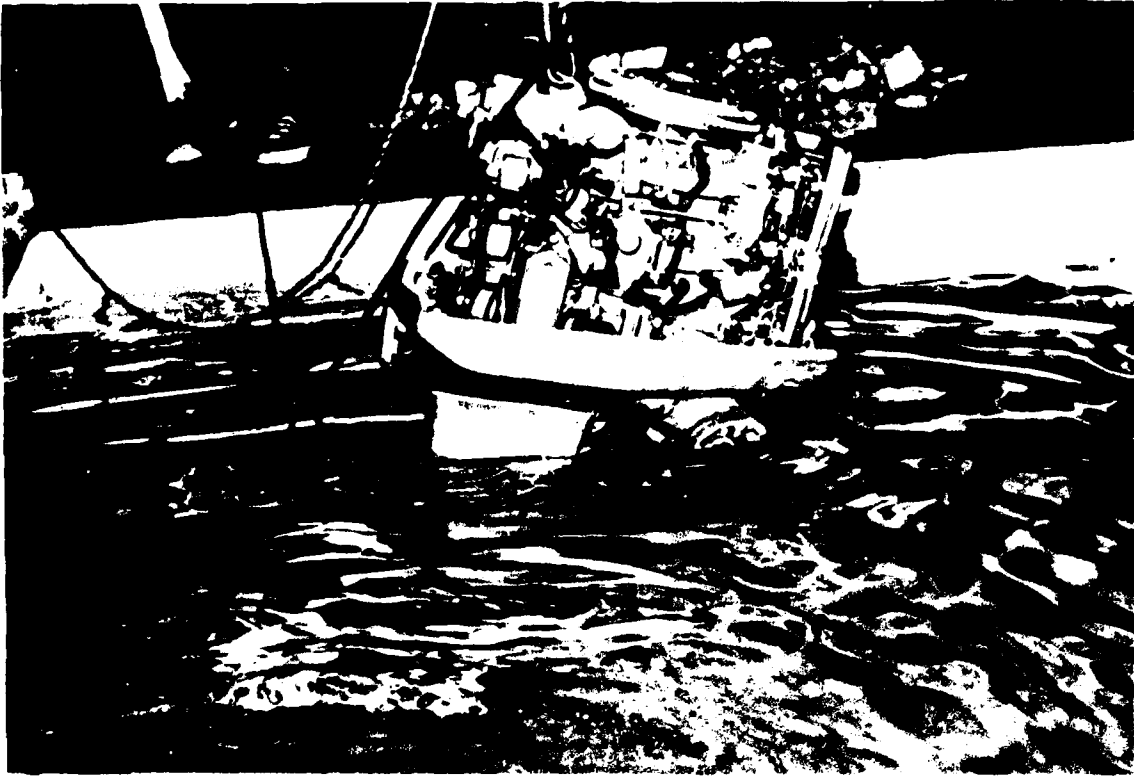


Figure A-7. 65 HP Evinrude Submerged To Mounting Bracket

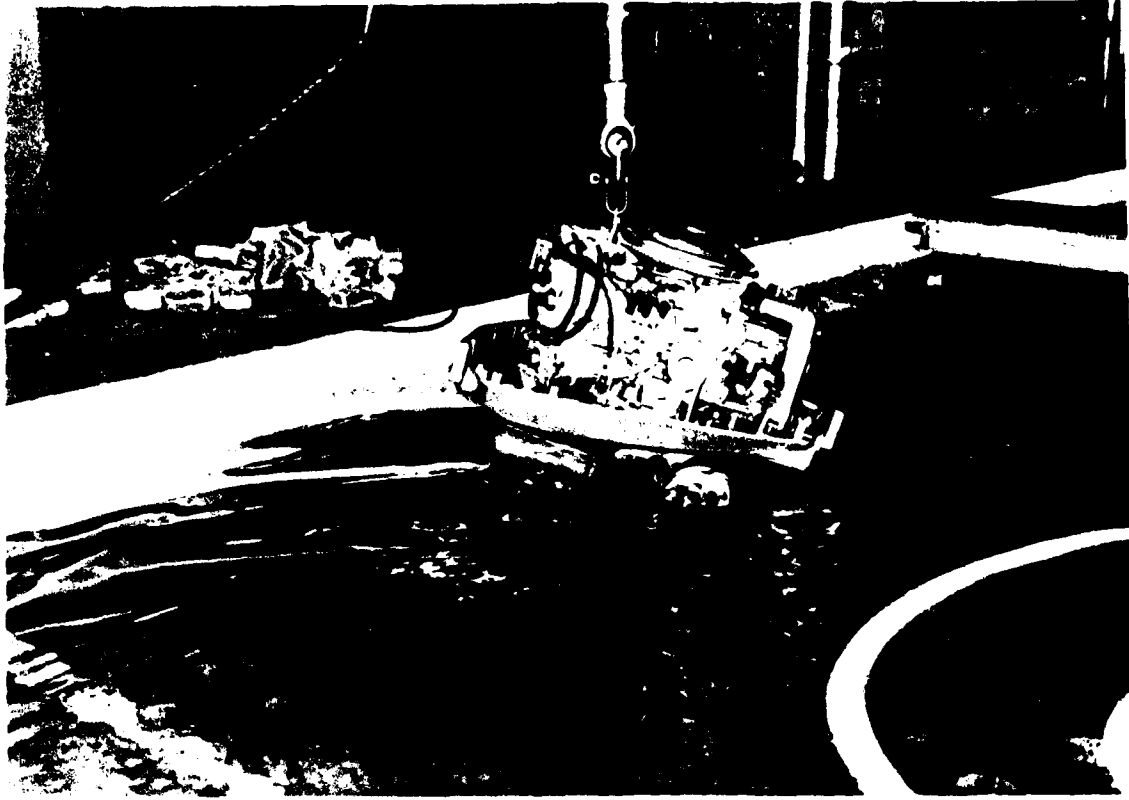


