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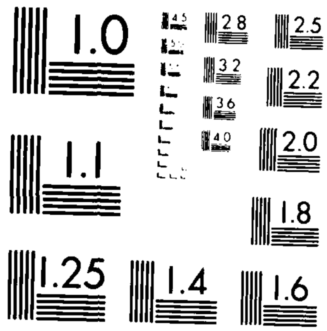

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Report No. CG-D-36-83

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A STUDY TO DETERMINE THE NEED FOR A STANDARD LIMITING THE HORSEPOWER OF RECREATIONAL BOATS

OCTOBER 1978

FINAL REPORT

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16. Abstract

This report delineates the efforts undertaken to determine if there is a need for a standard that limits the maximum mounted horsepower on recreational boats. A definition of a powering related accident is derived and presented in the form of a decision tree. The steps taken to collect a data base, and an explanation of the computer model designed to aid in organizing and analyzing the data are presented with the results of the analyses. An evaluation of the current standard's effectiveness in predicting powering related accidents is presented along with a list of possible alternative approaches to saving the lives of boaters involved in powering related accidents. Conclusions drawn from the data analysis are presented with recommended considerations for future studies. Results of the study indicate that there are a significant number of lives (over 100) lost each year because of powering related accidents. These results indicate that there is a need for a powering standard. Powering accident mechanisms were identified, and detailed accident scenarios were developed for fatal accidents within the data base. The data indicate that the current standard predicts the high risk and fatality probability for johnboats which have high ratios of mounted horsepower divided by formula rated horsepower, but is not a good predictor for other boat types currently being manufactured. The standard seems to be less effective for newer boats with larger horsepower engines. The data also indicate regional differences in fatality rates, accident types, and accident probabilities with the Southeast being the highest risk region. A list of alternatives that need further investigation in future effort is presented with cost/benefit predictions for some of the more viable approaches.

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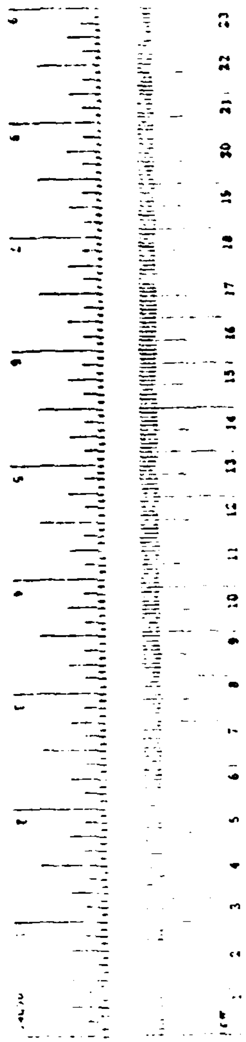
METRIC CONVERSION FACTORS

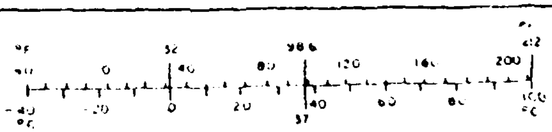
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



PREFACE

The evaluation of currently existing USCG promulgated standards at a point in time subsequent to their effective date is desirable to understand the changes created within the recreational boating environment and to determine if the intended effects are being generated. This project was initiated to determine if the safe powering standard meets its intended purpose, i.e., reducing the loss-of-life risks for recreational boaters.

ACKNOWLEDGEMENTS

It is traditional for authors of publications to acknowledge those people whose satellite efforts contributed to the finalization of the tabloid. The authors of this report take no exception; however, a special recognition is desired of those people whose articulation of the effort recorded herein significantly contributed to the productivity of this research. Those people whose efforts are so greatly appreciated are: Jack Bowman, Joe Matzkiw, Ron Giuntini, and Bobby Clements of Wyle Laboratories; and Geoff Fuller, Bud Hunt, Lars Granholm, CDR Charles Niederman, Lysle Gray, and CAPT Jack Coulter of the United States Coast Guard.

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1.0 INTRODUCTION/BACKGROUND AND SUMMARY

1.1 Background

Over the past several years, much has been accomplished in the Coast Guard's Boating Safety Program. Among other things, standards have been promulgated in the areas of safe loading, powering, and flotation. Each of these areas is now being re-evaluated/analyzed to determine whether the existing standards should be revised and/or continued. This effort concerns itself with the evaluation of the current powering standard formula that has been in effect since November 1972 and the identification of possible alternatives for reducing the number of fatalities associated with powering related accidents in recreational boats.

During the late 1960's and early 1970's, the Boating Industry Association and industry representatives made several attempts to establish a viable industry standard for "safe powering" of outboard boats. The results of this effort was an industry standard known as Project H-26 of the American Boat and Yacht Council's (ABYC) "Safety Standards for Small Craft." Project H-26 (Powering of Boats) defines a "formula" and a "test course" method for establishing the maximum horsepower for recreational boats.

Over a period from 1972 to 1975 the Coast Guard expended considerable effort in adapting the industry standards to a federal standard. The first (now existing) standard promulgated by the Coast Guard was modeled after the ABYC Formula Method, and became effective in late 1972. Concurrently, research was being performed by Wyle Laboratories, for the Coast Guard, toward obtaining a "performance" standard to supplement or replace the Formula Standard (Reference 1). The report documents research and analysis of various test courses, boat/motor combinations, and several projects which were aimed at defining an appropriate test course for outboard boats.

As a result of this performance study, and of Coast Guard analysis of boating accident data, further work in this area was suspended pending the establishment of a need for a powering standard and/or the establishment of a more appropriate standard in terms of safety. The effort reported on herein was intended to determine this need and to provide the basis for such need using previous research, boating accident data, analysis of existing powering standard effectiveness; and determine whether a new regulation would be more effective in reducing powering related accidents.

of the previous work has been directed toward a solution (test course) which predicated upon the assumption that a "safely" powered boat must be capable of cuting specific maneuvers without exhibiting undesirable instability character- ics under full throttle. Many discussions have resulted over this definition. l-throttle stability is certainly needed in some situations to avoid loss-of- trol accidents. However, this is not the only type of powering related accident , therefore, not the only characteristic that should be considered. Other racterisitcs are even more desirable when we address the question of "What is afe boat?"

definition of a safe boat (underway) could be the following:

> "A boat is safe under full throttle if, in the process of transacting a specific maneuver or operational mode, the operator has adequate warning of an unsafe condition or imminently threatening hazard, such that corrective action can be taken in time to avoid its further development."

ted differently, "a safe boat 'fails' gracefully (becomes unsafe in a slow gression)" as far as stability/maneuvering goes.

addition to developing a more viable definition than this, the principal purpose this phase of the safe powering program is to furnish technical information and ident data analysis to aid Coast Guard management in making the decisions con- ned in Figure 1-1.

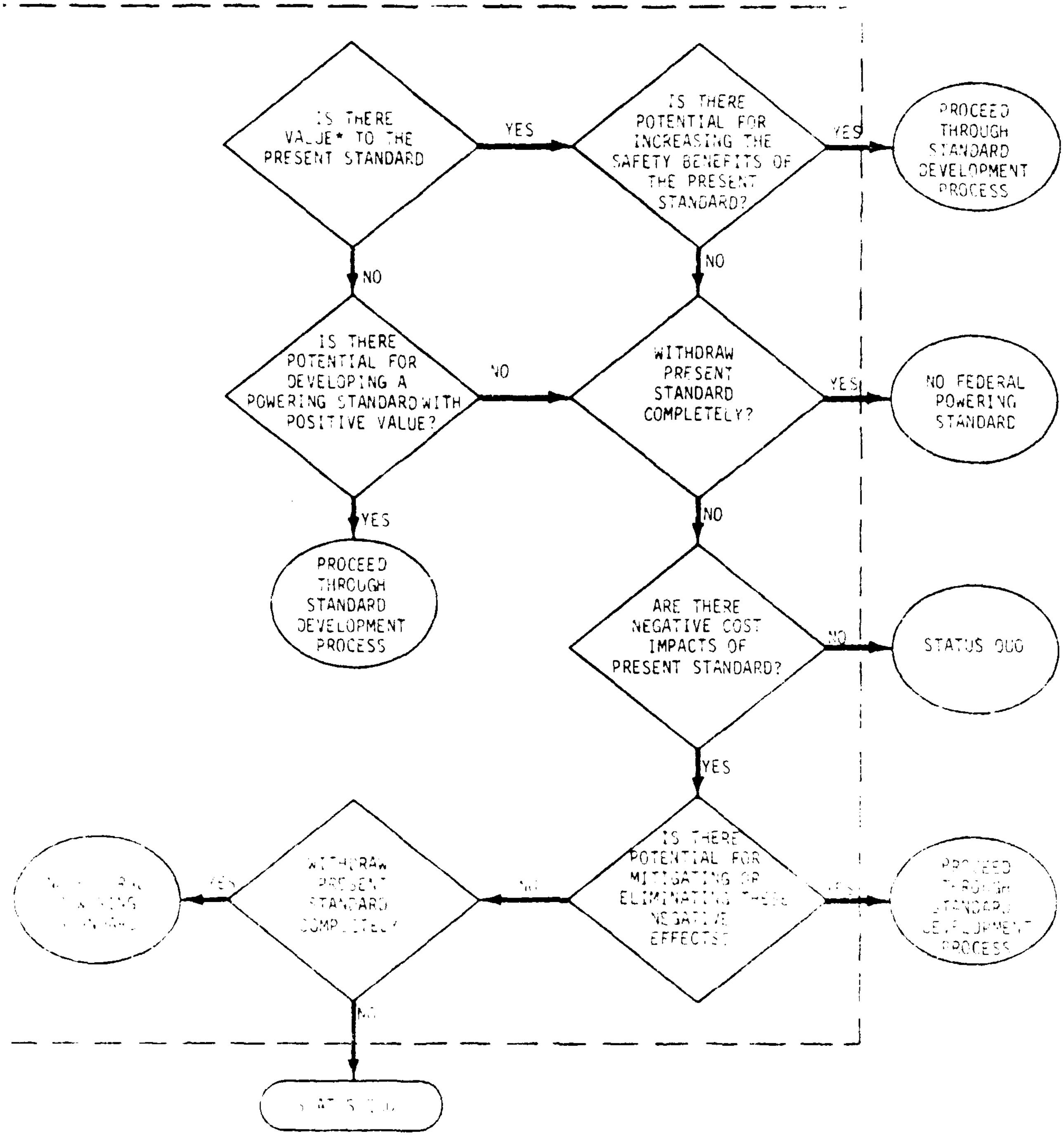
a means to the above ends, we have proceeded to:

A. Define a "powering related" boating accident.

B. Determine the frequency of occurrence of powering related accidents and predominant "accident mechanisms" (or common event-cause combinations).

C. Evaluate the effectiveness of the present formula in predicting boater risk.

D. Identify possible alternative methods for reducing the number of fatalities resulting from power related accidents.



*VALUE IS TAKEN TO MEAN THE EXCESS OF BENEFITS OVER COSTS.

----RANGE OF MANAGEMENT DECISION-MAKING THIS PROJECT DESIGNED TO SUPPORT.

FIGURE 1-1. THE POWERING STANDARD DECISION PROCESS

1.2 Considerations

[illegible] research (Reference 2) performed by Wyle Laboratories, Coast Guard in-house [illegible]earch and other contractors, it is apparent that the "boat/environment/operator [illegible]tem" presents a very complicated set of interactions.

[illegible] type of boat hull has unique underway characteristics. As speed is increased [illegible]ciently, any boat will eventually reach its threshold of instability, whether [illegible] turn or straight ahead mode. The present idea, then, is to limit power such [illegible] the stability threshold cannot be reached. Herein lies the problem. There [illegible] no convenient method whereby the threshold stability speed can be predicted and [illegible]sequently no convenient way of establishing the safe horsepower applicable to a [illegible]en boat. Obviously, it can be done for a particular boat if enough money is [illegible]ended. This effort would be very costly and, for the average boat builder, it [illegible] be far beyond his capability.

[illegible] hull types are common: flatbottom, shallow to deep V, rounded chine, [illegible]hedral, etc. Each of these hull types has a seemingly endless variety of [illegible] shapes and, consequently, a variety of performance characteristics. [illegible], some of these shapes perform better than others at high speeds or in [illegible]. Flatbottom john boats have severe maneuvering problems at speeds around [illegible] knots; generally, the V hull family can take speeds in the 40 knot range [illegible] handle fairly well and make reasonably well-banked (coordinated) turns; [illegible] family over 17 feet in length usually has enough drag that speeds much [illegible]ts are difficult to obtain regardless of the horsepower. Turns at high [illegible] in W hull boats are very "flat" and, as a result, can produce high lateral [illegible] vectors on occupants. It is apparent that the stability/handling character- [illegible] typical recreational boats are a function of speed and boat type.

[illegible] development of a revised formula or a performance powering standard will be [illegible]cated and costly. Therefore, the Coast Guard must be assured that such [illegible]ment is warranted.

[illegible] herein, the present standard is providing little reduction [illegible] accidents. However, the existing standard is very inexpensive [illegible], government, and consumer (directly). Simply stated, the total [illegible] the costs associated with calculating the horsepower capacity [illegible] and labeling the boat with that capacity - easily less than

1.3.3 Task IV - Preliminary Identification of Alternative Approaches

... was directed towards the identification, feasibility analysis, and pre- ... effectiveness analysis of alternate solution concepts.

... a change in the environment, the operator, or the boat could ... the accident chain and thus prevented the accident. Those possible ... that would alter or break the event sequence in the accident chain and that would enhance survivability in the event of an accident were identified analyzing the powering data. Those changes were used to construct alterna- ... safety enhancement concepts and they fall into two general categor- ... standards approaches, and 2) education/enforcement alternatives.

... criteria, the standards approaches address:

- Revising the current standard
- Developing a new standard
- Substituting other standards in lieu of a powering standard

... enforcement approach addresses alterations in boater actions and ... measures are intended to make the boater aware of the powering ... boat system (in terms of engine size and utilization).

... be careful not to construe possible fatality reductions as ... justifications. For example, powering accident data for pre-1972 ... strong potential benefit for implementation of the current ... however, the powering accident data for post-1972 craft shows litte ... effectiveness for that standard.

1.3.4 Conclusions and Recommendations

... the performance of this project ... The most significant general con-

4. Determine fatality distribution by "maneuvering" (boat activity) and "falls overboard" (accident type).

5. Determine the mean horsepower for each geographical region for boats in PRAM.

The conductance of these analyses gave rise to the following important points:

- There are regional differences in the powering related fatality distributions with the Southeast region having the highest number of fatalities and the Pacific Coast region having the least.

- Johnboats are a major contributory boat type to powering related fatality statistics with a large percentage of these involving falls overboard.

- Overall, (including the johnboats) the Southeast region accounted for a higher power ratio than any other region; but also had the lowest average mounted horsepower engines. This again indicates that the small, lightweight, hard chine boats with small engines present the greater high risks.

- The Southeast region accounts for more fatalities resulting from accidents involving course changes or maneuvers than any other region.

- Bass boats indicate the same tendencies as johnboats; however, the number of bass boats in the data base is so small that [illegible] conclusions cannot be drawn with a high level of confidence.

- The current powering standard was evaluated in terms of several risk parameters. This showed no increase in risk and non-compliance for post-regulation boats, but considerable increase in risk for pre-regulation boats.

[illegible] explanations are possible for the observed differences in pre- and post-[illegible] data, particularly in terms of boat design and engine changes that are [illegible] in the powering formula.

[illegible] current powering standard has some validity, as evidenced by its effectiveness [illegible] pre-1972 boats and for johnboats. However, since the promulgation of the [illegible], it has shown no overall effectiveness, indicating the need for investigat-[illegible] powering regulatory concepts and/or improving the current standard. [illegible] that the current standard can be modified in order to be more [illegible] general, and for certain boat types. A modest attempt was made in [illegible] the formula, and evaluate its effectiveness for different power-[illegible]. However, the data indicate that the current standard is not effective [illegible] all boat types, especially recently made boats.

[illegible] investigation of the regulatory effectiveness including efforts [illegible] of the safe powering project can be found in References 3 and 4.

[illegible] of the effort to determine the effectiveness of the current [illegible] questions existed. These questions involved explanations as [illegible] results gave the indications presented. After discussions [illegible] Guard personnel, it was agreed to pursue the answers to [illegible] this phase of the project.

[illegible] directed to:

- [illegible] determine any differences in fatality distribution in the [illegible] areas the Task II report identifies.

- [illegible] distribution by boat type and type of accident. [illegible] severity of accident and risk for johnboats. Discuss fatality [illegible] related to apparent gunwale height.

- Investigate the differences in power ratio distributions between four [illegible] areas identified in the Task II report.

We have found few statistically significant and engineeringly important measures which indicate that the formula is effective in determining a safe powering level. The most significant indicator found was that, prior to being promoted as a regulation, the formula predicted very accurately the unsafe powering level of boats. This could be true as there are ways of complying with the standard, but still defeating it by altering the configuration of the boat hull. This would indicate that the present formula is good, but must be refined to eliminate the loop holes or inadequacies.

However, for the few statistically significant and engineeringly important measures with positive indications, there were many engineeringly important measures that gave no statistical merit to the present formula. An example is shown by the fact that there is no significant change in the number of fatalities for boats in compliance with boats not in compliance with the existing formula horsepower capacity. This indicates that the current standard does not indicate an unsafe power level, and that a different standard should be promulgated.

Perhaps the most important finding of Task III is contained in the evidence that there does appear to be avenues to pursue that, if developed properly, will greatly increase the safety and well being of the average boater. One must keep in mind, however, that for any standard or regulation, there is a group of people who, for various reasons, choose to ignore the rule and not comply with its stipulations. The Safe Powering Standard is no exception.

The major findings of the evaluation of the effectiveness of the current powering standard are:

- In terms of accident frequency and severity, the current powering standard is <u>not</u> effective for outboard boats less than 20 ft in length manufactured after 1973.

- The current powering standard appears to have <u>considerable effectiveness</u> for outboard boats less than 20 ft in length made prior to 1972, and for johnboats in general.

- The current powering standard apparently is <u>not</u> effective for outboards less than 20 ft in length that are not johnboats, when all years of manufacture are considered (i.e., when pre- and post-powering regulation boats are not distinguished).

- Each of three powering ratios considered [i.e., 1)mounted horsepower/rated horsepower, 2) mounted horsepower/length of the boat, and 3) mounted horsepower/total weight of the system.] were shown to have a significant relationship to accident severity, and to accident type, when both pre- and post-regulation boats were included.

- It was found that compliance with the current standard was no more frequent for experienced boaters than for the non-experienced. However, boating safety education was shown to lead to greater compliance.

- It was found that the boats in compliance with the current standard were significantly less likely to be involved in a fatal powering accident than those that were not in compliance, when both pre- and post-regulation boats were included.

- Accident mechanisms were identified and detailed accident scenarios were developed for fatal accidents at five accept nodes.

1.3.2 Task III - Evaluation of the Current Standard Effectiveness

Task III utilized the Task II data base to determine if the current standard [illegible] altered the accident probability or severity of the accidents experi[illegible] than twenty (20) feet in length and powered by an outboard [illegible] of several indicators that measure the effect of the [illegible] of the boater. Numerous tests have been applied to the [illegible] the present standard increases the safety of the boater in [illegible]

[illegible] this question is uniquely different in this project as [illegible] in any recreational boating safety research and develop[illegible] of the boater and the effectiveness of a standard is [illegible] and exposure within the entire boating population. By [illegible] confidence level in the results of the analyses on [illegible] a true picture of the accident propensity is promoted. [illegible] analyzed the data for indications of effectiveness, some of [illegible] fatalities, number of accidents, accident rates, and accident [illegible] these accomplishments and presents some of the conclusions that can be drawn from the data as thus far analyzed.

Having arrived at a definition of a powering related accident and presenting this definition in the form of a decision tree, we have used this tree to identify all of the powering related accidents for the year 1975 (fatal and non-fatal) and all of the fatal powering related accidents for 1976. Over 7500 accidents were reviewed with 450 of these being selected as powering related. It was these accidents that became the sample to be coded in the Powering Related Accident Model (PRAM).

PRAM is a matrix type model that was developed solely for this project from considerable modeling expertise from Wyle personnel, consultations with several persons within the USCG, from previously developed models, and a repetitive review of several previously constructed models. Effectively, PRAM summarizes and organizes the accident data supplied by the selected sample.

PRAM identifies accident mechanisms and provides the information for development of powering related accident scenarios. It is the PRAM data that was used as input to the engineering analyses, the benefit estimations, and the evaluations of effectiveness of powering related concepts (including the present safe powering standard).

To validate the data that would be stored in PRAM, each of the 450 accidents was independently coded by two analysts. The two resulting sets of data were compared by computer checks and a third analyst to alleviate any disagreements between the two data sets. Additionally, random samples from each of the two sets were examined in depth to insure the correctness of all inputed data.