Figure A-8. 85 HP Evinrude Submerged To Mounting Bracket

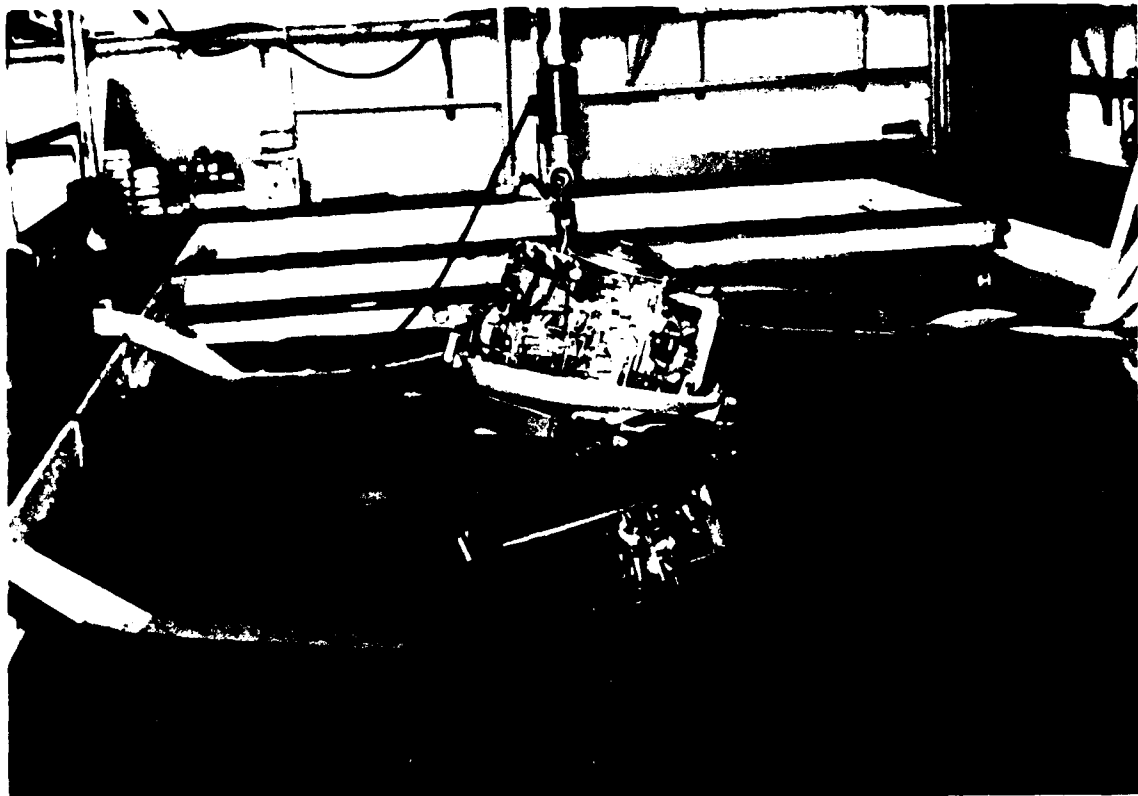


Figure A-9. 135 HP Evinrude Submerged To Mounting Bracket

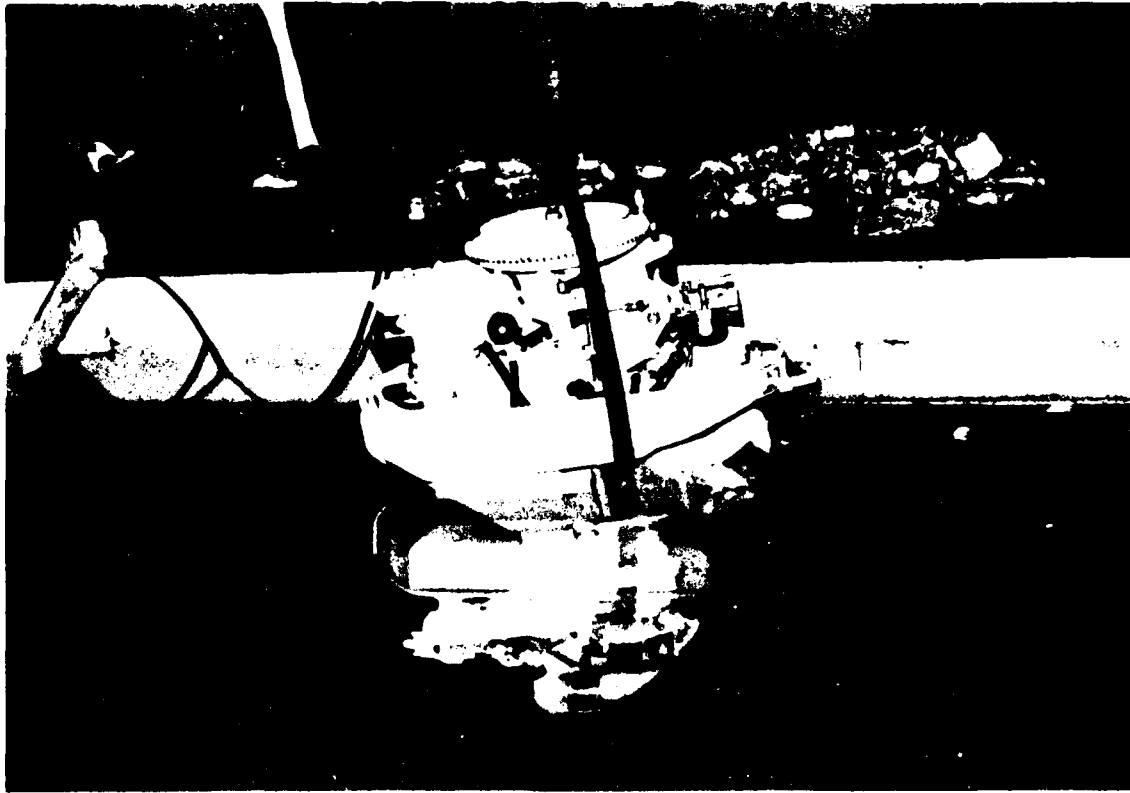


Figure A-10. 35 HP Chrysler Submerged To Mounting Bracket

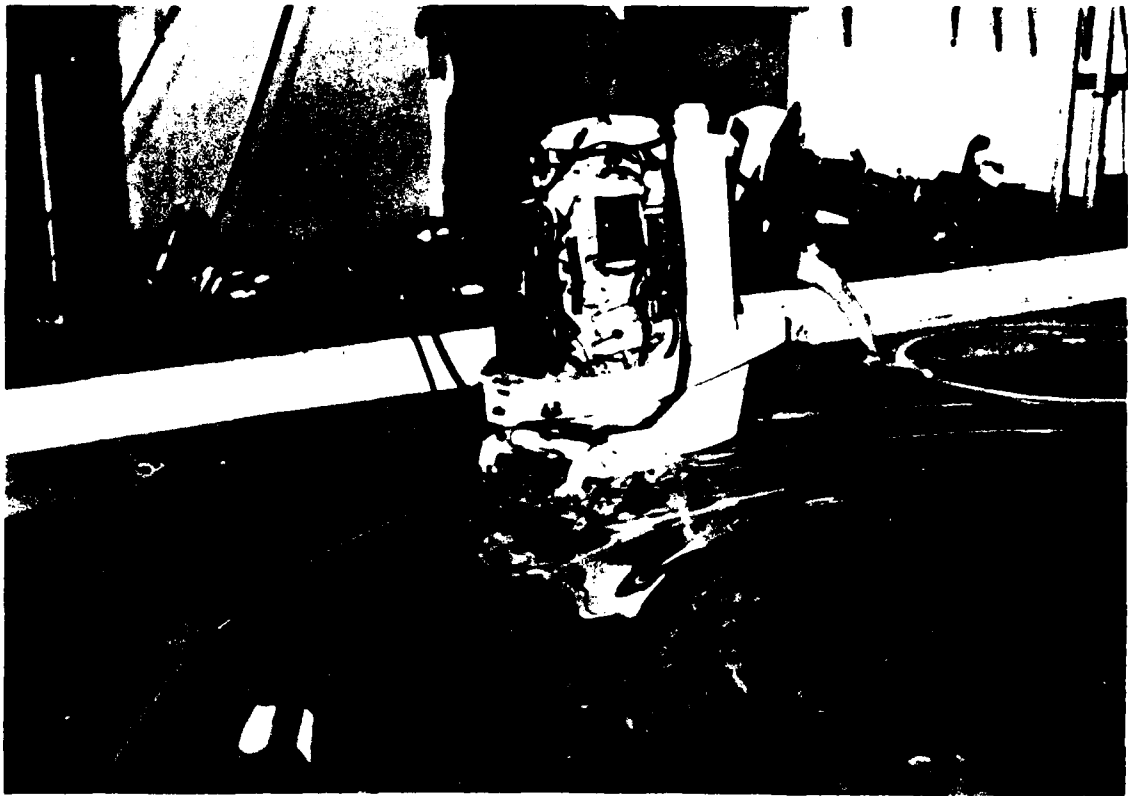