Having analyzed the data in PRAM, several interesting findings have blossomed. Some of these findings are:

- There is a need for a powering standard. This is indicated by the 204 deaths attributable to powering related accidents in 1975 and 1976, along with the associated injuries and property damage.

- Several comparisons of pre- and post-regulation boats in the sample were made. The data indicated that the ratio of mounted to rated horsepower was the same for pre- and post-regulation craft.

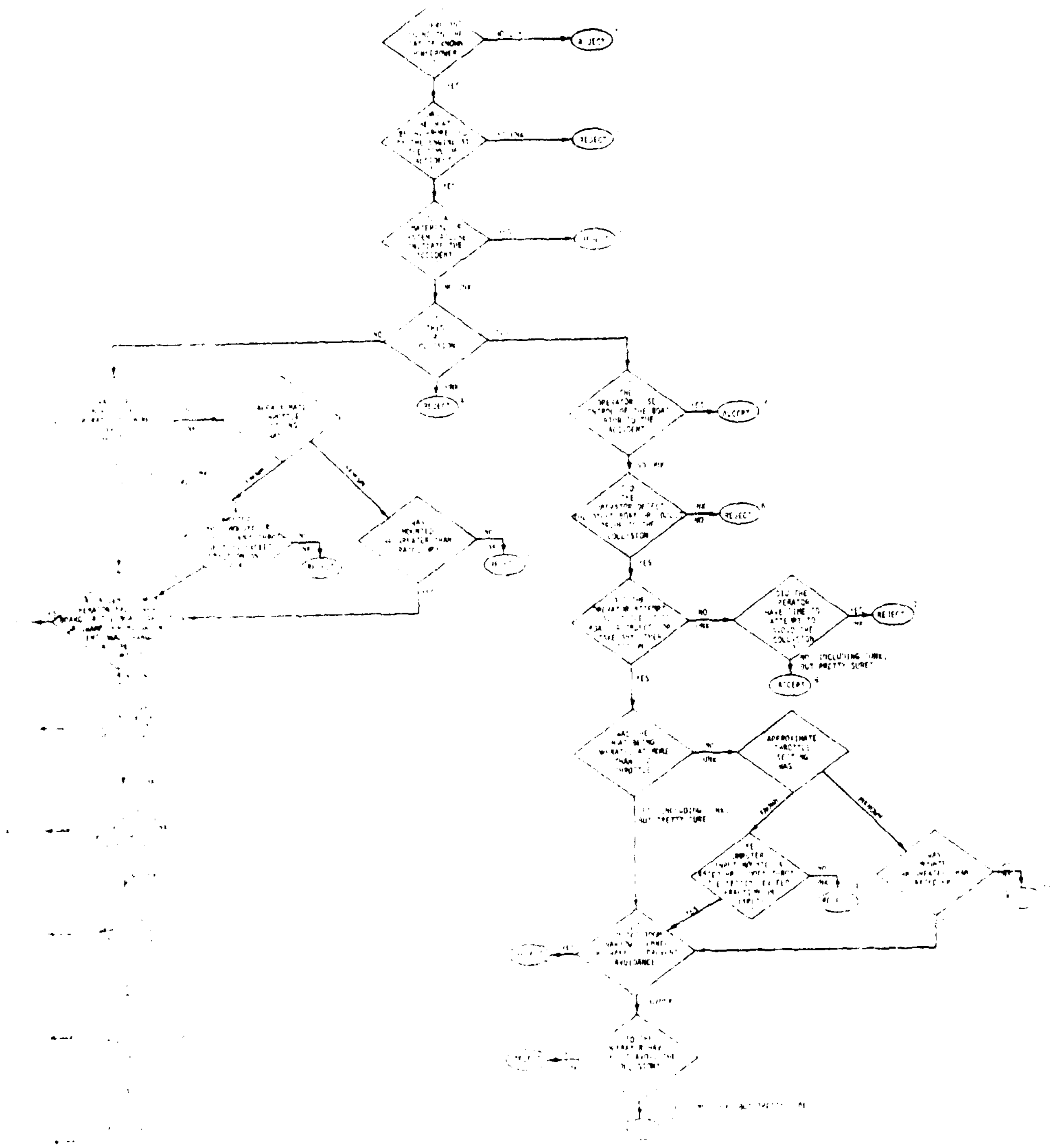


FIGURE [illegible] POWERING RELATED ACCIDENT DECISION TREE

It can be seen that all accidents are potentially "horsepower related" if stressors and subsystem environmental effects are to be included in the definition. The intent of the Coast Guard's requirements for defining "power related" accidents appeared to be to arrive at some consistent means of reducing the scope of the accidents to be reviewed under this effort to manageable proportions.

Vast emphasis was placed on the task of defining a powering related accident to make sure that every possible consideration and circumstance was investigated to determine the influence of propulsive power on the event sequence and the regulatory dependency on the man-machine system.

Having defined a power related accident, i.e., having selected a group of accidents to analyze, a statistical matrix model was developed. This development revealed refinements for the definition and started an iterative process which resulted in a highly complex definition and comprehensive model (see Figure 1-5). The complexity of the powering problem is evidenced by the in-depth thought process the analyst must employ to decide if an accident is power related. Once the analyst decides, his thought process is captured in the model and utilized in the evaluation phase of the project.

Although it may appear that the definition and the accident model were independently generated, the two were simultaneously derived through iterative refinements dictated by each other and the insight gained with each update. Section 2.0 discusses the development of the definition and the development of the model. The interdependency and simultaneity of the two should be kept in mind.

The analyses done here answer the question, "Is there a need to investigate the powering standard that is presently in effect?" The answer is asserted in the fact that there were 450 powering related accidents involving 469 boats and resulting in 204 deaths during 1975 and 1976 alone. This is a very significant statistic when one realizes that 1 out of every 14 deaths accounted to recreational boating was directly involved in accidents that the present safe powering regulation is supposed to alleviate. This point in itself provides sufficient reason for in-depth evaluation of the powering problem.

Several major accomplishments have resulted from the efforts on this project and are presented in detail in the subsequent sections. This report summarizes

D. Speed - Horsepower is directly related to the potential for speed. Speed, in turn, affects:

- The reaction time available to the vessel operator to avoid an object.
- The kinetic energy which must be dissipated during a collision or attempt at stopping the vessel.
- The inertial forces acting on the boat occupants during sudden maneuvering.
- The body forces acting on the boat and occupants during steady-state turns.
- Vessel maneuvering capability.

E. Thrust - The thrust vector is very important to the position of the boat in space at any given point in time. Vessel thrust is obviously important for maneuvering capability, trim, heave, heel, and yaw during any maneuver or straight-ahead operation. The sudden application of excessive thrust during a low-speed turn can lead to shipping water over the side to which the boat is turning.

Figure I-4 summarizes the discussion above, showing that horsepower can act on the stressors, subsystem environment, and acceleration/thrust, which, in turn, act upon the occupants and the boat elements, such that powering related accidents can precipitate.

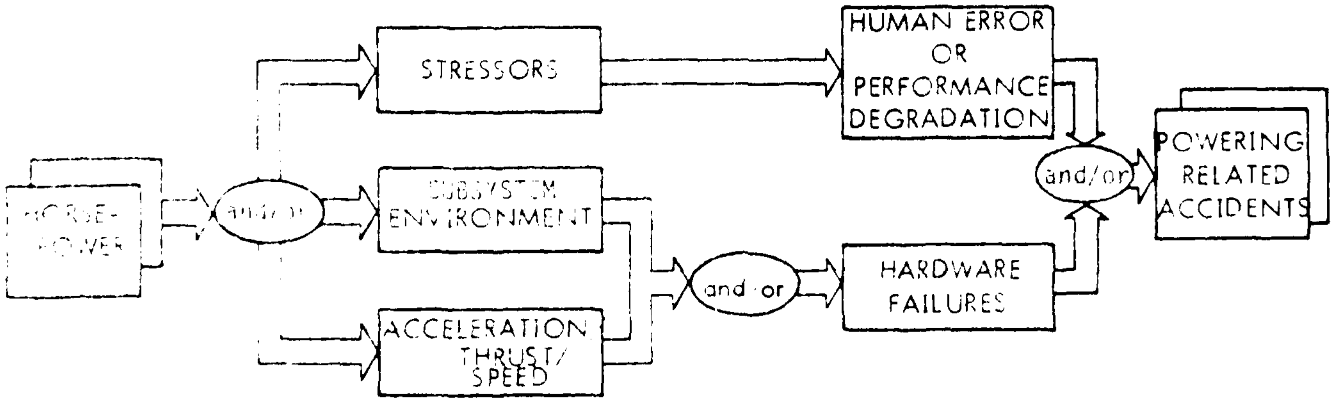


FIGURE I-4. HORSEPOWER AS A FACTOR IN POWERING RELATED ACCIDENTS

$$S_B = f(B_{ss}, O_{ss}, E_{ss})$$

Further, each subsystem could be expressed as some function of its basic subelements so that:

$$B_{ss} = g(B_{ss_1}, B_{ss_2}, B_{ss_3}, \ldots B_{ss_n})$$

$$O_{ss} = h(O_{ss_1}, O_{ss_2}, O_{ss_3}, \ldots O_{ss_m})$$

$$E_{ss} = k(E_{ss_1}, E_{ss_2}, E_{ss_3}, \ldots E_{ss_p})$$

The point of this is that there are some boundary conditions within which this system exhibits "safety". Sometimes a small deviation in one of the subelements can act as a catalyst in actuating other accident causal factors.

Some potential accident causes that could be acted upon or aggravated by horsepower are as follows:

A. Stressors - Horsepower is directly involved in the generation (both from an amplitude and frequency content) of severe noise, shock, vibration, and windburn effects on the functional capabilities of boat occupants. This, in turn, affects their ability to avoid and recover from accidents which may occur on the water.

B. Subsystem Environment - Noise, shock, and vibration (noise being a subset of vibration in this case) also act on the boat elements and cause failure of mechanical/hardware components and parts, leading to the occurrence of certain accident types.

C. Acceleration - Horsepower is directly related to the boat's ability to accelerate, which, in turn, can cause occupants to be thrown overboard. However, acceleration can have the positive effects of allowing the boat to move quickly away from an impending collision and spend minimum time in transition (usually with poor visibility between the displacement and the planning modes of operation).

Also, sudden acceleration or deceleration may lead to a fall overboard or swamping. This partial list illustreates the many ways in which powering can contribute to boating accidents.

The second problem in defining powering related accidents is concerned with the recognition that the effect of powering is dependent upon many other elements.

The basic definition problem can be illustrated in Figure 1-3.

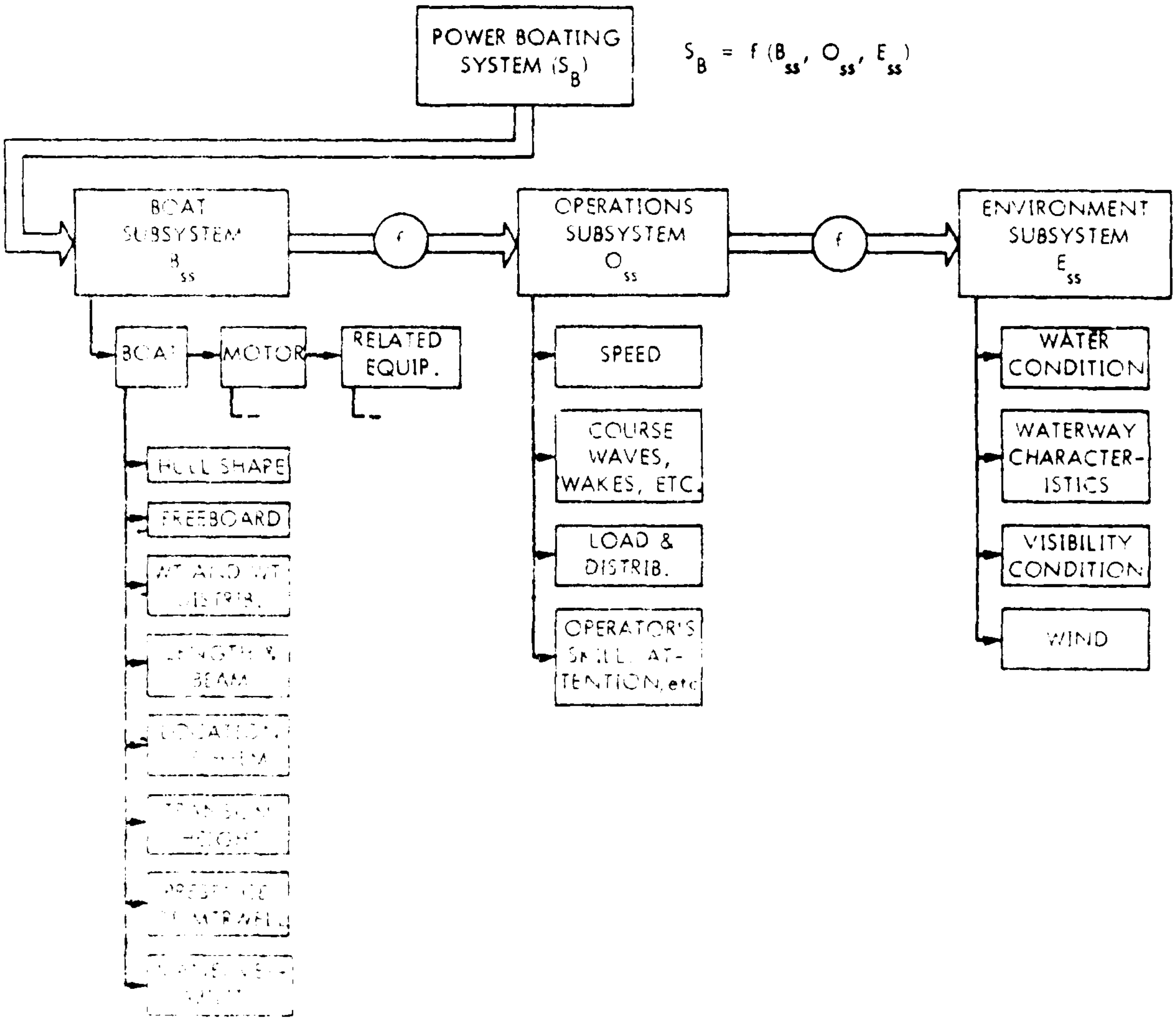


FIGURE 1-3. POWER BOATING SYSTEM

The figure indicates that the power boating system is composed of three basic subsystems — the boat subsystem, operation subsystem, and the environmental subsystem, and that, theoretically at least, it could be expressed as:

1.3.1 Task II - Define, Model, and Analyze Power Related Accidents

The purpose of Task II is to define a powering related accident and establish the data base to use in the remainder of the project and in any subsequent analysis. It is, by far, the most important task of the safe powering project. Operationally, defining a powering related accident is equivalent to defining the sample to be coded and analyzed. An incorrect or incomplete definition of power related accidents biases the evaluation of the current standard and its effectiveness in saving people's lives and preserving the integrity of personal property. If the definition is conservative, many accidents will be filtered out, thus giving a false representation of a highly effective standard because of the minimal number of fatalities and property losses registered. Conversely, if the definition is too liberal, it registers fatalities and property losses that could better be prevented by other safety standards such as safe loading, flotation, etc. The definition must, therefore, be as precisely correct in encompassing powering related accidents as is possible to ensure that the results of the effectiveness analysis are realistic and self-meritorious.

The definition of a powering related accident is a complicated and illusive problem. In one sense, we could almost say that any accident which occurs while the boat is underway with power is powering related. Obviously, we cannot accept such a general definition. At the opposite end of the spectrum, powering related accidents could be defined as only those directly attributable to boats operating at full speed. Common sense tells us that for our results to be meaningful results, the definitions must lie somewhere between these extremes.

Powering may contribute to virtually every type of event-defined accident. For example, excessive speed during a sudden maneuver may result in a capsizing, fall overboard, or swamping. High speed while underway straight ahead may cause excessive pounding and shock which leads to a fall overboard, injury, or collision in which the boat is proceeding too fast for the conditions. Too little as well as too much power may contribute to accidents - for example, in handling large wakes or following seas where optimum advance speed is critical, and the ability to speed up is important. Furthermore, the link between powering and accidents is not invariably speed. The weight of an excessively large outboard engine may increase the chances of swamping for small boats because of the reduction in freeboard.

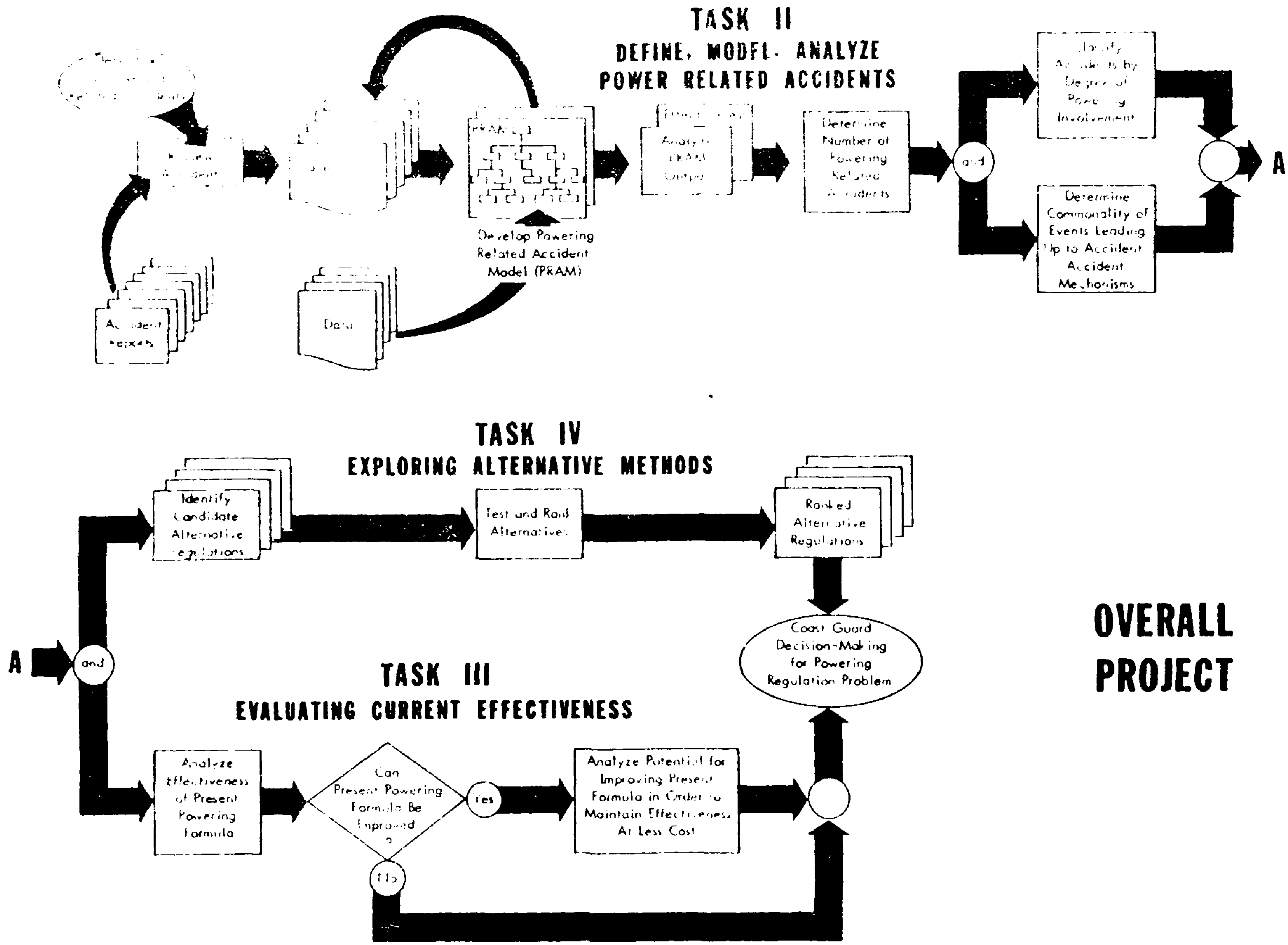


FIGURE 1-2. OVERALL PROJECT

$2.00 per boat, including Coast Guard compliance testing. Assuming 400 [illegible] outboards per year are constructed, then the total cost per year is less than $1 million. Using a cost of $480,000 per life saved, only two or three lives per year need to be saved in order for the existing standard to be cost effective.

Since the standard was promulgated in November 1972, boating industry market surveys indicate that roughly 2-1/2 million boats have been built which are subject to the standard. Compliance testing performed by Wyle under DOT-CG-31538-A, "Perform Compliance and Defect Testing of Recreational Boats and Associated Equipment," indicates that about 85% of the boats sampled were labeled in compliance. This information contained in the data sample selected for this study indicates that approximately 81% of all boats in the field are in compliance. This, however, includes boats that were built before the effective date of the present standard.