Figure A-11. 130 HP Chrysler Submerged To Mounting Bracket

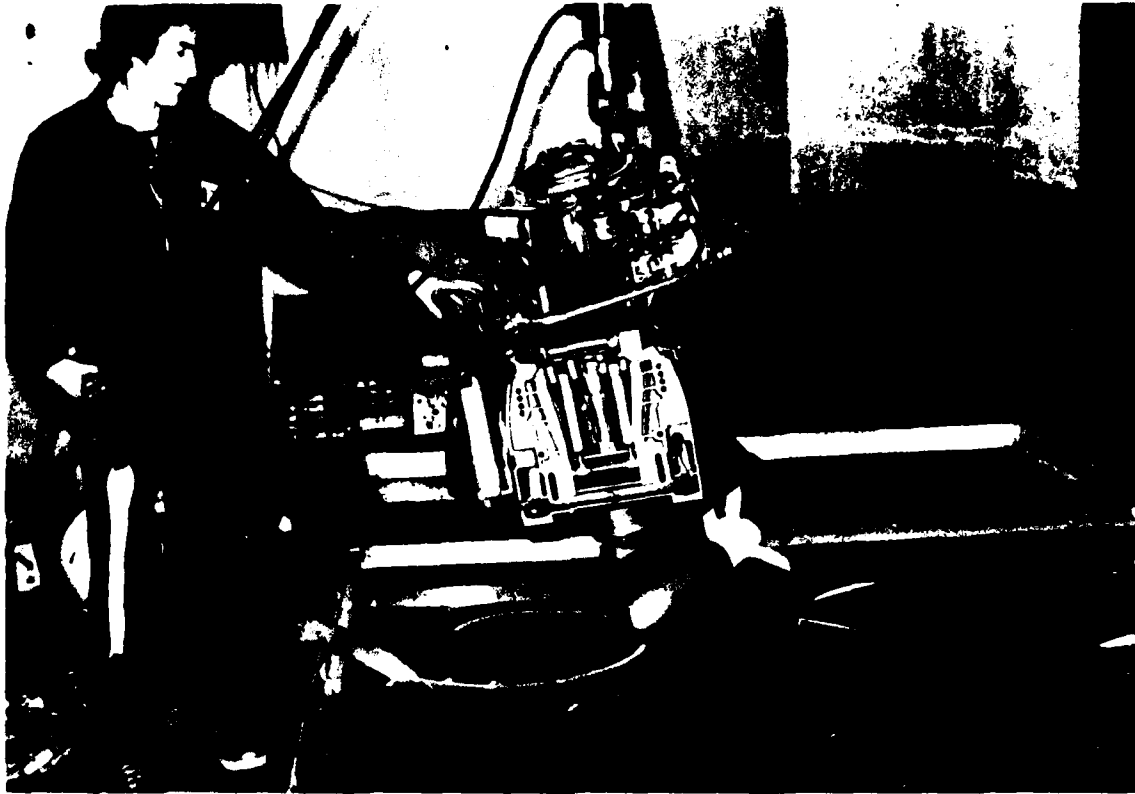


Figure A-12. Power Tilt Gear On 135 HP Evinrude

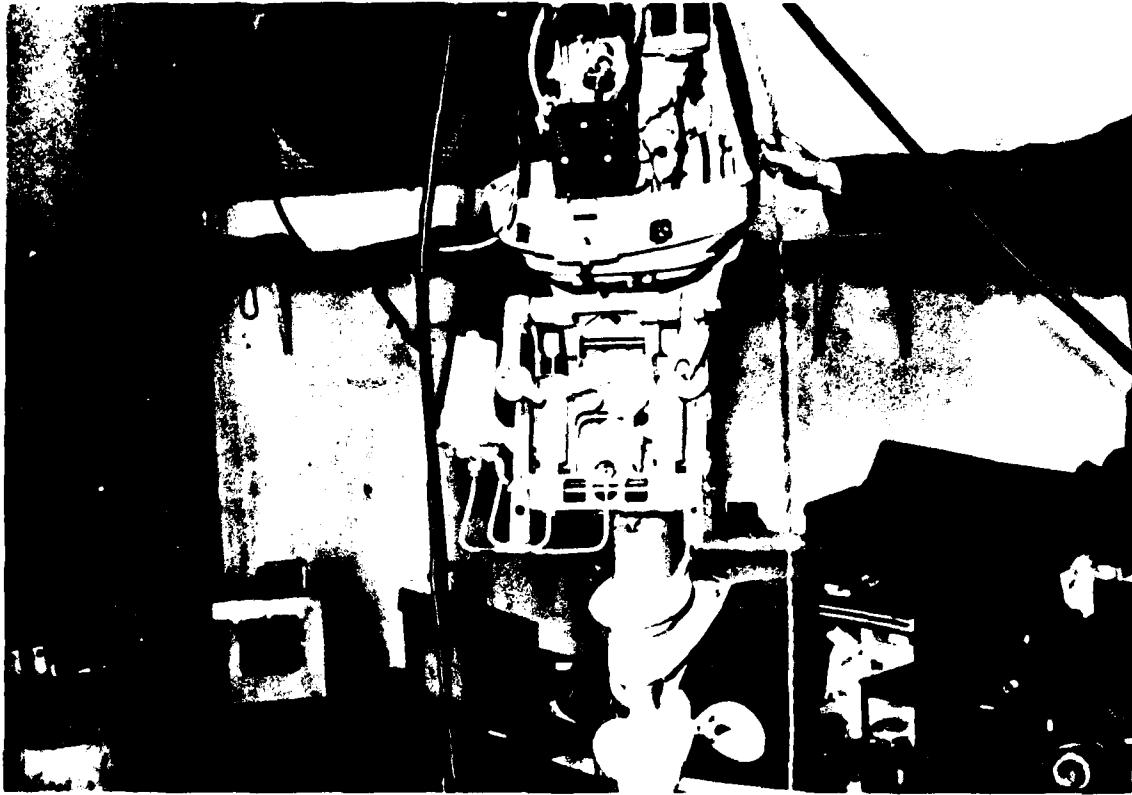