We are aware of the fact that the Boating Industry Association (BIA) Formula standard was in effect prior to the federal standard. If we use BIA estimates of the number or percentage of boats constructed by BIA members and to BIA standards, we can estimate that maybe a third of the boats built prior to 1972 also had a (voluntary) standard in effect (the boats were labeled). From Wyle's experience, prior to 1972 the number of dealers who actually limited outboard horsepower to that shown on the BIA labels was small in comparison to the number to do so because of the federal standard. So, in actuality, the situation is quite complicated, and it is difficult to estimate the exact effect of the existing standard (see Reference 3).

1.3 Project Overview

A graphic presentation of this project is shown in Figure 1-2. The dependence of the current standard evaluation and determination of proper alternative concepts on the adequacy of the definition and modeling is clearly seen in the figure. It is extremely important that these tasks are correctly and comprehensively undertaken since any future task, whether under this project or some follow-on project, will utilize them as a starting foundation.

- Power related accidents account for over 100 fatalities per year and approximately six percent of all reported accidents
- The current standard formula is not a good predictor of risk for all boats (i.e., without distinguishing pre- and post-regulation craft) in the powering related accident sample
- The current standard formula appears to be a good predictor of risk for pre-1972 boats and johnboats (all years)
- Regional differences in power accident risks exist
- The potential for significant benefits resulting from amendments to the current standard and/or other approaches exist, pending more detailed analysis

Based upon these conclusions and other findings reported herein, the following major recommendations are offered:

- A theoretical and empirical sensitivity analysis of the current standard formula should be performed
- Field investigations should be conducted in order to verify the assumptions of the analysis in this report, particularly those made with respect to exposure data
- Nationwide Boating Survey (NBS) and Boating Accident Report (BAR) data collection forms should be modified to provide needed powering related data currently not available
- A detailed formulation of the alternative powering safety enhancement concepts, and their associated costs and benefits, should be undertaken

1.4 Report Content

Subsequent sections of this report present the technical approach and analyses supporting these conclusions.

Section 2.0 presents a detailed discussion of the derivation of the definition of a powering related accident and a detailed chronology of the selection of the accident data analyzed under this project. Additionally, this section presents the development and validation procedures for the computerized Powering Related Accident Model (PRAM) and the analytical results of the analyses on the powering related accident sample. This section concludes with a presentation of the accident mechanisms initiating powering related accidents and scenarios typifying accidents resulting from each mechanism.

Section 3.0 presents a statement of the current standard for the reader's ready reference. Also, this section presents the selection criteria and exhibits for the non-powering related sample. Subsequent to this discussion is a detailed presentation of the efforts to determine the effectiveness of the current standard formula in predicting the risk of having a powering related accident with increasing mounted horsepower in view of several relevant variables. Interpretations of the results are provided to assist the reader where appropriate.

Section 4.0 presents in detail the analyses performed to clarify and assist in explaining the results found in Task III.

Section 5.0 presents a detailed discussion of the preliminary alternatives to preventing the type of fatalities accounted for in the powering related accidents in our sample.

Section 6.0 presents the conclusions and recommendations derived from the data analysis during this project.

Appendix A presents the iterative development of the Powering Related Accident Model (PRAM), and Appendix B presents the instructions utilized to include data from non-powering related accident reports in the PRAM.

2.0 DEFINITION AND ANALYSIS OF POWERING RELATED ACCIDENTS

2.1 Definition and Identification of Powering Related Accidents

2.1.1 Criteria for Defining a Powering Related Accident

In order to establish a starting point for defining and identifying a powering related accident, it was decided to select a small group of accidents from the USCG accident file and review them for available pertinent data (described below) for the powering project and to determine the categories into which the accidents could be grouped. Three hundred and thirty-five (335) cases were selected at random from the 1975 and 1976 accident files maintained by the U. S. Coast Guard, Washington, D. C. Of these, one hundred and eighty-three (183) were immediately rejected as being non-powering related for one of the following reasons:

1. The boat(s) involved were not powered by an engine.
2. The boat(s) were not underway.
3. The accident was a fire or explosion accident.
4. There were no survivors, no witnesses, and no definite indications that the boat was in motion at the time of the accident. (This group did not include: a boat found with the motor in gear and gas tank empty; or a boat found beached with apparent grounding damage and motor in gear, as these would be definite indications that the boat was in motion).

The one hundred and fifty-two (152) accidents remaining were broken down into the following categories:

ACCIDENT DESCRIPTION	YEAR OF ACCIDENT 1975	1976	TOTAL NUMBER
1. Involving swimmer or skier	2	3	5
2. Hit boat or pier	26	46	72
3. Grounding	1	5	6
4. Hit submerged object	15	18	33
5. All other	16	20	36
TOTAL	60	92	152

This total was still too large a sample to be manipulated efficiently by hand. Therefore, since we were attempting to identify accident types, and not predict frequencies, we decided to sample the above categories again to reduce the file down to a manageable number. Although sampling a sample is not normally a sound statistical procedure, we felt that the probable degradation would not be experienced in the accident-type analysis due to the fact that we would not filter and lose any accident type but would only be limiting the number of accidents in the large categories. *The sampling plan for this step was as follows:*

ACCIDENT DESCRIPTION	SAMPLE RATE	TOTAL REMAINING
1. Involving swimmer or skier	1 for 1	5
2. Hit boat or pier	1 for 3	24
3. Grounding	1 for 1	6
4. Hit submerged object	1 for 3	12
5. All other	1 for 1	35
TOTAL		82

After reading and reviewing the eighty-two (82) remaining accidents, they were again sorted into the following categories:

1. Hit Submerged Object
2. Hit Other Boat or Object - Did Not See Prior to Accident or Attempt to Avoid
3. Hit Other Boat or Object - Attempted to Avoid
4. Accident Peculiar to Water Skiing
5. Falls Overboard
6. Swamping/Capsizing - Hit Large Waves
7. Swamping/Capsizing During Maneuver
8. Swamping/Capsizing During Acceleration
9. Lost Control Prior to Swamping or Capsizing.

After discussing each accident category and the degree of powering involvement in the cause or possible future solution, the following list of accident categories versus degree of powering involvement was derived:

<u>Significantly Powering Related</u>

1. Those accidents where the operator lost directional control of the vessel while it was underway and under power.
2. Those accidents where the boat did not respond to the helm as the operator intended while it was under power.

3. Those accidents where persons fell overboard or the boat capsized or swamped during a maneuver.
4. Those accidents where the boat capsized or swamped and indications exist that its seaworthiness had been degraded by the speed at which it was operating.
5. Those accidents where a sudden application of thrust initiated the accident.
6. Those accidents where the vessel's kinetic energy contributed significantly to the severity of the accident and no other viable regulatory approach appears to exist.

Tangentially Powering Related

1. Those accidents where kinetic energy was a factor but other viable regulatory approaches exist.
2. Those accidents involving a material or subsystem failure.
3. Those accidents where the operator was unable to detect an object, and a collision occurred, due to visibility problems involving the vessel's trim or heel angle.
4. Those accidents where the operator was impaired by powering-related stressors.

Not Powering Related

All other

Based on the foregoing, the following machine sort for the powering related accidents was derived:

RUN #1

Eliminate if:

Horsepower = zero
or Horsepower = unknown
or Operation at time = racing
or drifting
or drifting, fishing
or drifting, hunting
or drifting, diving or swimming
or drifting, fueling

```
                        or   at anchor
                        or   at anchor, fishing
                        or   at anchor, hunting
                        or   at anchor, diving or swimming
                        or   at anchor, fueling
                        or   tied to dock
                        or   tied to dock, fueling
                        or   unknown

      or  Type of accident = grounding
                        or  fire/explosion (fuel)
                        or  fire/explosion (other)

      or  Cause of accident = load related - hoisting or lowering anchor
                        or   miscellaneous - equipment failure (steering, throttle,
                                                                  etc.)
                        or   miscellaneous - starting in gear
                        or   unknown

      or  Accident descriptors = boat found/body found, no witnesses
                        or  improperly moored
                        or  carbon monoxide poisoning

      or  Cause = failure to detect hazard - submerged object (logs, rocks,
                                                     swimmer, diver, etc.)

      and Property damage = less than $1000

      and Number of drownings = zero

      and Number of other victims = zero

      and Number of injuries = zero

  RUN #2

      List if:

          Horsepower = unknown

      or  Operation at time = unknown

      or  Cause of accident = unknown

  RUN #3

      List entire file by order of state and within state by month and day.
```

The above was checked against the 82 accidents in our file which we accepted as powering related and the coding as per the 1975 Boating Accident Report (BAR) Printout. All of the cases we accepted "passed" the above sorting procedure. Manually checking the above criteria against eight random pages (25 cases per page) in the 1975 printout indicated a rejection rate of fifty-four (54%) percent could be expected from the above coding sort. That rejection rate is lower than should be possible for the following reasons:

1. Accident descriptors are only coded 5% to 10% of the time. Rarely is more than one coded. It was our observation that two or more should be applicable to each accident. As this coding is unreliable, it could not be used for identifying acceptable cases.

2. Not all applicable cause codes are always coded and often the cause codes are not appropriately used relative to the series heading. As an example, improper lookout is often coded when the other boat was seen prior to the accident.

It should be noted, however, that of the thirty or so cases we checked, no "major" errors in coding were detected, which is a positive reflection on the coding staff.

After the machine sort criteria was derived, the decision tree shown in Figure 2-1 was derived for sorting the accidents into two groups, 1) powering related (accepts) and 2) not powering related or tangentially powering related (reject) files. The decision tree was tested by having someone unfamiliar with the tree and boating accidents code a number of accidents (15) and check them against our interpretation. 100% agreement was achieved. All 82 cases we accepted were checked against the decision tree, and only one disagreement with our earlier subjective evaluation was noted. The case was unique and the tree accepted it, whereas we rejected it.

Thus, from the above, it can be seen that identifying and defining powering related accidents is an interdependent process. By defining a powering related accident one identifies powering involvement. By identifying the powering involvement, one refines the powering definition. For a candidate accident to survive the iterative selection process, it must show powering involvement at each decision point. These decision points are refined as new events are discovered which demand expansion of the decision tree. Hence, the "small" group of accidents chosen to provide powering related selection criteria did so by providing the powering related definition and identification mechanisms. The definition, therefore, is a multi-event decision tree where an accident that survives the "tree" becomes "identified" as a powering related accident.

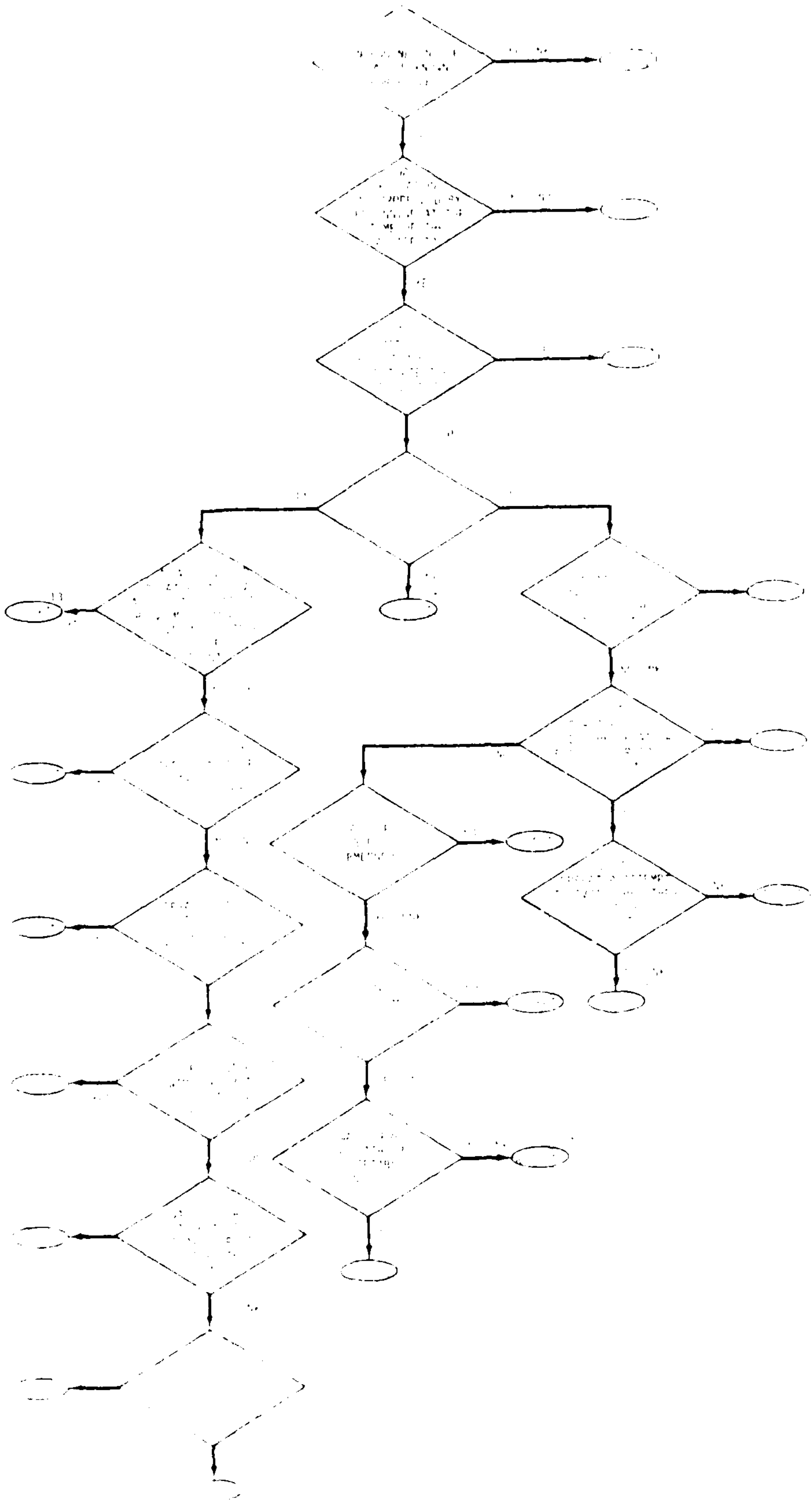


FIGURE 2-1. DECISION TREE FOR POTENTIALLY POWERING RELATED ACCIDENTS

2.1.2 Initial Accident Sample

Application of the machine sort on the 1975 accident file yielded 3600 accidents to be investigated by coders to determine if they were accepted or rejected by the decision tree. Each of the computer selected accidents was taken through the tree with 1200 of them being accepted as powering related accidents. Upon further analysis and consultation with USCG personnel, it was decided that the definition of a powering related accident needed further refinement; i.e., the sample needed to be reduced in size, particularly in the area of collisions and loading related accidents where the involvement of powering was tangential or secondary in nature.

The result of this further analysis reduced the number of "Accept" cases by 49%. (Those accidents that were originally "Accept" cases but are now "Rejects" are not statistically lost since they will be analyzed under projects in the safe loading and collision area). The decision tree was modified under this effort to that shown in Figure 2-2. The differences between this tree and the original tree are subtle. The first four decisions in the tree are not different. On the non-collision branch (node 13 and below), the change in Figure 2-2 was the addition of the top decision in that branch. This was inserted to reject those accidents where underpowering may have been a significant causal factor, and other accidents that were not related to overpowering. Note that accidents involving boats operating at less than half throttle can be included in the sample, but only if their horsepower per foot of boat length ratio is high. Thus, a small boat with a large engine, which could experience a powering problem at low throttle settings, is included in the sample; i.e., it can be accepted.

For the collision branch of the tree, several changes were made. The concept behind the decisions in the tree in Figure 2-2 was to include those accidents where: 1) the operator theoretically had a chance to avoid the collision (he detected the other boat, etc.), and 2) his speed (lack of time) precluded the execution of an effective avoidance maneuver. Cases where the operator lost control of the boat are still accepted. Cases where the object of the collision was not detected, or the operator did not respond in time because of alcohol or other stressors, or where the environment (waterway, etc.) precluded avoidance were collisions which the decision tree rejected. It should be noted that the decision tree allows for some engineering judgment in cases where the decisions can be surmised but are not directly known.

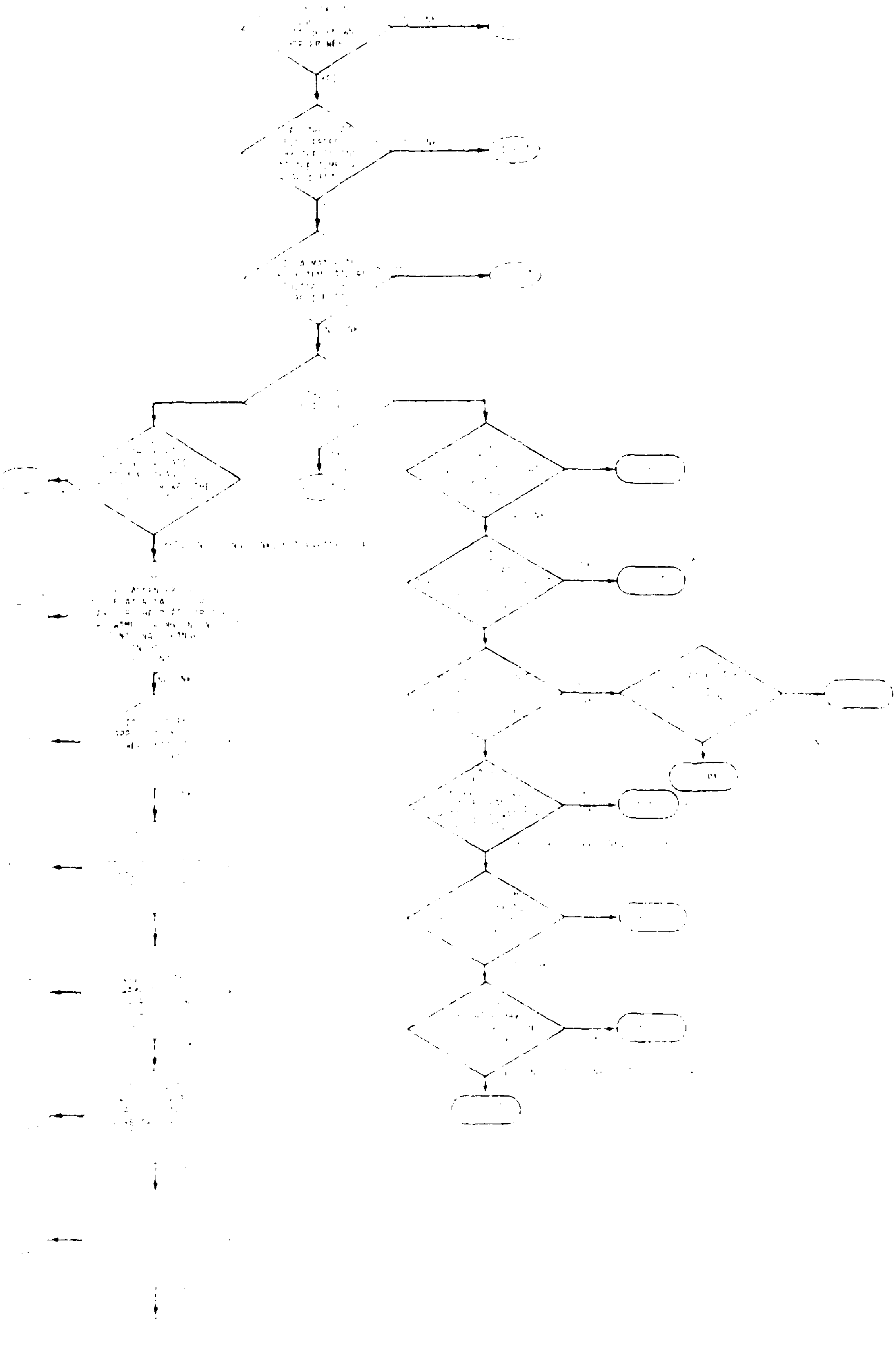


FIGURE 1-2. REVISED [illegible]EEPING RELATED ACCIDENT DECISION TREE

The remaining accident sample was then interrogated to determine the comprehensiveness of the information available to the coders. A coding sheet was prepared and a trial sample of twenty (20) accidents was processed. Results from the sample indicated that additional information was needed on a few of the key variables in many cases and that a problem existed in the decision tree for nodes involving throttle settings and speed. It was also apparent that the decision tree should allow one to recognize a boat that was being operated at a low throttle setting but, due to the size of the engine, was actually being supplied more horsepower than the boat was able to accommodate safely.

Additional research into the problem of determining whether a boat was over powered according to the present standard formula was apparently hampered here because the coder could not determine a value for "Horsepower in Use" with a high degree of confidence.

Equation (1) was used to obtain the critical throttle setting to exceed the value of one-half the rated horsepower of a given engine (see References 5 and 6).

$$\text{Horsepower} = K \cdot (\text{rpm})^{2.5} \quad (1)$$

This relationship has been shown to be close to empirical data and allows borderline cases to be processed fuether in the powering related accident decision tree since it credits the operator with using slightly more horsepower than empirical data indicate.

Equation (2) was used to calculate horsepower in use if speed and weight are known (see Reference 7).

$$\text{Speed} = \frac{160}{\sqrt{\text{Weight/Horsepower In Use}}} \quad (2)$$

The relationship of horsepower to throttle setting is shown in Equation (3).

$$\%\ \text{hp} = (\%\ \text{Throttle})^{2.5} \quad (3)$$

tailed discussion of the derivation of equations and the impact to the present dard evaluation is presented in Appendix A, "The Powering Related Model," ume II. Conversations with members of the Boating Industry Association and the , review of boat manufacturers' literature, and water tests conducted by Wyle onnel led to derivation of the formula for computing horsepower in use for a n engine and throttle setting. This formula was programmed into a calculator h was available to the coders. The analyst could then input rated horsepower mounted horsepower into the calculator and obtain a throttle setting needed to ed one-half of the rated horsepower. The calculator was also programmed to lay the horsepower in use and a throttle setting required to produce it on a n engine if the speed of the boat and weight of the boat, motor, and gear are wn. It was found that in most cases, there was enough information about the tical variables in these equations to calculate the desired variables. This nique filled in informative data for variables that the casual observer would clude was unknown or unavailable.

the resolution of problems concerning critical variables, 600 accidents were ined for further processing after processing through the revised decision shown in Figure 2-2.

2.1.3 Final Powering Related Accident Definition

on the preliminary analysis of the 600 accidents, further refinement of the ring Related Decision tree, and therefore, the "Definition," occurred. This ement was previously predicted because of the iterative nature of deriving nition based on expanding applications. The final definition is shown in re 2-3, where an accident is defined as a powering related accident if the ident falls out at any of the accept nodes. As one progresses through the sion tree, the complexity of the definition and the detailed thought process employed in deciding if the accident is accepted at any node becomes Because the definition is so complex, it is difficult to select any accurately describe a "typical" accident that would be accepted at each following scenarios were developed to better understand the accident that would be selected at each node.

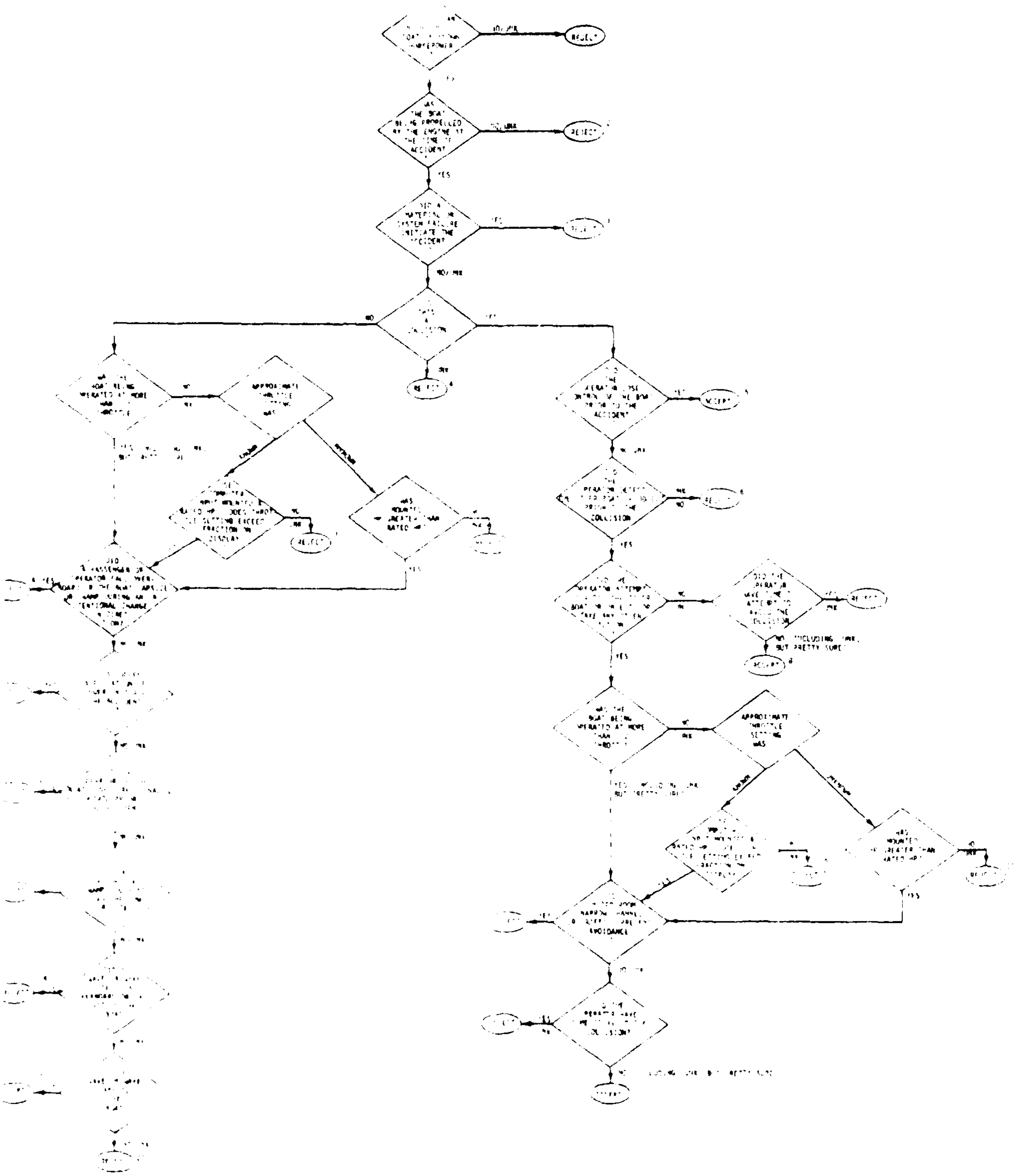


FIGURE 2-3. FINAL POWERING RELATED ACCIDENT DECISION TREE

Related Accident Scenario Node [illegible]

A motorboat was proceeding at a fast rate of speed. While attempting to pass a boat which it was overtaking it hit the wake of the other boat, causing the overtaking boat to go out of control and strike the boat that was being overtaken.

Related Accident Scenario Node 6*

A [illegible] enters a marina area at 3/4 throttle. While proceeding past several docked boats, the operator notices one vessel backing out of its dock, directly [illegible]. Before he can react to the situation, the collision occurs.

Related Accident Scenario Node 12*

[illegible] was proceeding up a river at a fast rate of speed. As it rounded [illegible] the river, the operator noticed another boat heading toward him. [illegible] attempted to turn away from the impending collision, but could not. [illegible] collided as the turns were being executed.

Related Accident Scenario Node 14

[illegible] proceeding at full power pulling skier. Observer sitting on top [illegible] facing rear of boat watching skier. Skier falls down, operator [illegible] return to skier and observer falls overboard, is hit by [illegible] propeller and drowns or is injured.

[illegible] proceeding at full power pulling skier. Skier falls and [illegible] to return to pick up the skier. In [illegible] the boat ships [illegible] the down-side rail [illegible] capsizes. One or more occupants drowns [illegible].

[illegible] Scenario Node [illegible]

[illegible] throttle [illegible] while passenger [illegible] from the seat [illegible] passenger falls overboard and drowns before operator can return [illegible]

[illegible] powering [illegible]

TABLE 2-[illegible] (concluded)

	NO. OF ACCIDENTS	REL. PCT.
...s	7	1.5
...ania	7	1.5
[illegible]	7	1.5
	6	1.3
...setts	6	1.3
[illegible]	6	1.3
...na	5	1.1
[illegible]	5	1.1
	5	1.1
[illegible]	5	1.1
	4	0.9
	4	0.9
	4	0.9
	3	0.6
	3	0.6
	2	0.4
	2	0.4
[illegible]	2	0.4
[illegible]	1	0.2
	1	0.2
	1	0.2
	1	[illegible]
	1	[illegible]
	1	[illegible]

2.3.1 Raw F[illegible]ency Distributions

:n of the information presented on the following pages was used to evaluate the iative effectiveness and benefits of powering regulation concepts. This is esented below to show the type of raw data contained within the model. Unique d/or interesting frequencies in the raw data are singled out. Comparisons with e data from non-powering accidents is presented in Sections 3.0 and 4.0.

TABLE 2-2. STATES [illegible] ORDER OF FREQUENCY
OF BOATS IN POWERING RELATED ACCIDENTS

STATE	NUMBER OF BOATS	REL. PCT.
alifornia	62	13.2
lorida	37	7.9
ew York	32	6.8
labama	20	4.3
ichigan	20	4.3
ew Jersey	20	4.3
orth Carolina	18	3.8
exas	18	3.8
issouri	17	3.6
outh Carolina	16	3.4
llinois	14	3.0
entucky	14	3.0
onnecticut	13	2.8
eorgia	12	2.6
regon	12	2.6
rizona	10	2.1
ennessee	10	2.1
innesota	9	1.9
ississippi	9	1.9
hio	9	1.9
ndiana	8	1.7

2.3 Accident Mechanism Identification and Scenario Development

[illegible] previous sections the sample of powering related accidents to be analyzed [illegible]dentified and defined, and the analysis tool (PRAM) was discussed. This [illegible]e was coded and the results of that coding are presented herein, with addi[illegible] analyses. The PRAM data are compatible with SPSS sorting routines and [illegible]stical packages. Additional analytical subroutines have been written to [illegible]late powering ratios and other statistics from the coded PRAM data.

[illegible]atios that have been used in some of these analyses are: 1) mounted horse[illegible] over rated horsepower (a ratio greater than one for a boat signifies non[illegible]iance with the current standard); 2) mounted horsepower over boat length (hp [illegible]t), and, 3) mounted horsepower over total weight (boat + gear + people). [illegible] ratios reflect measures of compliance with the current standard (ratio 1) and [illegible] measures to be used in alternative powering regulation concepts (ratios 2 [illegible]). These three power ratios were selected through consultation with Coast [illegible] personnel because of their relevance to the evaluation of the current stan[illegible] their potential for the development of new standards and the availability of [illegible]eeded information in the data base.

[illegible] powering ratio 1 above, one needs to divide the mounted horsepower by [illegible]ted horsepower. A boat that was rated for a 100 hp engine and had a 120 hp [illegible] mounted on it would have a power ratio number 1 of 1.2. To compute power [illegible], the mounted horsepower is divided by the boat length to the whole foot, [illegible]. Thus, a 120 hp engine on a 15 ft 9 in. boat would generate a [illegible] 2 of 8.0. The third power ratio is computed by dividing the [illegible] by the sum of the boat weight, the weight of gear on board, and [illegible] people on board. For example, a 120 hp engine mounted on a 850 [illegible] 300 lbs of gas and gear and 400 lb of people would generate a [illegible] 3 of 0.08.

[illegible] much of the PRAM data as frequencies for the various codes. [illegible], and forms the Powering Related Accident Data Base. The next [illegible] presents more detailed results and discussions of the meanings of [illegible] tabulations. The detailed scenario development and accident mech[illegible] is culminated later, in Section 2.3.3.

TABLE 2-1. PRAM DATA BY NODE OF ACCEPTANCE

POWERING RELATED ACCEPTANCE NODE (BRIEF DESCRIPTION)	NO. OF BOATS	NO. OF RECOVERIES*	NO. OF FATALITIES
5 (lost control)	103	286	3
8 (no attempt to avoid collision)	32	88	12
12 (not enough time to avoid collision)	52	173	12
14 (fall overboard or capsizing during turn)	72	145	59
15 (sudden application of power)	31	51	22
16 (loss of directional control)	36	72	15
17 (wave over bow)	47	123	34
18 (fall overboard due to wave)	52	135	22
19 (capsizing)	44	102	21
Fatalities on other boats in these accidents which were not accepted in the decision tree			4
Total	469	1175	204

* These figures are slightly below the true figures because of unknowns which are not included and because some entries exceeded coding limitations [i.e., for some boats the code ("9"=8 or more) was used].

ch boat that had a powering related problem was coded in PRAM. In other models, ch as ARM for example, each victim is coded. Since boats are coded in PRAM, ere may be one boat coded for each accident in the sample, or more than one if e accident involved more than one boat with powering problems. If only one boat a multiple boat accident had a powering problem (according to the powering lated accident decision tree), then that was the only boat that was coded.

e PRAM sample contains 383 boats from accidents in 1975 and 86 boats from fatal cidents in 1976. There are a total of 469 boats coded in PRAM from 450 accidents wo boats were coded from 18 accidents, and three boats were coded from 1 accident).

ıe PRAM sample is broken down by node of acceptance in the powering related accident :cision tree in Table 2-1. The number of boats at each node, the number of recover- ːs at each node, and the number of fatalities at each node are shown. Several ،pects of these data are intriguing. The probability of recovery (i.e., number of ːcoveries divided by total number of recoveries and fatalities) for boaters at node in the powering related accident decision tree is much higher (0.99) than at any :her node. The probability of recovery at nodes 14 and 15 is lower (0.71 and 0.70, ːspectively) than at other nodes. These probabilities are not absolute, since two ːars of fatality data are included in PRAM and only one year of recovery data. How- ver, the relative differences indicate the nodes where significant numbers of fatal- ties are occurring. The fact that at least 31 boats were accepted at each node and ıat recoveries and fatalities occurred at each node, indicates that the decision ree generates a sample that has data for each kind of powering accident. Each kind f powering accident occurs in the sample with some regularity.

2.2.5 Summary of PRAM

ıe Powering Related Accident Model was developed to organize and summarize data r the accidents that are powering related. The model can provide scenarios of ommon powering accidents and identify the dominant mechanisms of these accidents. RAM also provides statistics and probabilities on factors relevant to the estima- ion of potential benefits attributable to alternative powering regulation concepts, d data to enable the evaluation of engineering solutions to the powering problem.

l powering accidents in 1975 were included in the PRAM sample, along with all ıtal powering accidents from 1976. In total, this represents 450 accidents involv- ıg 469 boats and 204 fatalities. The large number of accidents and fatalities ıdicates that powering accidents are a significant problem.

The next five coded variables contain most of the severity information for the accident. Property damage, injuries, and fatalities for the other vessel, if any (fatalities for this vessel were coded earlier) are coded.

Finally, event trees and other detailed information were coded for accidents according to their nodes of acceptance. These variables were created to provide a means of coding the detailed information that is often available in fatal accident reports, and sometimes present in non-fatal accident reports. The sequences of interrelated events in powering accidents are particularly important, and this information is captured in the event trees and other variables that are specific to each node of acceptance. The trees were developed to enable engineering solutions to powering problems by providing data of a detailed nature concerning accident causes. Solutions (in the form of proposed standards) which break sequences of events in common powering accidents, or break variable interrelationships, may be tested in future research. Their effectiveness can be estimated from the PRAM data. By building this part of the model around the node of acceptance, the key information that was used to decide if the accident should be in the powering related sample is coded.

2.2.4 Final Accident Sample

Wyle proposed to sample at least two to three hundred accidents for PRAM. Originally, it was thought that two years worth of data would have to be screened in order to obtain a sample of powering related accidents of two to three hundred. When the accidents from 1975 were screened initially, approximately 1200 were found to be possible PRAM candidates. Later, revisions in the powering related accident decision tree resulted in reducing this number by about 800 or more accidents. At that point, the Coast Guard and Wyle had a meeting to decide what additional accidents, if any, should be sampled. It was decided that the fatal accidents from 1976 should be sampled to provide more of the detailed information needed for the sequential event trees, and to provide more "known" data points throughout the model, since more data is typically reported in fatal cases. It was felt that the non-fatal data already sampled from 1975 would be sufficient to show differences between fatal and non-fatal powering accidents, if any.

Thus, the PRAM sample includes all powering related accidents from 1975 and all fatal powering related accidents from 1976. These accidents were selected from Coast Guard accident report files using the powering related accident decision tree described earlier.

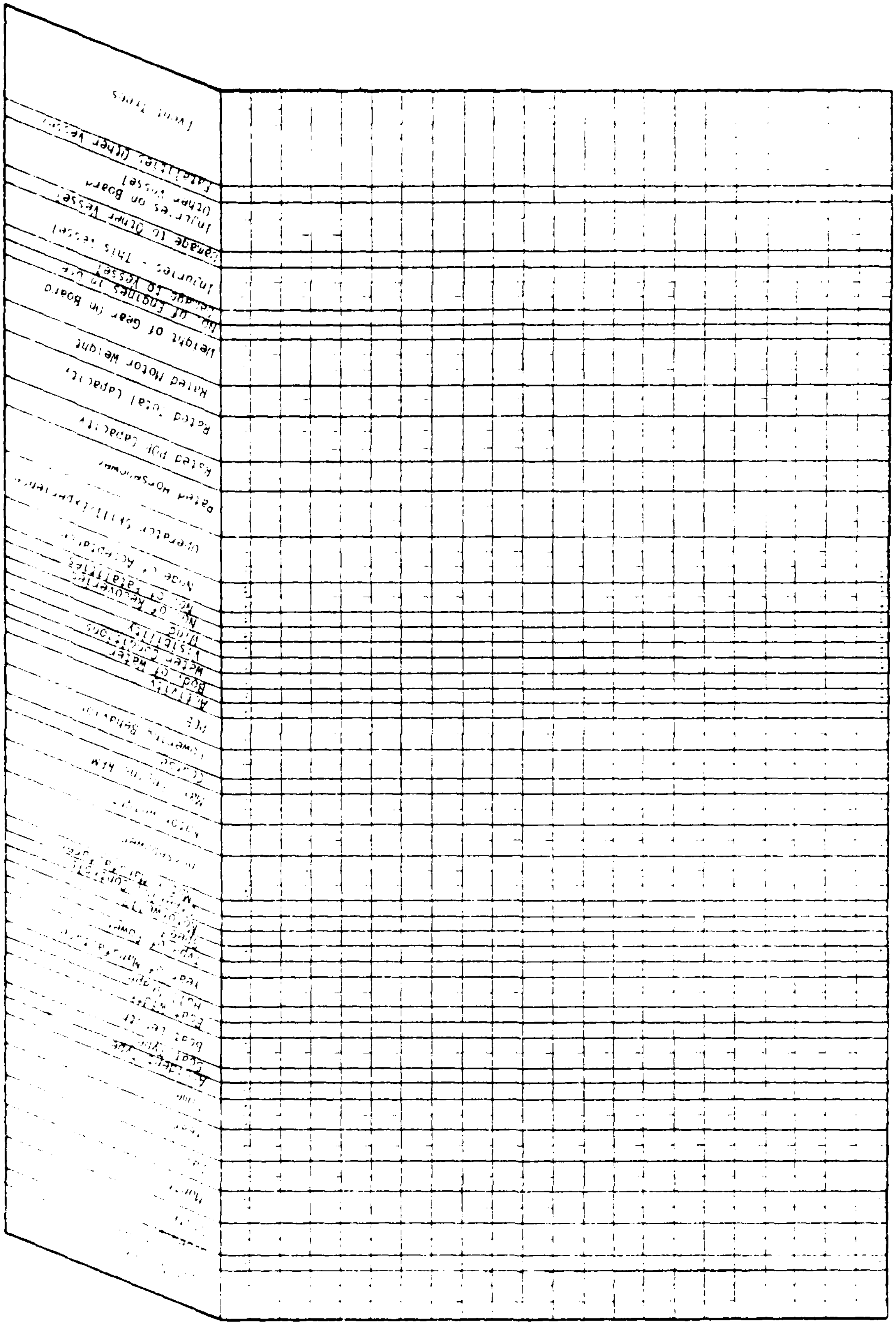


FIGURE 2-5   BRAM CODING SHEET

in Figure 2-5 and instructions are presented in Volume II of the PRAM technical brief (Appendix A). In this section, the types of data to be collected and the coding form will be discussed in general, and a few variables which caused special problems will be presented.

Several bookkeeping variables are included in PRAM and grouped in the first set of columns on the coding sheet. The "boat number" and "coded by" variables are included so that accidents could be identified later, and analysts could be consulted, when needed, during the verification process. The state, month, year, and time of the accident are other bookkeeping variables in the same vicinity on the coding sheet, along with the accident type.

Boat variables are then coded in successive columns, including boat type, length, width, hull shape, year of manufacture, and type of power. The speed at the time of the accident, motorwell information, and type of steering controls are coded next. The following four columns are for the relevant information about the motor (manufacturer, horsepower, weight, and maximum rpm). When speed was not stated in the accident report, but the throttle setting and total system weight are known, a program on Wyle's HP-97 was written for the analyst to use in computing the boat's approximate speed (for planing hull craft). It was felt that such an estimate would be preferrable to coding "unknown for speed.

The next several variables to be entered on the coding sheet ("course" through "operator skill/experience") provide some information concerning the particular accident. "Course" and "Powering Behavior" are decision tree variables which indicate intentional and unintentional control activations involving steering and the throttle. Most of the other variables to be entered in this group (water conditions, visibility, etc.) are coded directly as stated on the accident report. The "Node of Acceptance" refers to the nede where the accident was accepted into the PRAM sample in the powering related accident decision tree.