Figure A-13. Power Tilt Gear On 130 HP Chrysler

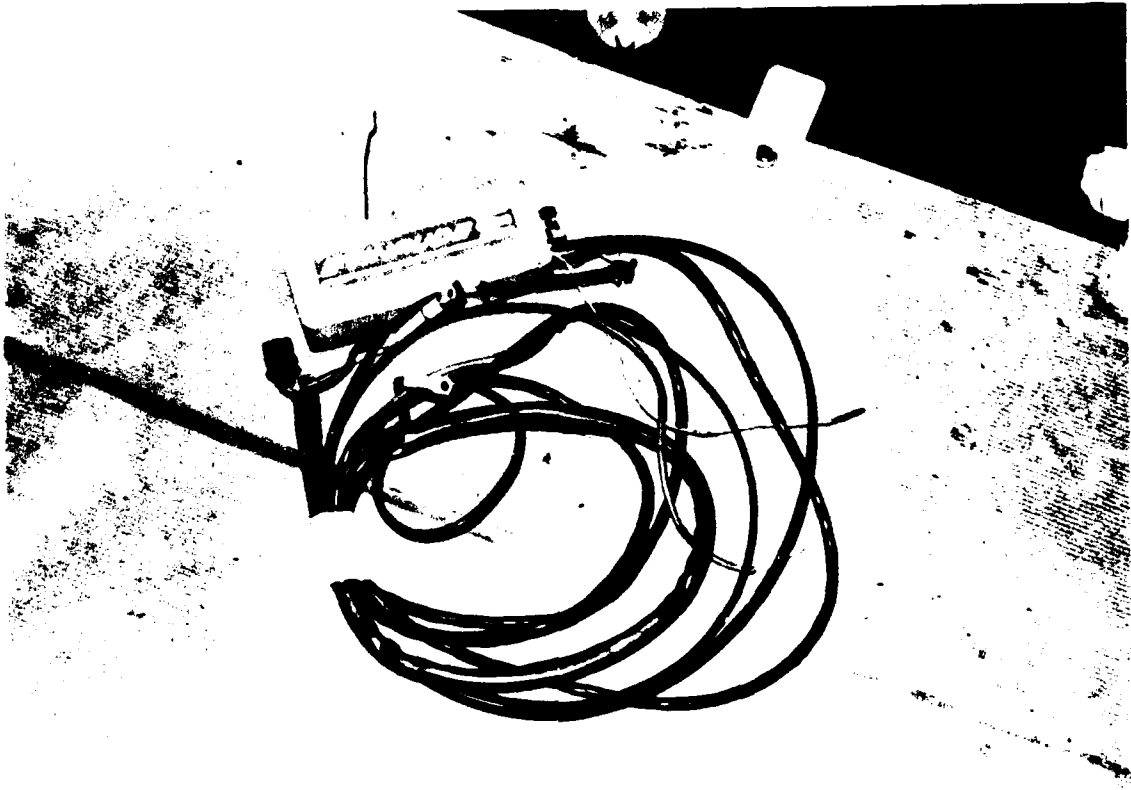


Figure A-14. Control Unit For Evinrude Motors