The rated capacities of the coded boat are recorded in the next several columns. Several of these are calculated from other known data using Coast Guard standards and formulas. The weight of gear on board and number of engines in use are coded in order to provide more information concerning overloading and the evaluation of powering regulation alternatives.

[illegible] verified to correct [illegible]ypunching errors and coding errors. [illegible] codes were then recycled for keypunching the corrections independently for each of the two coders. The process iterated until two complete duplicate decks of correctly coded data were obtained. The only way that a keypunching or coding error could survive this verification process undetected would be if the exact mistake were made twice independently on the same variable. Such an occurrence is a remote [illegible]. Even then, approximately fifteen percent of all of the coded accidents (at least ten percent of each group of 50) were verified code by code by the project leaders (R. White, C. Stiehl, and N. Whatley). When errors in coding or interpretation were discovered, these were reviewed with all analysts by the project leaders. In the coding of the powering related accidents, the initial disagreement rate (the percentage of disagreements, column by column, in the comparison of the two keypunched decks of coded data) was approximately 10 percent of the columns. This rate includes keypunching errors, and some variables cover more than one column. Thus, the true disagreements between analysts were on the order of 5%. [illegible] rate of agreement (95%) between independent coders using PRAM gives a [illegible] that the model does a very good job of capturing the important information [illegible] the accidents in a clear manner. Indeed, most of the disagreements [illegible] involved cases where one coder was willing to assume a little more [illegible] about an accident, and coded a value for a variable while the second [illegible] "unknown." All of the analysts were questioned as to whether they had [illegible] accidents which were not adequately handled by the model; i.e., accidents [illegible] model had no provision for coding the main thrust or problem in the accident. [illegible] indicated that there may have been one or two, but that these [illegible] very unique and would not warrant the creation of special variables [illegible] problems, such as overloading were coded indirectly when the capa[illegible] not known. For this problem, boat length, people on board, and [illegible] be used in an analysis program to determine overloading.

[illegible] great deal of face validity through the close relationship [illegible] development. The quality assurance procedures pro[illegible]. Perhaps the most important points in this regard are: [illegible] between the analysts was very low, and [illegible] virtually all [illegible] handled without difficulty by the model

[illegible] and Coding Form

[illegible] this [illegible] shown

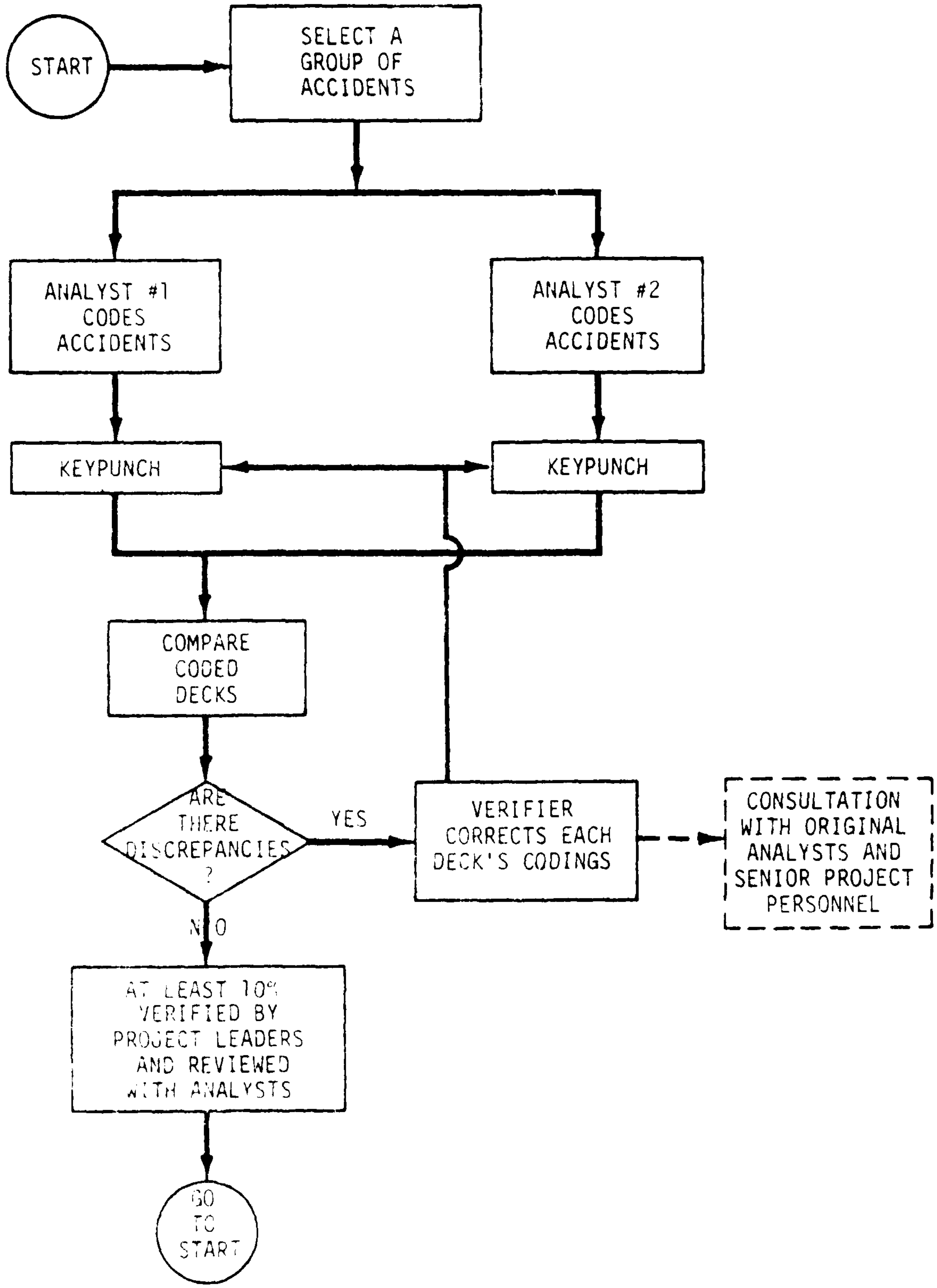


FIGURE 2-4. PRAM QUALITY ASSURANCE PROCEDURES

benefits attributable to alternative powering regulation concepts, as well as to evaluate the effectiveness and need for the present standard. Further details on some of these issues have been developed in Appendix A, particularly in Volume I.

2.2.2 Validation of the Model

The preliminary validation of the model was accomplished through the processing of scenarios through PRAM. These scenarios were developed to describe accidents processed through different acceptance nodes of the powering related accident decision tree (see Section 2.1.3).

Prior to the writing of Volume I of the PRAM technical brief (see Appendix A), 20 non-fatal accidents were processed through PRAM. The processing of these accidents led to some modifications in the coding instructions for PRAM and the adaptation of a few variables to more adequately reflect the accident data.

Prior to the writing of Volume II of the PRAM technical brief, all of the fatal accidents which had been accepted into the PRAM sample were reviewed. Event trees and other detailed accident variables were developed for nodes of acceptance in the powering related accident decision tree which accepted ten or more fatal accidents. At least ten accidents were needed at a node in order to generate enough data to warrant the construction of these variables. These variables were constructed in order to capture as much of the detailed sequential information concerning events in the accident as possible.

[illegible] to the validity checks described above, a PRAM coding validation pro[illegible] [illegible]ped. In any effort of this kind, the model is only as good as the [illegible] procedures developed for the data input validation, and use of [illegible] PRAM, the model was developed through considerable review of pre[illegible] accident data, and consultation with Coast Guard and other experts. [illegible] to the data in the development stages adds to its external valid[illegible] [illegible] for detail and accuracy in defining powering accidents and select[illegible] [illegible] the accident sample also increase the validity of the data [illegible] order to make optimum use of these techniques and procedures, the [illegible] be coded correctly.

[illegible] assurance procedures are diagrammed in Figure 2-4. Each accident was [illegible] independently by two analysts. The independent codings were keypunched and [illegible] column by column for discrepancies. The discrepancies were

After PRAM was developed, through reviewing previous modeling efforts, reviewing accident data, and consulting with Coast Guard personnel, it was presented in a two volume technical brief - reproduced in Appendix A. In order to capture some of the sequential dependencies in the events relating to powering accidents, event trees were developed for each type of accident that was accepted into the PRAM sample. Thus, PRAM has many of the good features of a matrix model (flexibility, completeness) and some of the benefits of a tree model (sequential dependencies, interrelationships). Some of PRAM's specifics are denoted in the following paragraphs.

The model codes information by boat. Other models code information by victim (the Accident Recovery Model (ARM), and the Flotation Effectiveness Model (FEM)). Only vessels with significant powering problems were coded in PRAM in Task II. The model is organized so that bookkeeping data are grouped in the first set of columns (month, year, time, accident type, etc.). Boat data concerning the particular boat to be coded are grouped in the next columns (boat type, boat length, etc.). Following the boat data, accident data are coded (course, powering behavior, activity, etc.). Capacity information is then coded (rated horsepower, rated POB capacity, etc.), followed by damage and injury information (damage to vessel, injuries -this vessel, etc.). Finally, event trees and special variables are coded. These variables and event trees are specific to the node of acceptance on the powering related accident decision tree for this boat.

PRAM has been designed to make use of prediction and assessment methodologies developed for ARM and other models. Portions of these existing programs and analysis techniques can be applied directly to PRAM. Additional analyses were designed specifically for PRAM, which uses routines in Statistical Programs for Social Sciences (SPSS). These analytical techniques were developed primarily for the evaluation of powering regulation alternatives and benefit estimations using accident severity variables.

In summary, PRAM has been developed using accident data, Wyle expertise developed from previous data analysis efforts, and consultations with the Coast Guard. The model has been designed to perform three functions: 1) to summarize/organize powering related accident data and provide scenarios of common powering related accidents, 2) to identify the dominant mechanisms of these accidents, and 3) to provide statistics and probabilities on all relevant factors and combinations of factors in these accidents. The model was used to facilitate the estimation of examination of the 1975 accidents revealed that accidents involving fatalities contained a great deal more information for variables to be coded for the model than did non-fatal accidents. We therefore sorted through the 1976 file for powering related accidents involving fatalities. The result was the selection of 86 of these cases to be coded in PRAM. The selection of these yielded a total sample of [illegible] powering related accidents involving 469 boats (or cases) and 204 fatalities [illegible] the model for both years.

Since the definition of a powering related accident and the decision tree are synonymous, any safe powering standard, to be effective, must prevent or reduce the severity of these accidents.

2.2 Development and Validation of Powering Related Accident Model

In the previous section, the method for selecting powering related accidents was described. This section describes the development and validation of the powering related accident model (PRAM). This model was developed in order to categorize and summarize the accident data. PRAM provides frequency data and other information which can be used to identify prevalent powering related accident mechanisms and event combinations.

2.2.1 The PRAM

[illegible] selection procedure outlined previously generated a file of accidents [illegible] with respect to powering problems. This file was used, along with [illegible] building and data analysis expertise, to formulate PRAM. The scenarios [illegible] acceptance nodes of the powering related model decision tree were [illegible] sure that the model could accept the relevant information for [illegible]

[illegible] model which is very similar to other analysis models developed for the [illegible] style. It has many variables, allowing for the coding of all relevant [illegible]. Unknown data does not preclude the coding of other known data in [illegible] matrix-like model. In models composed of one or a few large [illegible], unknown data may prevent the decision at a high node in a tree, [illegible] preventing the coding of information that is known lower in the tree. [illegible] happen in PRAM. (For further discussion of the differences in these [illegible] models, see Reference 3.)

Power Related Accident Scenario Node 16*

A. Operator is proceeding at high speed across a lake. He hits a wave and loses control of the boat, which goes into "dynamic instability" and capsizes. One occupant drowns either due to "sudden drowning," being a nonswimmer, or being hit on the head during the capsize.

B. Operator is proceeding up narrow waterway at high speed. Rounds a bend and finds boat in path. In attempting to avoid other boat, loses control and capsizes. One occupant drowns or extensive property damage occurs.

Power Related Accident Scenario Node 17

Boat proceeding at high speed encounters large wave which enters over the bow and swamps the boat. One or more occupants drown prior to rescue.

Power Related Accident Scenario Node 18

Boat proceeding at high speed encounters a wave or wake which causes one or more of its occupants to fall overboard or fall within the boat. One or more occupants drown prior to rescue, or is severely injured by the fall within the boat.

Power Related Accident Scenario Node 19

A boat proceeding at high speed encounters a wave or wake which causes the boat to capsize. One or more occupants drown prior to rescue.

2.1.4 Final Accident Sample

After all of the refinements to the decision tree were made, all of the 1200 accidents selected by the machine sort from the 1975 file were reprocessed through the tree. The result was a selection of 383 powering related cases to be processed through the Powering Related Accident Model. It should be noted that each "case" represents a single boat, and that in some multiple-boat accidents, more than one boat experienced powering related problems. Thus, the total number of powering related cases is greater than the actual number of accidents. It was felt that additional cases could be selected from the 1976 accident file to provide a broader coverage of boater exposure without grossly affecting the total sample size.

* Note: The scenarios do not encompass the recklessness of boat operators or passengers, which would be hard to overcome by a powering standard.

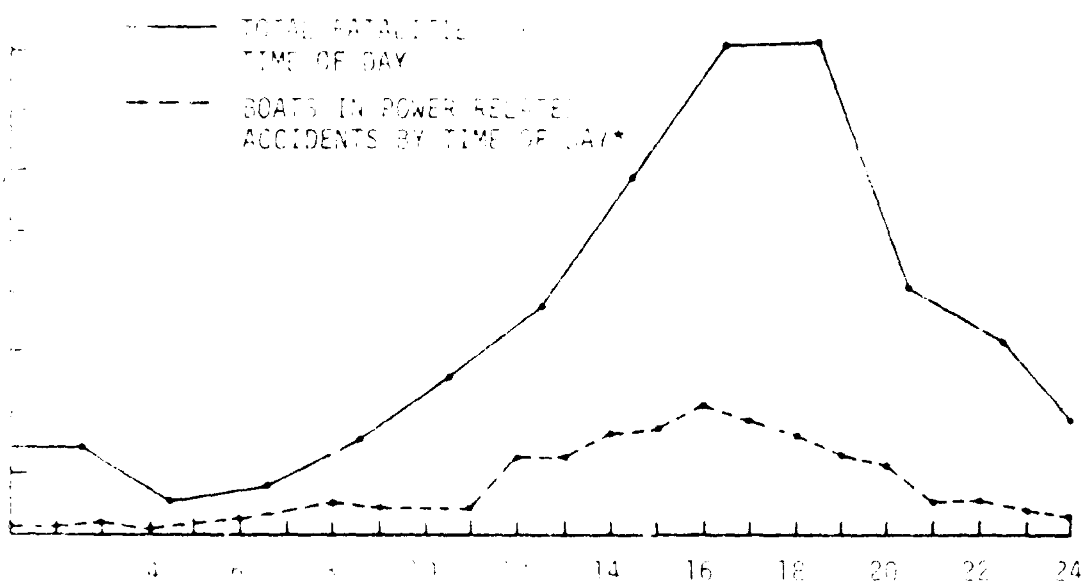
TABLE 2-3. MONTHS BY ORDER OF FREQUENCY OF BOATS INVOLVED IN [illegible] POWERING RELATED ACCIDENTS

MONTH	NUMBER OF BOATS	REL. PERCENTAGE
August	94	20
June	81	17.3
July	76	16.2
May	75	16.0
September	34	7.2
April	32	6.8
March	20	4.3
October	18	3.8
February	12	2.6
January	10	2.1
November	8	1.7
December	8	1.7
Unknown	1	0.2

Over [illegible] of the accidents occur during the five heaviest exposure months. The probability is directly proportional to exposure, since 75 of all accidents during [illegible] occurred in the same five months.

TABLE 2-4. BOATS INVOLVED IN POWERING RELATED ACCIDENTS BY TIME OF DAY

TIME OF DAY	NUMBER OF BOATS	REL. PERCENTAGE
1600	53	11.3
1700	47	10.0
1500	43	9.2
1400	41	8.7
[illegible]	41	8.7
1900	32	6.8
1300	31	6.6
1200	31	6.6
2000	28	6.0
2200	15	3.2
[illegible]	14	3.0
[illegible]	14	3.0
[illegible]	12	2.6
[illegible]	12	2.6
[illegible]	12	2.6
[illegible]	10	2.1
[illegible]	[illegible]	1.7
[illegible]	5	1.1
[illegible]	4	0.9
[illegible]	3	0.6
[illegible]	3	0.6
[illegible]	0	0.0
[illegible]	0	0.0
[illegible]	0	0.0
[illegible]	[illegible]	2.1



[illegible] COMPARISON OF TYPES OF ACCIDENTS BY TIME OF DAY

TABLE 2-5. ORDER OF BOATS INVOLVED IN
POWERING RELATED ACCIDENTS BY ACCIDENT TYPE

ACCIDENT TYPE	NO. OF BOATS	REL. PERCENTAGE
Collision/Grounding	180	38.4
Falls Overboard/Within the Boat	147	31.3
Swamping/Capsizing/Flooding/Sinking	128	27.3
Struck by Propeller	13	2.8
Other	1	0.2

TABLE 2-6. FREQUENCY OF BOATS INVOLVED IN POWERING
RELATED ACCIDENTS AND ALL ACCIDENTS* BY TYPE OF BOAT

BOAT TYPE	NO. OF BOATS IN ALL ACCIDENTS*	RELATIVE PERCENTAGE**	NO. BOATS IN P-R ACCIDENTS	RELATIVE PERCENTAGE
Open Motorboat	903	62.7	298	63.5
Cabin Motorboat	1717	21.9	49	10.4
High Performance			15	3.2
Auxiliary Sail	793	10.1	2	0.4
Houseboat	[illegible]	1.3	2	0.4
[illegible] Powered			[illegible]	0.2
Other	310	4.0	[illegible]	1.1
[illegible]			86	18.3
[illegible]			[illegible]	2.3

* [illegible] for 197[illegible]
** Percentage based only on [illegible] boat types listed.

TABLE 2-7. COMPARISON OF NUMBER OF BOATS IN ALL ACCIDENTS* AND IN POWERING RELATED ACCIDENTS BY BOAT LENGTH CATEGORIES

BOAT LENGTH CATEGORY	NO. OF BOATS IN ALL ACCIDENTS*	RELATIVE PERCENTAGE**	NO. BOATS IN P-R ACCIDENTS	RELATIVE PERCENTAGE
Less than 16 ft	2053	22.9	201	
16 - 26 ft	4549	50.8	227	
[illegible] ft	1309	14.6	11	
[illegible] ft	361	4.0		
[illegible]	30	0.3		
[illegible]	652	7.3	5	1.1

[illegible] of the boats having powering related accidents were boat lengths regulated [illegible] standard.

[illegible] FREQUENCY OF BOATS IN POWERING RELATED ACCIDENTS BY BOAT WIDTH

BOAT WIDTH (FEET)	NO. OF BOATS	REL. PERCENTAGE
5	97	20.7
6	74	15.8
[illegible]	63	13.4
[illegible]	59	12.6
[illegible]	40	8.5
[illegible] 3	13	2.8
[illegible] than 10	12	2.6
[illegible]	9	1.9
[illegible]	102	21.7

[illegible] FREQUENCY OF BOATS IN POWERING RELATED ACCIDENTS BY HULL SHAPE

[illegible]	NUMBER OF BOATS	REL. PERCENTAGE
[illegible]	39	8.3
[illegible]	28	6.0
[illegible]	17	3.6
[illegible]	[illegible]	1.7
[illegible]	[illegible]	0.6
Round Bottom	1	0.2
Unknown	373	79.5

* [illegible]
** [illegible] categories used in the table.

Unknowns for this variable are quite high due to lack of manufacturer's information on earlier model boats, and lack of model specification on BARs.

TABLE 2-10. FREQUENCY OF BOATS IN POWERING ACCIDENTS BY YEAR OF MANUFACTURE

YEAR OF MANUFACTURE	NUMBER OF BOATS	REL. PERCENTAGE
1974	53	11.3
1972	52	11.1
1973	44	9.4
1975	39	8.3
1971	30	6.4
1968	23	4.9
1970	19	4.1
1969	18	3.8
1976	11	2.3
Prior to 1968	98	20.9
Unknown	82	17.5

At least 42.4% of the boats involved in powering related accidents were built after the effective date of the present standard (the addition of some of the unknowns would increase this figure).

TABLE 2-11. FREQUENCY OF BOATS IN POWERING ACCIDENTS BY TYPE OF POWER

TYPE OF POWER	NO. OF BOATS IN ALL ACCIDENTS*	RELATIVE PERCENTAGE**	NO. BOATS IN P-R ACCIDENTS	RELATIVE PERCENTAGE
Outboard	3955	50.8	323	68.9
I/O	1299	16.7	70	14.9
Inboard	2405	30.9	61	13.0
Other	129	1.7	15	3.2

Nearly 70% of the boats in powering related accidents were outboards, the type of boats covered by the regulation, whereas only 50.8% of the boats in all accidents were outboards. The percentage of inboard boats in powering related accidents appears to be considerably less than the percentage in all accidents.