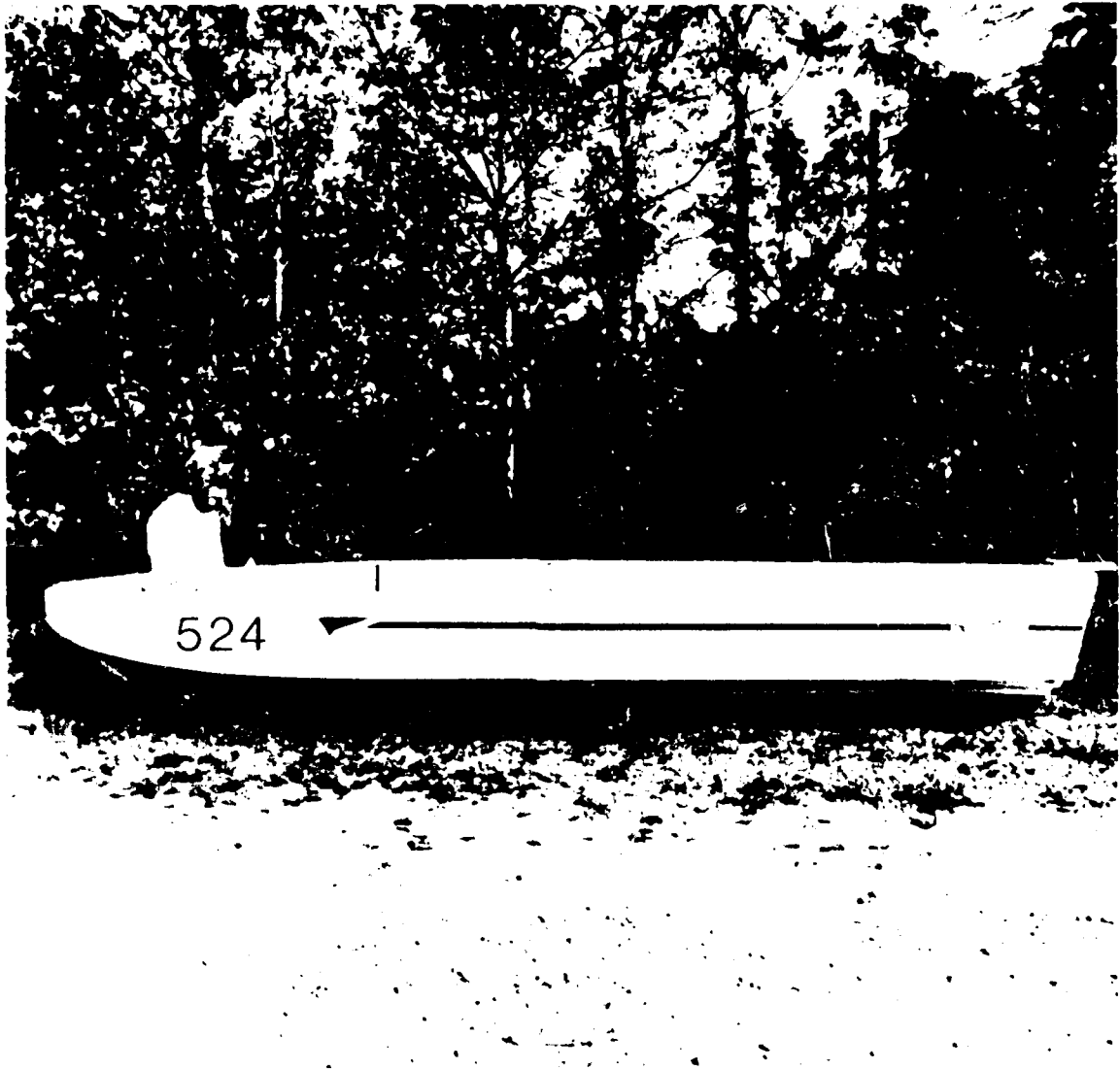
APPENDIX B

PHOTOGRAPHS OF BOATS WITH HALF PASSENGER LOAD
FOR LONGITUDINAL DISTRIBUTION ANALYSIS (SECTION 5.0)