* CG-357 for 1976
** Based upon only those categories used in the table.

TABLE 2-12. FREQUENCY OF BOATS IN POWERING ACCIDENTS BY [illegible]

SPEED (MPH)	NUMBER OF BOATS	REL. PERCENTAGE
0-10	51	10.9
21-30	40	8.5
11-20	22	4.7
31-40	13	2.8
41-50	6	1.3
Unk., but Increasing	16	3.4
[illegible] but Decreasing	15	[illegible]
[illegible]	306	65.2

[illegible] those boats where the speed was known, nearly 70% were traveling at speeds [illegible] thought to be safe for most water craft.

TABLE 2-13. FREQUENCY OF BOATS IN POWERING ACCIDENTS BY TYPE OF STEERING CONTROLS

[illegible] CONTROLS	NUMBER OF BOATS	REL. PERCENTAGE
Remote Steering	353	75.3
[illegible] lled from Eng.	96	20.5
[illegible]	20	4.3

[illegible] of the accidents in the data base there is indication that the operator [illegible] attempt to change course prior to the accident; however, [illegible] the cases [illegible] indication that he did attempt to change course, there is also [illegible] that he did not lose control of the boat in making his corrections [illegible] those cases.

[illegible] of the sample, the accident did not occur during an intentional [illegible], and for approximately 20[illegible] of the cases, it was not known if the [illegible] attempted to change course. [illegible] half of the operators who did attempt [illegible] course in these accidents did not lose control of their boats. Loss of [illegible] during an intentional course change accounted for about 22[illegible] of the data, [illegible] causes of loss of control being the operator being displaced [illegible] control station while executing the maneuver, or waves and wakes, etc.

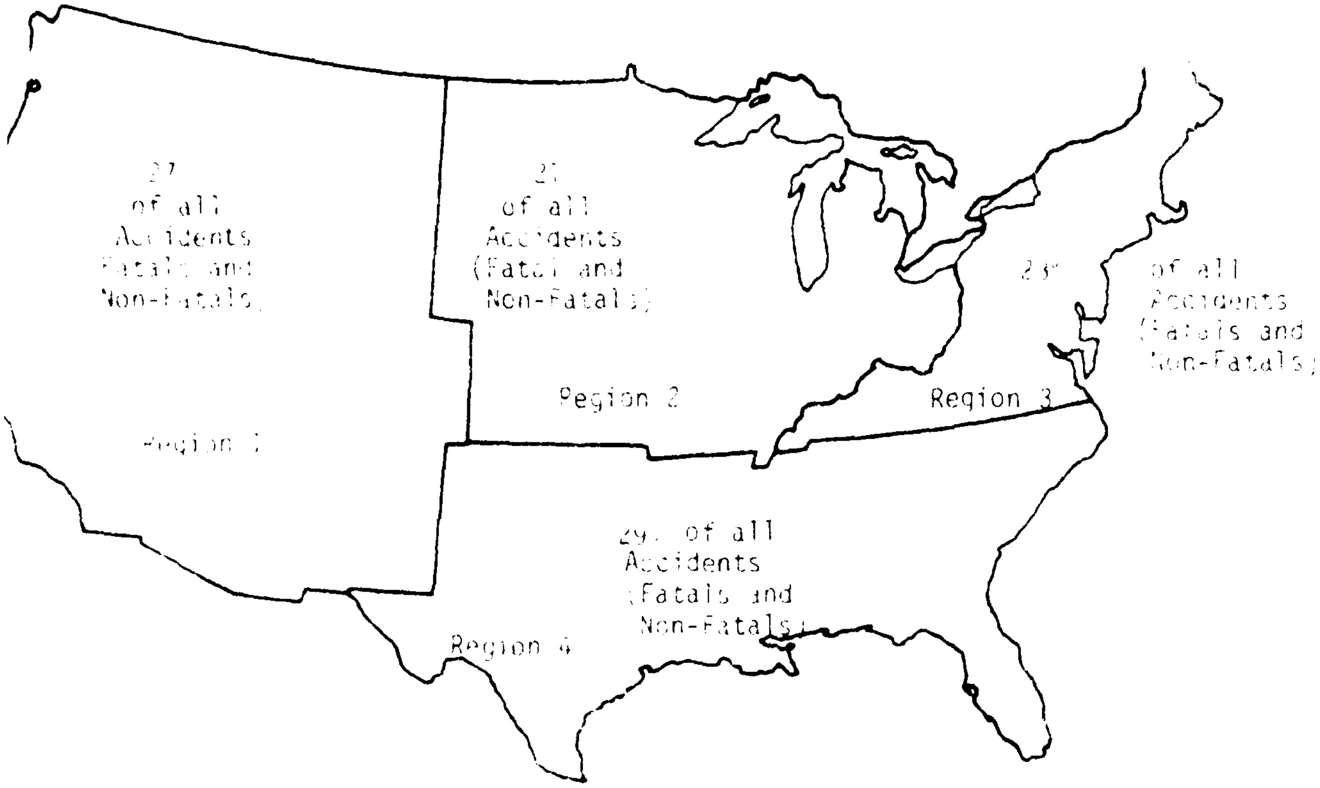
2.3.2 Analytical Results

Section 2.3.1 presented the basic results of the coding of the PRAM sample, one variable at a time. In this section, the discussion will concentrate on those variables and variable combinations that provide significant input to the identification of powering accident mechanisms, the development of powering accident scenarios, and the evaluation of powering regulation concepts.

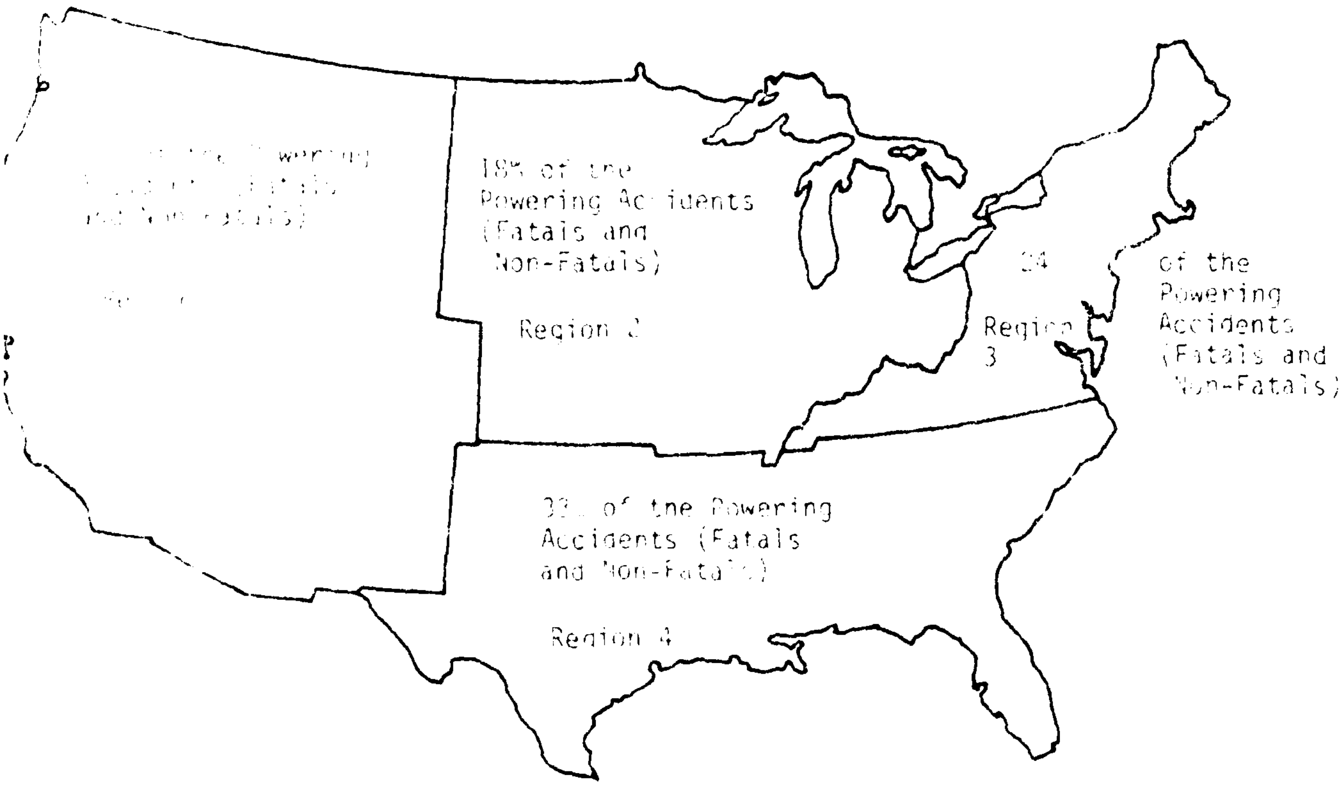
The powering related accidents and the accidents reported in CG-357 are broken down by geographic region in Figure 2-7. The regions are comprised of the states shown below:

Region 1	Region 2	Region 3	Region 4
Washington	North Dakota	Maine	Texas
Oregon	South Dakota	New Hampshire	Arkansas
California	Nebraska	Vermont	Louisiana
Idaho	Kansas	Massachusetts	Tennessee
Nevada	Minnesota	Connecticut	Mississippi
Arizona	Iowa	Rhode Island	Alabama
Montana	Missouri	New York	North Carolina
Wyoming	Wisconsin	Pennsylvania	South Carolina
Utah	Illinois	New Jersey	Georgia
Colorado	Indiana	Delaware	Florida
New Mexico	Michigan	Maryland	
Alaska	Ohio	West Virginia	
Hawaii		Virginia	
		Kentucky	
		Washington, DC	

The powering problem has a regional character. In the categorization of the PRAM data by states, Alabama, North Carolina, and South Carolina (all southeastern states) ranked fourth, seventh, and tenth in powering accident, respectively. The same states ranked fourteenth, tenth, and twentieth in overall boating accidents according to CG-357 data for 1976. Meanwhile, Washington and Maryland, which were both in the ten states with the most accidents in 1976 (eighth and ninth, respectively), tied for twenty-eighth in the rankings for powering



ALL ACCIDENTS FROM CG-357 (1975) BY GEOGRAPHIC REGION



POWERING ACCIDENTS (FROM PRAM DATA BASE) BY GEOGRAPHIC REGION

FIGURE GEOGRAPHIC BREAKDOWNS

accidents. The tendency for southeastern states to have more powering accidents can be shown by the data in the two maps of Figure 2-7. The southeastern states represent approximately one-third of the powering accidents. Meanwhile, the north central region represents less than one-fifth of the powering problem.

This variable was singled out to be used early in this section merely to indicate the complicated nature of modeling, regulating, and predicting the powering problem. Based on these data (state) one could predict, just from knowing that an accident occurred in the southeast as opposed to the north central area, that it was nearly twice as likely that it was a powering accident. And yet, it is difficult to conceive of incorporating region of the country into a powering standard.

Accident Mechanism Variables

The next section will describe accident mechanisms and scenarios in detail for each PRAM accept node. In this subsection, general variables relating to powering accident mechanisms will be presented.

As shown in Section 2.3.1, there are three basic accident types in the PRAM sample. Collisions, capsizings/swampings (including floodings and sinkings), and falls within the boat or overboard count for 455 of the 469 boats in the PRAM sample (97%). Thus, the mechanisms for these accident types, identified in the safe loading projects, collision projects, and in-depth collision and capsizing/swamping investigations, are applicable to powering. However, the powering accident mechanisms and scenarios represent special subgroups within each of these accident types.

Speed was unknown in 306 (65%) of the cases; therefore, nothing can be stated with confidence about its role in these accidents. This large number of unknowns occurred despite the fact that speed was estimated when throttle setting and total weight were known.

For 401 cases (86% of the total) the operator did not change throttle setting or this information was unknown. For those who did change throttle setting, 44 increased power and 23 decreased power (one unknown as to increase or decrease).

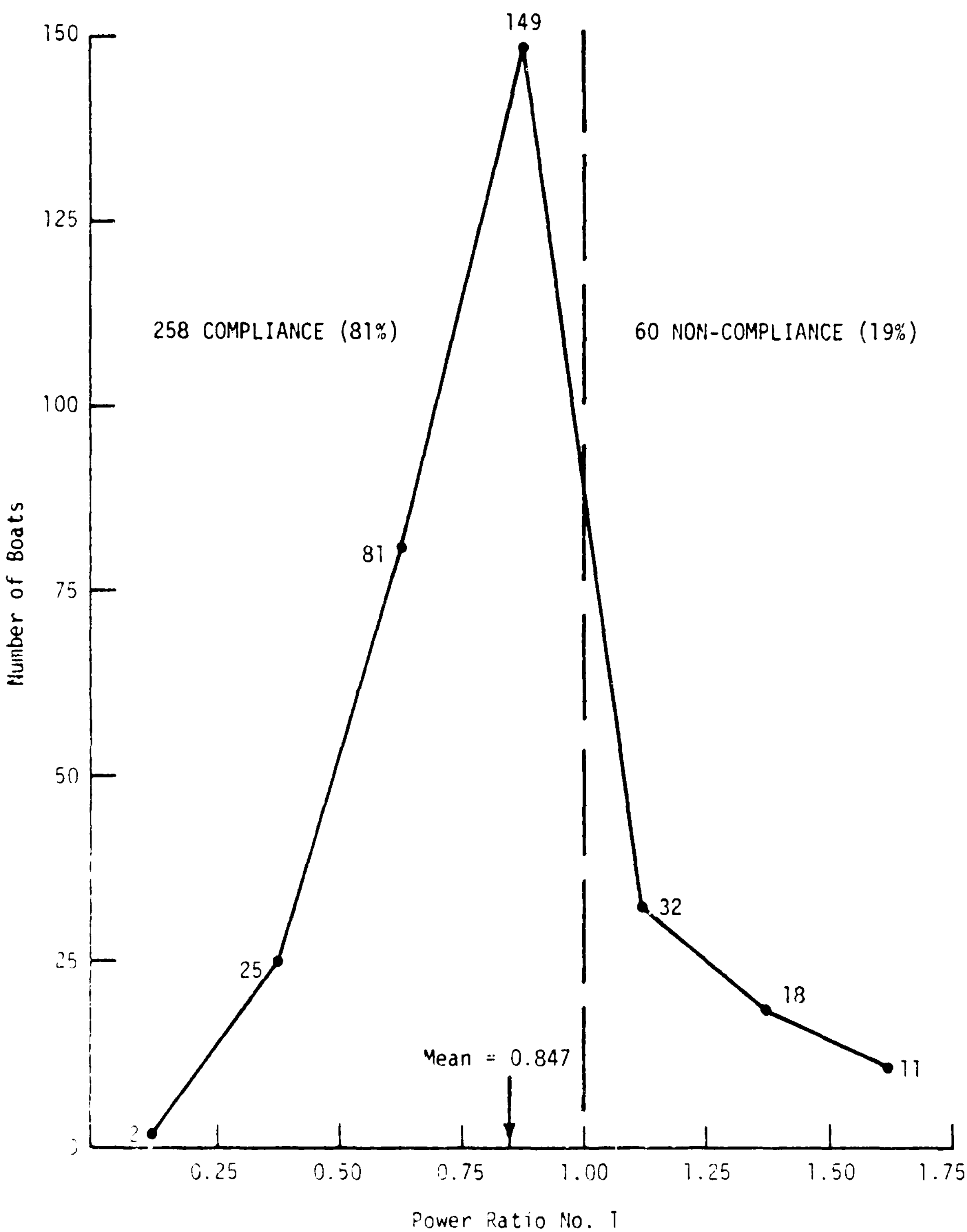
water conditions could have been a factor for about half of the accidents (calm - 50%), with 38% of the boats in choppy or rough conditions, and 12% in very rough conditions or a swift current. For the cases reported in CG-357 where water conditions were known (1976 data, earlier data not available), [illegible] were in calm water, 36% were in choppy or rough conditions, and 8% were in strong currents. The wind was strong or at a storm level in only 50 (11%) of the cases, and was calm, light, or moderate otherwise. For the known cases reported in CG-357 (1976), 13% were in strong or storm level winds, with the remainder in calm, light, or moderate winds.

The mode of acceptance data when viewed in conjunction with the accident type data reported above, indicate that a variety of accident mechanisms have to be described in order to account for all powering accident scenarios. The data reported in the preceding paragraphs show that it is not true that a few values of a few variables will describe the conditions that are dominant in powering accidents. More detailed accident data are presented for each accept node in the next section, and commonalities (sources for potential accident prevention programs and standards) are called out there, when possible.

Severity/Effectiveness Variables

The fact that 204 fatalities are included in the PRAM sample and over 1000 victims, indicates the magnitude of the powering problem. Several variables were included in PRAM in order to indicate the cost of these accidents in damage, injuries, and lives lost. Other data were included in order to allow the evaluation of regulatory concepts, including the present standard.

Frequency plots for each of the powering ratios identified previously were obtained and are shown on succeeding pages. Figure 2-8 shows the number of boats at each range of values for mounted horsepower divided by rated horsepower (the latter was determined by the formula in the powering standard). For the purposes of [illegible] all boats were used, including those that were built before 1972. Some of the older boats were in compliance with the regulation before it was adopted. The powering standard, if effective, should prevent many powering accidents, [illegible] reduce the severity of them when they do occur. Figure 2-8 shows that [illegible] boats in the PRAM sample were in compliance with the powering standard and



NOTE: 151 UNKNOWNS

FIGURE 2-8. FREQUENCY PLOT FOR MOUNTED HP/RATED HP FOR BOATS IN PRAM

...wering accidents anyway. If the standard were very effective, then many of ... accidents would have been prevented. While these data cannot stand alone, ... are suggestive of the fact that many powering accidents are not prevented ... by compliance with the current standard.

... I-4 presents the same data for boats built prior to 1972 and after 1972, separately. The curves are nearly identical. The current powering standard ... not alter the distribution of powering ratios for boats involved in those ...dents. As shown in the figure, the mean for power ratio number one (mounted ...power: rated horsepower) was the same for pre-regulation and post-regulation ... This mean (0.85) makes sense intuitively, since many boaters may buy an ... slightly less horsepower than the boat is rated for, rather ... greater than the rating. These data can be broken down still fur-... the distribution of power ratio number one is tabled only for outboards ... in length (i.e., only for those to whom the standard applies) the data ... result. A chi-square test* shows no significant relationship between ... of boat and power ratio (χ^2=1.66, four degrees of freedom, p 0.75). This ...ates no changes in the distribution of power ratios after the regulation was ...ed for the boats involved in powering accidents.

... of chi-square tests are used in this report. The purpose of this foot-... to ... describe the tests that were performed, and some of the proper-... of these tests. When one wishes to determine the significance of differences ... (or more) groups, a chi-square test may be used. The null hypothesis ... that there are no differences in the frequencies observed in the frequen-... in the data table. More specifically, the hypothesis under test is ... that the two (or more) groups differ with respect to some characteristic ... with respect to the relative frequency with which group members fall ... categories. The hypothesis is tested by counting the number of cases ... group which fall in the various categories, and comparing the proportion ... from each group in those categories with the proportion of cases from ... By convention, a level of significance of 5% (i.e., α=0.05) is ... as an acceptable probability of Type I error. The alternative ...thesis that is accepted when H_0 is rejected is that there are differences ...ween groups in the observed frequencies in various categories. The differences ... further examined by inspection. In some cases, the contribution to the chi-... calculation from a single comparison (one category) is enough to make the ... statistic significant. In these cases, such a category obviously is ...ted to a significant difference between the two groups.

* (continued)

en the data table is a breakdown of frequencies in a 2x2 contingency table, the st is computed as,

$$\chi^2 = \frac{N(|AD-BC|-\frac{N}{2})^2}{(A+B)(C+C)(A+C)(B+D)}, \quad df=1$$

ere A, B, C, and D are the table entries. For a larger data table, with r rows d k columns,

$$\chi^2 = \sum_{j=1}^{k} \sum_{i=1}^{r} \frac{(O_{ij}-E_{ij})^2}{E_{ij}}, \qquad df=(r-1)(k-1)$$

ere O_{ij} is the observed frequency in cell (i,j) and E_{ij} is the expected frequency ll (i,j). The E_{ij}'s are computed by multiplying the marginal total for row i by e marginal total for column j and dividing by the total of all the frequencies in e table. When the χ^2 value has been computed, then a statistical table of the stribution function for χ^2 is consulted to determine the critical χ^2 value based on the degrees of freedom and the desired level of significance. When the com- ited χ^2 statistic exceeds the value that has been found in the table, then H_0 is jected, otherwise, H_0 is accepted. In this report, we have chosen α=0.05.

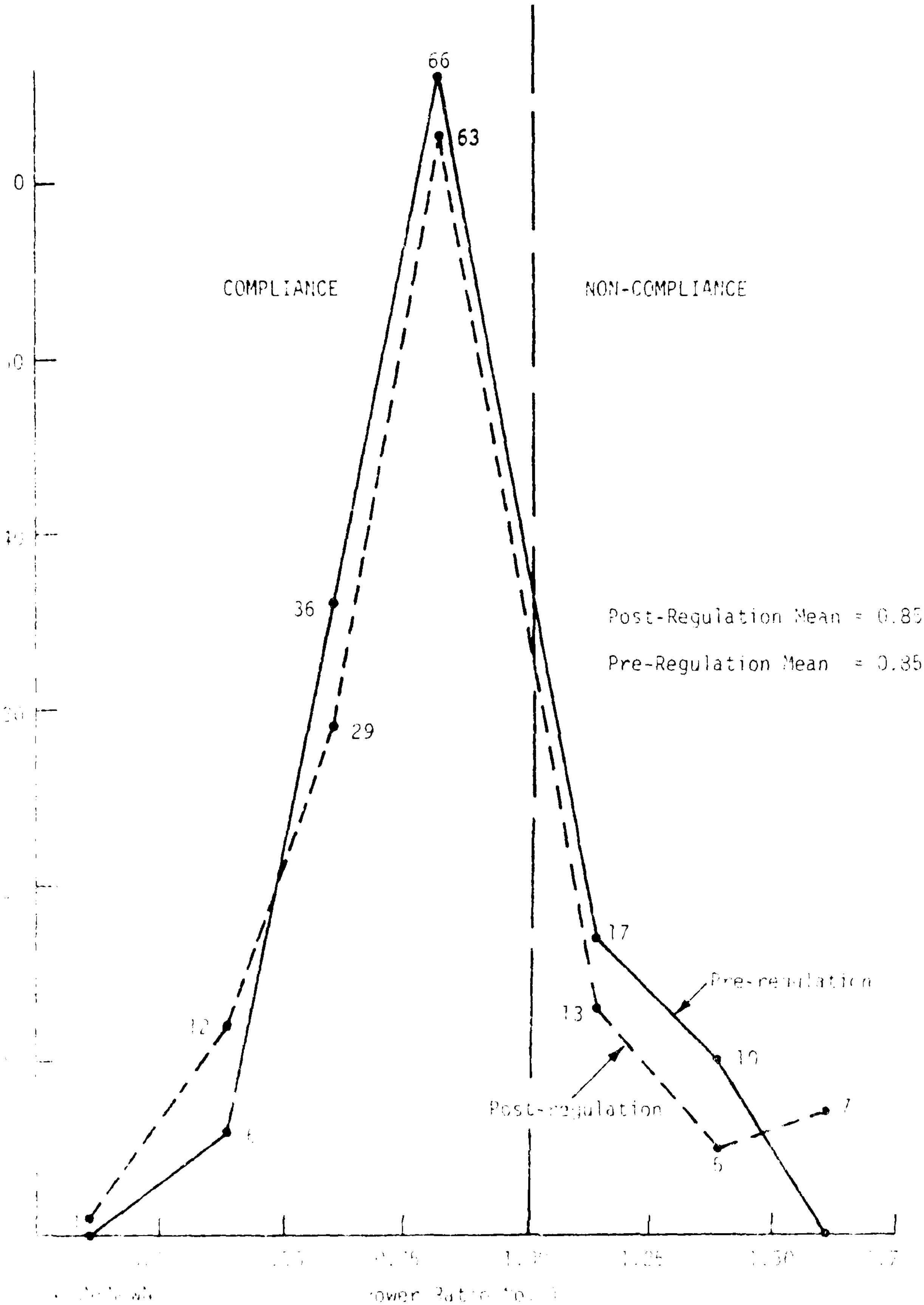
chi-square test on a 2x2 contingency table is often referred to as a "chi-square st for association" since the rejection of the null hypothesis implies some sociation between the two categorized variables; i.e., knowledge of one provides me information as to the probable value taken by the other. It also indicates at the cell by cell probabilities are different, such as in Table 2-19 of this port. A chi-square test on a 2xn contingency table is often referred to as a ni-square test for two independent samples" and results in a comparison of the o distributions across categories. The rejection of H_0 in this case implies that e distributions are not the same. These are the two major types of chi-square sts used in this report.

e interested reader is referred to:

Siegel, Sidney, Nonparametric Statistics for the Behavioral Sciences, New York: McGraw-Hill, 1956.

Hayes, William, Statistics, New York: Holt, Rinehart and Winston, 1963.

Winer, B.J., Statistical Principles in Experimental Design, New York: McGraw-Hill, 1971.


66
63
COMPLIANCE
NON-COMPLIANCE
36
29
Post-Regulation Mean = 0.85
Pre-Regulation Mean = 0.85
17
13
12
10
7
5
Post-regulation

ccident mechanism that is identified at this node is improper loading ee water in the boat. A typical scenario is:

A boat is proceeding at a fairly high rate of speed in rough water. As the amount of water that splashes into the boat increases, its loading effect increases and the rolling motion of the boat causes the water to slosh from side to side. Soon the operator is unable to maintain his course and a wave from the side of the boat causes the boat to capsize. Without PFDs, the victims soon drown or in some cases are trapped under the overturned boat.

Node 18

accidents accepted at Node 18 include falls within the boat and falls board that result from a wave or wake. The most frequently encountered dent mechanism for these accidents is unexpected boat movement. A typical ario for this mechanism is:

a) A boat is proceeding at a fairly high rate of speed with the occupants all seated in their seats or otherwise in good positions when, without sufficient warning, the boat makes a drastic movement because of the encroachment of a wave or wake. One or more of the occupants finds that the movement was of sufficient magnitude to throw him into the water, where, without a PFD, he soon drowns. In many cases, the occupants' or the operators' reactions have been impaired because of their ingestion of alcohol.

slightly fewer cases, the same accident mechanism is involved in the same e of accident portrayed in the above scenario with the exception that one more of the occupants contribute to the fall overboard by sitting on the k of a seat, on the gunwale, standing-up, or otherwise being in a poor ition within the boat. The results are often the same and the victim unders without a PFD.

Node 19

accidents accepted at Node 19 involve capsizings that are caused by a wave wake. The accident mechanism that is identified here is collision with a e. A typical scenario is:

a) A boat is proceeding at a fairly high rate of speed and encounters rough water which enters the boat over the bow or side as the boat is going too fast to follow the rolling motion of the water. With the boat being filled with water, the amount of freeboard is lowered and the boat eventually capsizes because of the continuing action of the waves. Without PFDs and, in many cases, being hampered by the ingestion of alcohol, the victims soon drown.

to prevent it from cranking when it is in gear and when the engine is cranked, the sudden surge tosses the occupant out of the boat. The victim, then, is either cut by the propeller, or drowns because he is not a good swimmer and is not wearing a PFD.

Node 17

ıccidents accepted at Node 17 involve boats which were swamped by a wave : over the bow or side. The accident mechanism frequently encountered s oscillatory momentum along the pitch axis. A typical scenario for an ıt involving this mechanism is:

) A boater proceeds against strong current or rough water caused by weather or other boat traffic. Because of the poor judgment on his load placement or the speed with which he should plough through, dynamic oscillations of the boat are forced out of phase with the waves. This condition worsens until a wave crashes over the bow, flooding the boat and drowning the engine. Free water in the boat compounds the problem by reducing freeboard and the oscillations finally reach such magnitude that the boat capsizes. Without PFDs, the occupants are soon victims of drowning.

r accident that is frequently encountered involving the same accident ism (i.e., oscillatory momentum about the pitch axis) is portrayed in enario:

) A boater is proceeding at high speed and rapidly encounters rough water Unable to stop, the boater jumps the first wave only to find the bow of his boat pitching under the top of the next wave. That wave crashes over the bow, fills the boat with water, and drowns the engine. The boat then capsizes and sinks, leaving the non-PFD wearing occupants in the free water and drowning.

ere were a few accidents accepte[illegible] t Node 14 that involved anothe[illegible]
chanism. This mechanism is impact of wave or wake from the side. A typical
enario for these accidents is:

c) A boat is proceeding at a fairly high rate of speed, perhaps pulling a skier. The skier falls or the operator otherwise decides to make a turn-around maneuver without reducing speed. While in the turn, the boat is hit by a wave or wake resulting in a capsizing or swamping of the boat. Since the occupants are not wearing PFDs, one or more become drowning victims.

Node 15

ose accidents accepted at Node 15 involve a sudden application of power
ether intentional or unintentional. The most frequently encountered accident
chanism here is sudden transverse acceleration. A typical scenario for an
cident involving this mechanism is:

a) Several persons are out pleasure cruising. The operator stops to drift for awhile or is proceeding along at idle speed. The operator decides to initiate more power and because of his misjudgment or his lack of experience, doesn't realize that this action will result in an occupant's dislocation or a collision or otherwise catastrophic action. One or more of the occupants ends up in the water without a PFD and dies either from drowning or from injuries received as the accident initiated.

other accident mechanism identified at this node is starting motor in gear.*
typical scenario for accidents initiated by this mechanism is:

b) During a normal day's boating the operator experiences trouble with the engine (a weak battery prevents electric start, or perhaps the engine just isn't running right). The operator or a passenger attempts to crank the engine by hand. The engine has no lock out

---

Note: These accidents were included in the sample because "starting in gear" was not originally stated or coded as the primary cause of the accident.

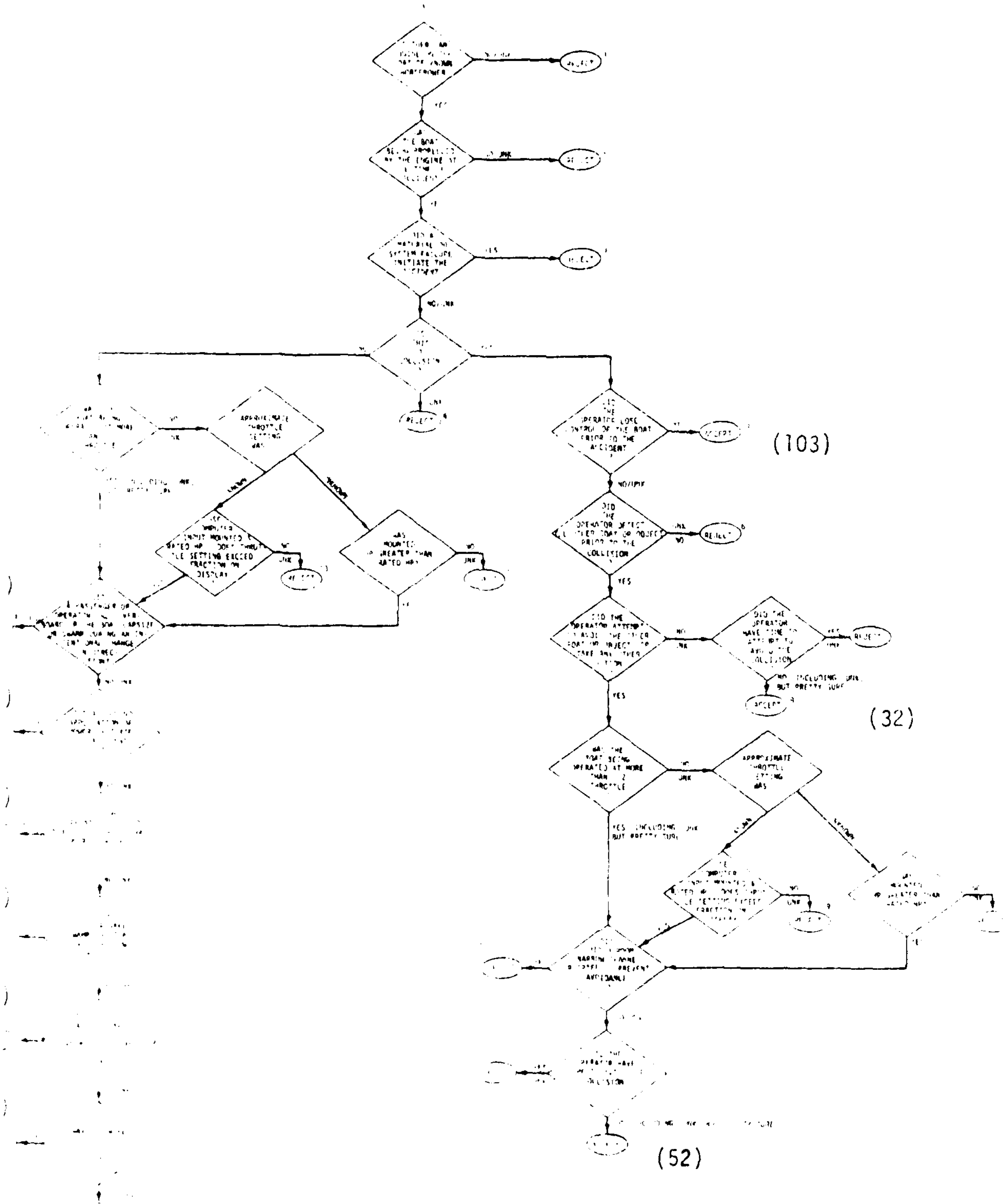


FIGURE 2-12. FREQUENCY DISTRIBUTION BY MODE OF ACCEPTANCE

2.3.3 Accident Mechanisms and Scenarios

The development of the provisions in PRAM for identifying the accident mechansims that initiate powering related accidents, and the detailed scenarios for the accident mechansims, is described in detail in Appendix A. This section uses these provisions to provide an indication of the relative frequency of occurrence of each mechanism. The distribution of powering related accidents by node of acceptance is shown in Figure 2-11.

Accident mechanisms and scenarios were derived for those accidents that were accepted at Nodes 14, 15, 17, 18, and 19 on the powering-related accident decision tree.

Node 14

Those accidents accepted at Node 14 involve capsizings, swampings, and falls overboard during intentional changes in direction (course changes). The most frequently encountered accident mechanism for these accidents was excessive lateral acceleration. A typical scenario for this mechanism is:

a) A boat is proceeding along its way at a fairly high rate of speed with one or more occupants improperly seated (i.e., sitting on a seat back, on the gunwale, or on the deck), and not wearing a personal flotation device (PFD). The operator starts to make a sharp (i.e., approximately 90°) turn and one or more of the occupants falls overboard, is hit by the boat or its propeller, and is killed or seriously hurt.

Slightly less often the same accident mechanism (excessive lateral acceleration) is involved in a scenario such as:

b) A boat is proceeding along its way at a fairly high rate of speed with its occupants properly seated in their seats but still not wearing PFDs. The operator starts to make a sharp turn and one or more of the occupants are thrown out by the violent action of the boat. The overboard victim is then hit by the boat or its propeller and is killed.

TABLE 2-21. HORSEPOWER: BOAT LENGTH VS. FATAL AND NONFATAL ACCIDENTS

RATIO #2

	NUMBER OF BOATS			
	0-3	3-6	6-9	9+
FATAL ACCIDENTS	82	40	17	25
NONFATAL ACCIDENTS	56	88	85	70

NOTE: There are 6 unknowns for this tabulation.

As with the other powering ratios before, the chi-square statistic for association in Table 2-22 is statistically significant (χ^2=11.51, degrees of freedom = 2, p<0.005), indicating that the distribution of boats in fatal accidents across powering ratio number three is different from the distribution for nonfatal accidents. The differences in the distributions are due to the fact that the boats in fatal accidents are more heavily concentrated in the lowest (0-0.1) category, while the boats in nonfatal accidents tend to be in the lowest or middle category.

Thus, all three power ratios have some predictive power in terms of severity, when severity is measured in terms of fatal versus nonfatal accidents.

This section has presented some analytical results from PRAM, many of which will be expanded in Section 3.0 when comparisons are made between powering and non-powering accidents. The next section deals with detailed accident data. Descriptions of the accident mechanisms are presented along with scenarios which reflect dominant powering problems.

TABLE 2-22. HORSEPOWER: TOTAL BOAT WEIGHT VS. FATAL AND NONFATAL ACCIDENTS

RATIO #3

	NUMBER OF BOATS		
	0-0.1	0.1-0.2	0.2+
FATAL ACCIDENTS	104	31	6
NONFATAL ACCIDENTS	114	77	13

NOTE: There are 124 unknowns for this tabulation.

is tabled below for fatal and nonfatal accidents. Some categories were collapsed to provide ample sample sizes in each cell of a crosstabulation.

The chi-square statistic for association for Table 2-20 is statistically significant (χ^2=9.39, degrees of freedom = 2, $p<0.01$), and indicates that the distribution of boats in fatal accidents across powering ratio number one is different from the distribution in nonfatal accidents. It appears, based upon these data, that the formula used in the current standard may bear some relationship to the severity (in terms of the distribution of fatalities by power ratio) of a powering accident; however, these data do not include exposure correlations or separate the pre- and post-regulation boats.

TABLE 2-20. MOUNTED/RATED HORSEPOWER FOR FATAL AND NONFATAL ACCIDENTS

RATIO #1

	NUMBER OF BOATS		
	LESS THAN 0.5	0.5 to 1.0	OVER 1.0
FATAL ACCIDENTS	14	60	25
NONFATAL ACCIDENTS	13	170	36

NOTE: There are 151 unknowns for this tabulation.

The chi-square statistic for association in Table 2-21 is very significant (χ^2=54.85, degrees of freedom = 3, $p<0.001$), and indicates that the distribution of boats in fatal accidents across powering ratio number two is different from the distribution in nonfatal accidents. In particular, the boats with low horsepower: boat length ratios in the PRAM data (6-9) are more likely to be in nonfatal accidents. (Again, this does not contain exposure information and includes boats built before and after the effective date of the regulation.) These two categories contributed 34.75 and 15.69 to the χ^2 statistic, respectively.

TABLE 2-19. BOATING SAFETY EDUCATION VS. COMPLIANCE

OPERATOR EDUCATION	NUMBER OF BOATS IN COMPLIANCE (MOUNTED HP: RATED HP < 1)	NUMBER OF NON-COMPLIANCE BOATS
None	134	41
At Least One Course	83	8

NOTE: There are 203 unknowns in this tabulation.

Severity Variables

The powering related accidents coded in PRAM account for 200 fatalities on the vessels coded and 4 fatalities on other vessels. These four additional deaths were from boats which were involved in a powering accident, but had no powering problem themselves. These boats may have had a collision with a boat that was coded in PRAM. The fact that there were only four fatalities on these other boats indicates that when multiple boats are involved in a powering accident (there were 26 total fatalities from boats involved in collisions in the powering sample) the fatalities are often people from the boat with the powering problem.

The total damage to the vessels coded in PRAM is between $220,000 and $440,000, while the damage to other vessels (ones that the PRAM boats collided with) is between $25,000 and $65,000. Thus, the total property damage is between one-quarter and one-half million dollars. These figures are based upon summing the lower (for lower bounds) and upper (for upper bounds) values for the codes used for each boat in the data base (see Appendix B).

[illegible] data (combined for PRAM boats and those that they hit) show between 30 and [illegible] man-months of incapacitation, and two people permanently disabled. These [illegible] do not express the magnitude of the powering problem as strongly as the 204 total deaths attributable to powering accidents in 1975 and 1976.

The [illegible] power ratios defined previously were crosstabulated with fatal versus [illegible] accidents in the PRAM data base. Presumably, if the ratios measure a propensity for having powering accidents, they might also measure the severity of [illegible]. That is, if the powering measure is high, this might indicate a [illegible] powering accident than if it were low. Each of these powering ratios

TABLE 2-17. HORSEPOWER PER TOTAL BOAT WEIGHT VS. ACCIDENT TYPE

	HP/TOTAL WEIGHT	
	LESS THAN 0.1	GREATER THAN 0.1
Collisions	52	49
Capsizings/Swampings	86	23
All Others	77	55

NOTE: There are 127 unknowns for this tabulation.

If experience with the vessel involved in the accident is cross tabulated with compliance or non-compliance with the current standard, the data in Table 2-18 result.

TABLE 2-18. COMPLIANCE VS. EXPERIENCE WITH THIS BOAT

OPERATOR EXPERIENCE WITH THIS BOAT	NUMBER OF BOATS IN COMPLIANCE (MOUNTED HP/RATED HP < 1)	NUMBER OF NON-COMPLIANCE BOATS
0-100 hrs.	76	18
100+ hrs.	94	21

NOTE: There are 260 unknowns for this tabulation.

The corrected Chi-square statistic for association in this table is non-significant ($\chi^2 < 0.01$), indicating no association between experience with this boat and a tendency for non-compliance in the PRAM sample. A similar result is found for total boating experience ($\chi^2 < 0.01$). When the data for boating safety education are tabulated (see Table 2-19), the corrected chi-square statistic for association is significant ($\chi^2 = 7.59$, 1 degree of freedom, $0.005 < p < 0.01$). This indicates that operators in the PRAM sample who had some formal boating safety instruction were much less likely to be in the non-compliance category than boaters with no boating safety education. This is indicative of a concern for general safety awareness and education on the part of the boater.