B-4

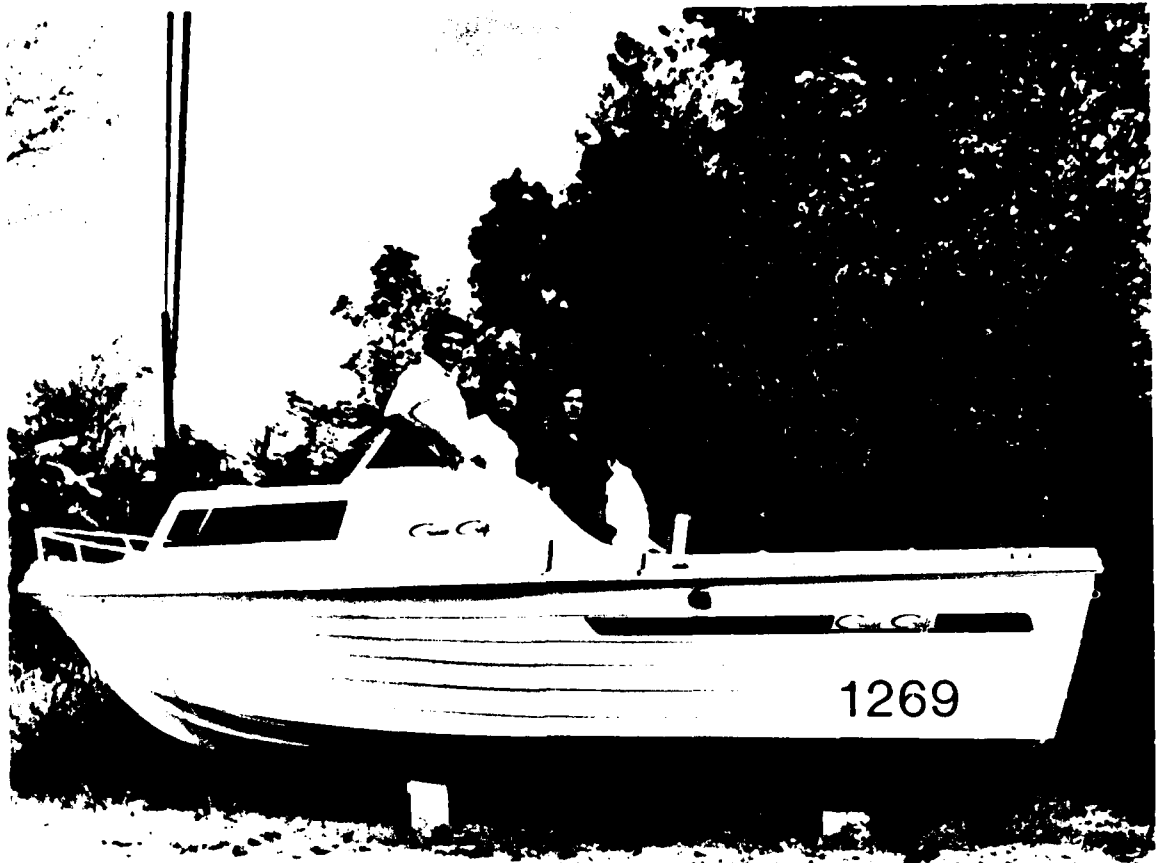




B-6

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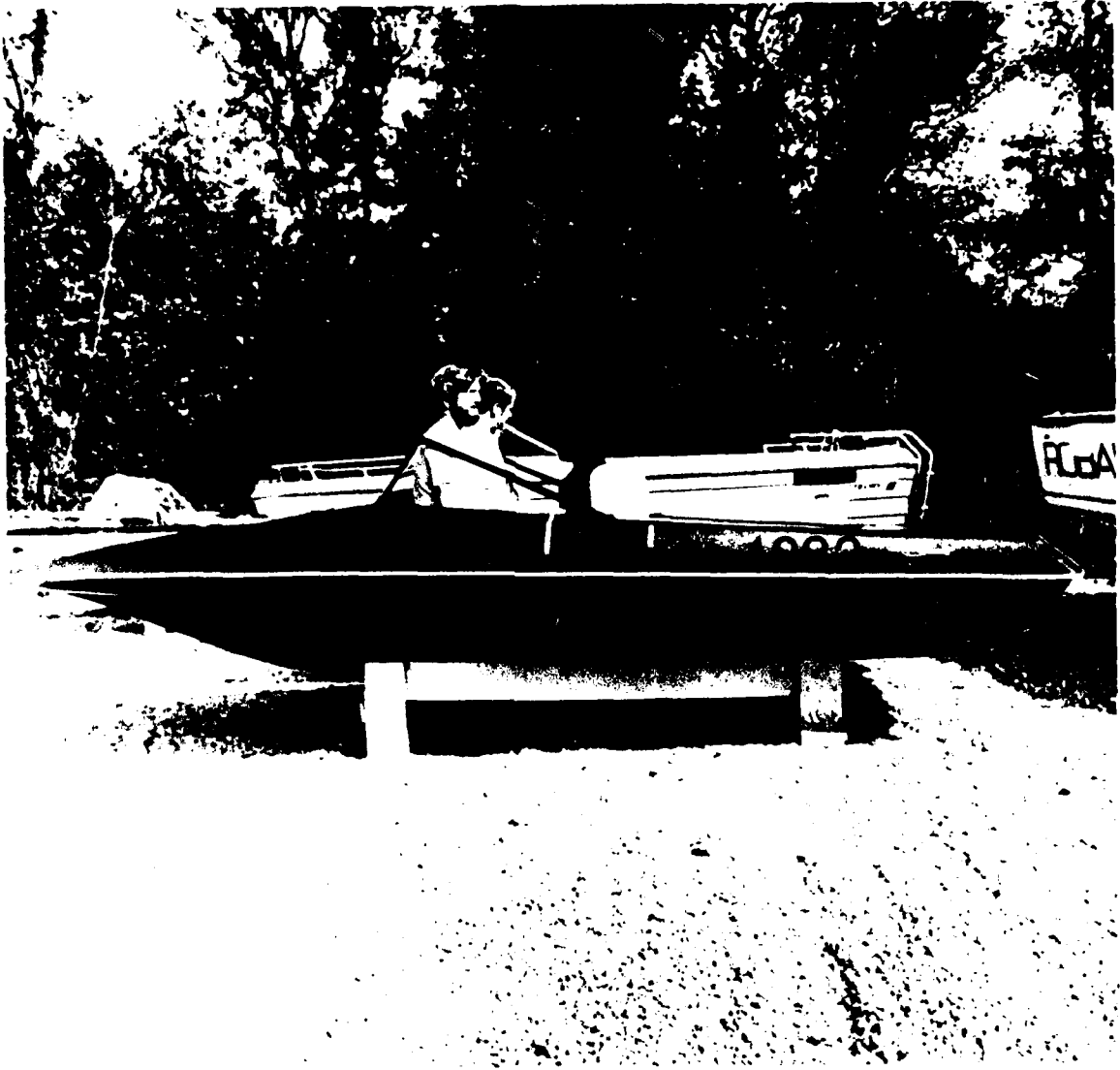
B-10



B-11



B-12







B-15



B-16