TABLE 2-15. ACCIDENT TYPE VS. COMPLIANCE WITH CURRENT STANDARD

	(POWER RATIO #1 $\leq$ 1.0) BOATS IN COMPLIANCE	(POWER RATIO #1 > 1.0) NOT IN COMPLIANCE
Collisions	113	16
Capsizings/Swampings	60	21
All Others	84	24

NOTE: There are 151 unknowns for this tabulation.

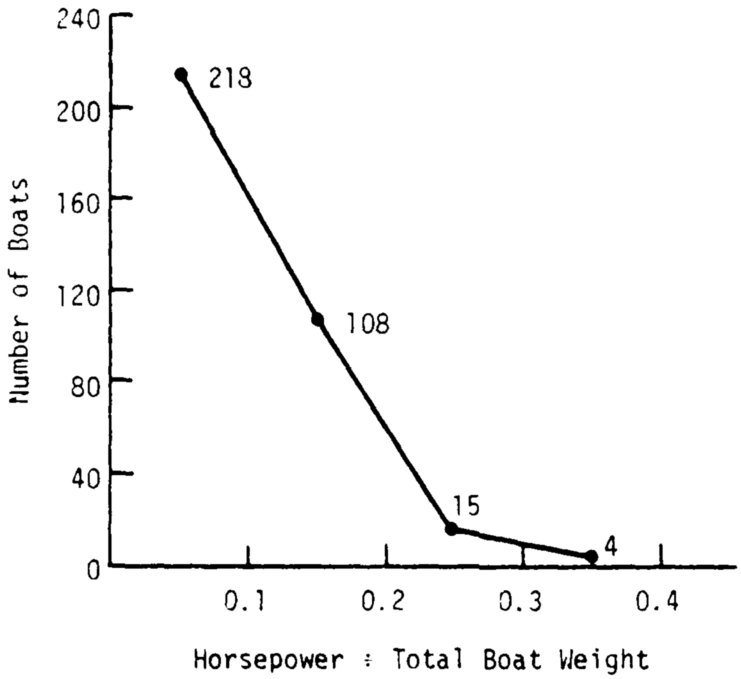
Accident type is crosstabulated with power ratio number two (norsepower per foot of boat length) in Table 2-16. The χ^2 statistic for these variables is very significant (χ^2=65.70, degrees of freedom = 6, p<0.001). It indicates that the proportion of boats involved in the three accident type categories differs from one category of hp/ft ratio to another. Capsizings and swampings are less frequent in the table as the horsepower per foot ratio increases. However, one must keep in mind that accidents initiated by water over the stern are not included in this sample.

TABLE 2-16. HORSEPOWER PER FOOT OF BOAT LENGTH VS. ACCIDENT TYPE

	HP/FT			
	0-3	3-6	6-9	9+
Collisions	21	51	53	52
Capsizings/Swampings	66	25	22	14
All Others	51	52	27	29

NOTE: There are 6 unknowns for this tabulation.

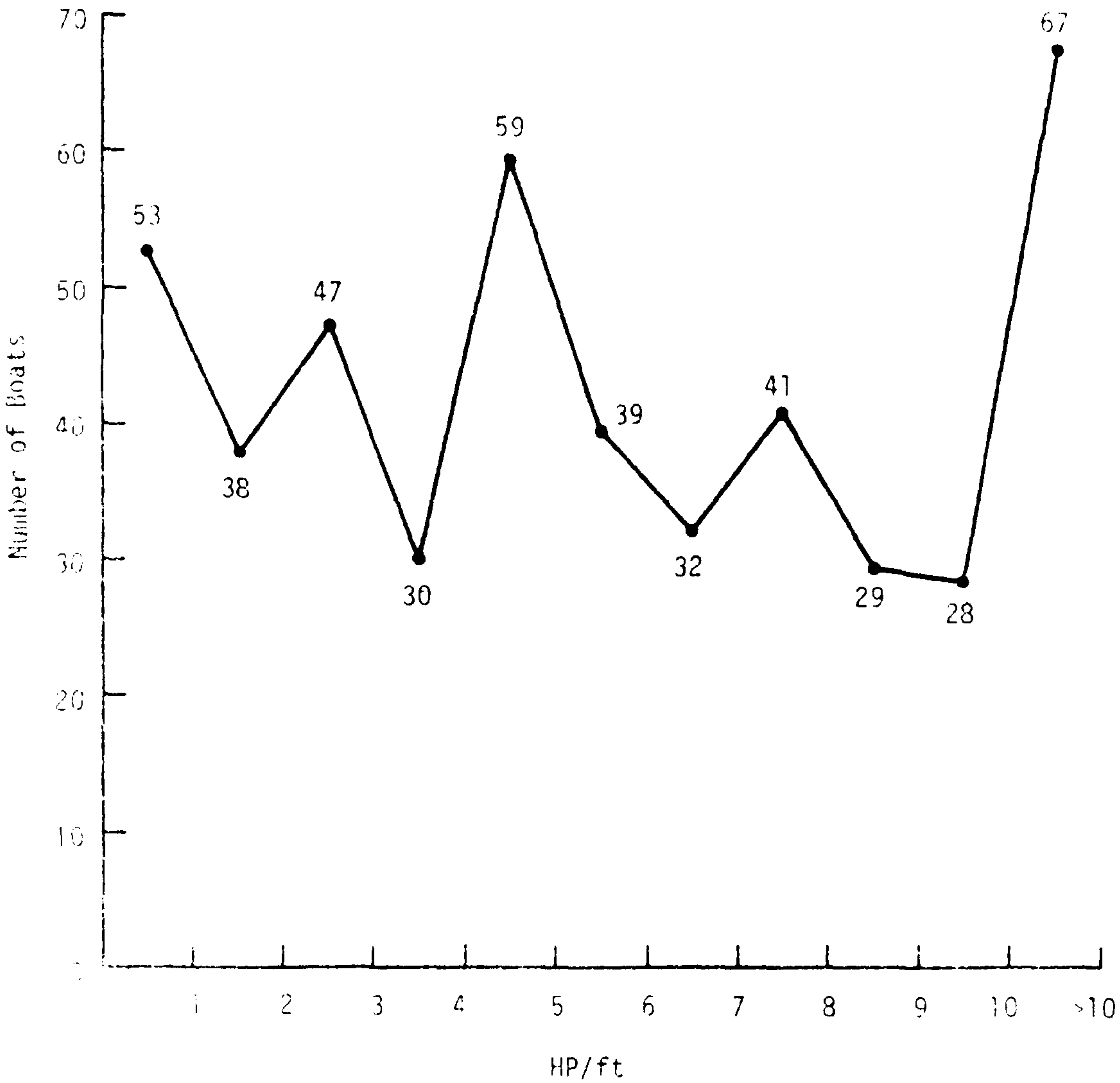
A similar table was generated for horsepower divided by total boat weight (power ratio number three). Several categories for tnis ratio were collapsed to create adequate sample sizes in the table. Table 2-17 presents these data. The chi-square statistic for this table is statistically significant (χ^2=16.63, degrees of freedom = [illegible]). The proportion of boats involved in the three accident type categories differs from one hp/wt ratio to another. The two cells in the category "capsizings/swampings" contributed 12.01 to the overall χ^2 calculation (more than enough to cause the statistical significance of the whole table), indicating that capsizings and swampings that are powering related are likely to involve boats with low horsepower/total boat weight ratios.



NOTE: 124 BOATS HAD UNKNOWN POWER RATIO NUMBER THREE

FIGURE 2-11. FREQUENCY PLOT FOR HORSEPOWER ÷ TOTAL BOAT WEIGHT

Accident type is crosstabulated with compliance or noncompliance with the current standard (mounted horsepower/rated horsepower less than 1.0 = compliance) in Table 2-15. Several categories in each variable were collapsed in order to provide ample sample sizes in each cell for a chi-square test of association. The statistic (χ^2=6.84, degrees of freedom = 2, $0.05<p<0.025$) is significant and indicates that boats in compliance with the current powering standard are distributed differently than boats not in compliance. For the noncompliance boats, collisions is the less frequent accident type, while for boats in compliance, this is the most frequent accident type. The contribution of these two cells to the chi-square statistic is 3.82 ($p(\chi^2 \geq 3.84)=0.05$ for 2 df), indicating that the category of collisions is the major source of the differences between the two groups.



NOTE: HP/ft unknown for six boats.

FIGURE [illegible]. FREQUENCY PLOT FOR HORSEPOWER PER FOOT OF BOAT LENGTH

TABLE 2-14. POWER RATIO NUMBER ONE DISTRIBUTION FOR PRE- AND POST-REGULATION OUTBOARDS UNDER 20 FEET IN LENGTH

	RATIO OF MOUNTED HP: RATED HP				
	.25-.50	.50-.75	.75-1.0	1.0-1.25	1.25<
Pre-Regulation	6	31	35	16	10
Post-Regulation	9	26	28	12	11

NOTE: Entries are the number of boats in the PRAM sample in each category. Unknowns (151) are not listed in the table.

Powering ratio number two (mounted horsepower divided by boat length) was computed for all boats in the PRAM sample. These data are plotted in Figure 2-10. The data are spread throughout all categories of horsepower per foot, with significant numbers of boats in each category. The fact that there are many boats with a high ratio of horsepower per foot (greater than ten to one) indicates that this measure might hold some promise as a regulatory measure in the limiting case of a very high ratio. That is, this measure takes on high values for many boats that were in powering accidents, and may be able to provide a means to discriminate powering accident craft and other craft. The determination of the effectiveness of such a concept is discussed in subsequent sections with these data compared to similar data for non-powering accidents.

A third ratio that was computed was horsepower divided by the total weight of the system (boat weight plus equipment/gas weight plus persons weight). These frequencies for powering ratio number three are plotted in Figure 2-11. This ratio shows little promise for a powering standard based upon the data from boats in powering accidents. Nearly two-thirds of the boats with a known ratio of horsepower to total boat weight were in the lowest ratio category. This means that this measure needs to be very accurately obtained in the lower end of the scale (ratios below 0.1) in order to discriminate between powering accident craft and other craft, or it does not discriminate well in any cases.

Several cross-tabulations were generated using the PRAM data in order to pursue relationships between important variables in the model. Several of these, including speed versus boat type and people on board versus rated persons capacity, contained so many unknowns (over 85%) that the tables were meaningless. These are not included in this report. However, several comparisons were made involving accident type, powering ratios, and operator skill/experience.

3.0 EVALUATION OF THE CURRENT STANDARD'S EFFECTIVENESS

Having defined a powering related accident and selected a group of these for investigation, some method was needed to evaluate the reason why the current safe powering standard had not prevented the fatalities associated with accidents. To do this, a group of accidents that was not determined to be initiated by overpowering needed to be selected and compared to the powering related accidents.

Additionally, there was a need to investigate accidents involving boats that were built before the effective date of the present regulation to determine if the regulation had any effect on altering mounted horsepower tendencies. Beneficial alterations should be reflected in a decrease in fatalities or accident propensity for boats built after the effective date of the regulation.

This section describes the process of selecting the non-powering related accidents and the results of the comparisons with the powering related accidents conducted to determine the effectiveness of the current standard in predicting or preventing fatalities associated with excessive horsepower outboard engines being mounted on recreational boats that are less than twenty (20) feet in length.

3.1 Current Standard

The current standard formula, as stated in Federal Register, Volume 37, Number 151, Title 33, Part 183, Subpart D, and reprinted here for ready reference, stipulates:

> "The maximum horsepower marked on a boat must not exceed the horsepower capacity determined as follows:
>
> (a) Compute a factor by multiplying the boat length in feet by the maximum transom width in feet including spray rails if spray rails act as chines or part of the planing surface. If the boat does not have a full transom, the transom width is the broadest beam in the aftermost quarter length of the boat.
>
> (b) Locate horsepower capacity corresponding to the factor in Table 183.53.
>
> (c) If the horsepower capacity in Table 183.53 is not an even multiple of 5, it may be raised to the next even multiple of 5.
>
> (d) For flat bottom hard chine boats with a factor of 52 or less, the horsepower capacity must be reduced by one horsepower capacity increment in Table 183.53."

TABLE 183.53 - OUTBOARD BOAT HORSEPOWER CAPACITY

COMPUTE: FACTOR = BOAT LENGTH X TRANSOM WIDTH

If factor (nearest integer) is	0-35	36-39	40-42	43-45	46-52
Horsepower capacity is	3	5	7-1/2	10	15

NOTE: For flat bottom hard chine boats, with factor of 52 or less, reduce one capacity increment (e.g. 5 to 3)

If factor is over 52.5 and the boat has	Remote steering and at least 20" transom height	No remote steering, or less than 20" transom	
		For flat bottom hard chine boats	For other boats
Horsepower capacity is (raise to nearest multiple of 5)	(2 X Factor) - 90	(0.5 X Factor) - 15	(0.8 X Factor - 25

This regulation applies to all outboard motor powered boats, less than twenty (20) feet in length and manufactured after November 1, 1972.

One must keep in mind, however, that the November 1, 1972 date is not a precise date for boats marked with horsepower capacities. This results from the fact that there were standards within the industry, promoted by the ABYC and BIA, in effect prior to this date. Also, some manufacturers, in anticipation of the approval of the standard, marked their boats according to the formula prior to the effective date. This is important to remember when comparing the accident probabilities for boats under the regulation and boats not under the regulation.

3.2 Non-Powering Related Accident Sample

To establish an accident file that contained non-powering related accidents that closely correlated the distribution of the powering related accidents with respect to type of boat and power, regions of the country, and severity (fatal vs. non-fatal), the 1975 and 1976 USCG accident files in Washington, D. C., were surveyed and a representative group of accidents was selected.

The [illegible] and meticulous effort conducted in Task II and discussed in Section [illegible] of this report to define a powering related accident showed additional merit when it came to defining a non-powering accident.

The accidents were considered to be non-powering related if they were rejected at any node on the powering related accident decision tree. The total number of accidents selected was determined so as to approximate the sample size of powering related accidents; the actual number was 400.

The accidents were selected manually from the files such that the ratio of fatal to non-fatal accidents, the percentages of outboard motors, and the distribution over the country for the non-powering related sample matched the powering related sample. This allowed the analysts to test the powering and non-powering samples equally without having to weight values because of small sample size. Such equality greatly increases the confidence one places on statistical significances in comparisons.

One significant difference between the powering related and the non-powering related samples is that all of the non-powering related accidents in our sample were taken from the 1975 accident file; whereas, eighty-six (86) of the fatal accidents in the powering related sample occurred in 1976. This fact does not negatively affect the validity of our analyses, since the two years can be isolated in our coding and the 1976 fatal accidents were intended to increase the event sequence information at various "accept" nodes to better identify the accident mechanisms and scenarios in the Task II effort.

Of the 400 accidents selected for the non-powering related sample, 235 were non-fatal accidents and 165 involved one or more deaths. Comparisons and cross-tabulations between the samples are discussed in Section 3.4 with interesting and significant findings being pointed out.

3.3 Coded Information and Coding Form

Because of the size of the non-powering accident sample, it was evident that a great deal of time could be saved during the coding effort if the information to be coded could be streamlined. Since the purpose of the non-powering related sample was to compare the probability of accidents between boats in compliance with the standard and boats not in compliance, it appeared that some of the bookkeeping information (such as state, month, day and time) would be of little value. Also, it was clear that information unique to powering related accidents would not be coded for non-powering accidents.

Since many crosstabulations of variables between the powering and non-powering samples would be required, the same coding sheet format was utilized for both samples to simplify the computer programming. The resultant coding sheet, shown in Figure 3-1, and coding instructions for the samples were identical with the exception that the coders were instructed to skip over the nonrequired variables and leave the columns for those variables blank on the coding sheet.

The coding instructions for coding the non-powering related accidents are presented in Appendix B of this report.

The same information was coded similarly for each variable regardless of whether it was a powering or non-powering accident. The variables and their columnar positions that were not coded for non-powering related accidents are:

Column(s)	Variable Name
5 & 6	State in which the accident happened.
7 & 8	Month when the accident happened.
9 & 10	Day of the month.
13 & 14	Time of day of the accident.
25	Motorwell.
26	Steering controls.
27	Motor manufacturer.
33 & 34	Maximum engine rpm.
35	Course.
36 & 37	Powering behavior.
41	Body of water.
43	Visibility.
44	Wind.
75 thru 80	Event trees.

It may appear that some of the variables that were not coded for the non-powering related accidents would be beneficial information for determining overall boating trends; however, that information is contained in boating survey reports for all reported boats and accidents. It is more beneficial to use the more complete survey information than draw conclusions from a small sample if the information is readily available. Therefore, we reduced the amount of time required to code

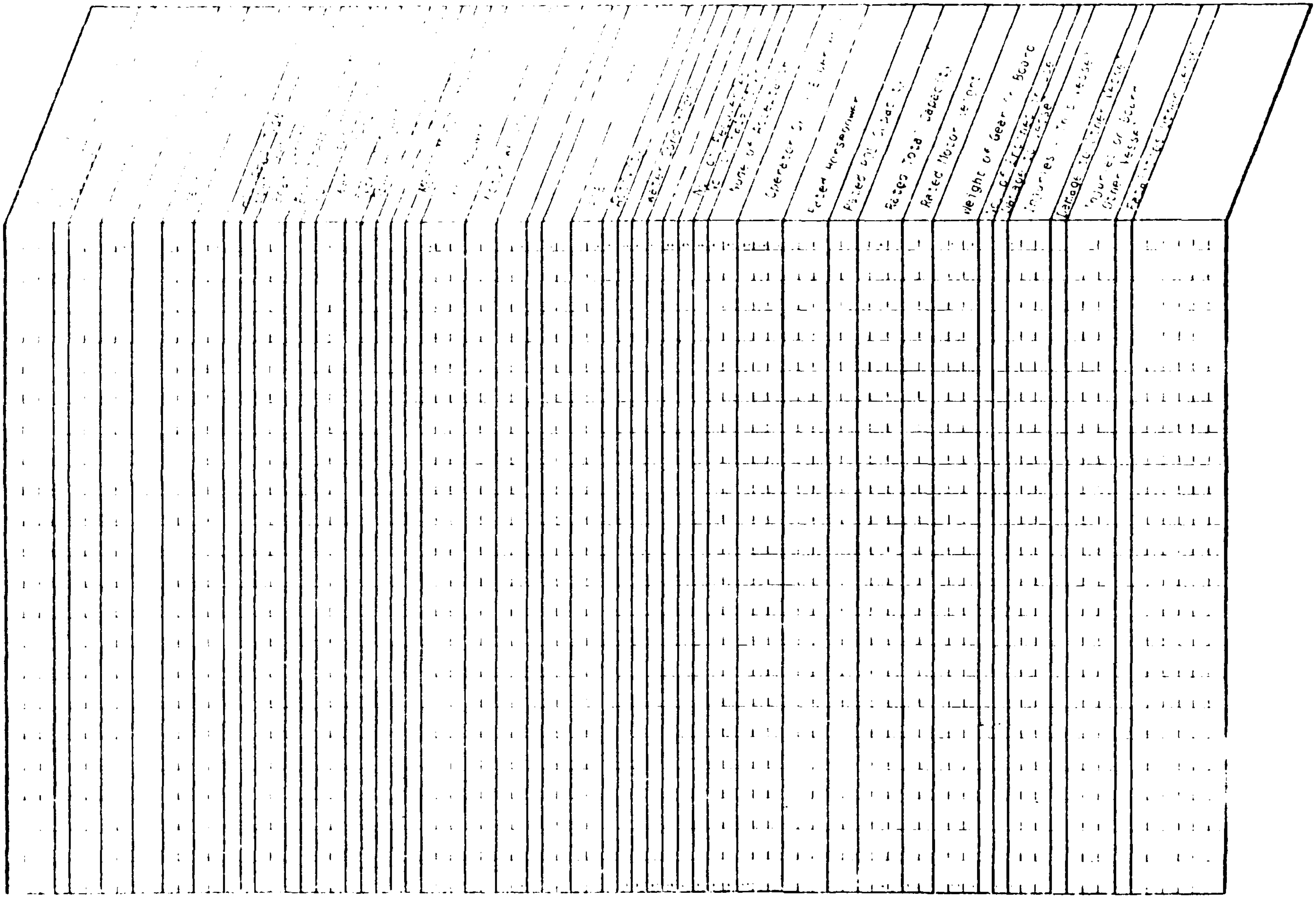


FIGURE 3-1. THE NON-POWERING RELATED ACCIDENT CODING FORM

the non-powering accident sample without losing any valuable information that could be included in the BARs.

Results of some of the earlier analyses and discussions with Wyle and USCG personnel indicated that the johnboats presented a particularly unique problem. To more clearly ascertain if this was a sound conclusion, the entire accident sample (both powering and non-powering) was reviewed and each boat was coded by whether or not it was a jonnboat type. Additionally, the weight of the boat hull for each boat in the sample was coded.

The information required to determine the power ratios for each boat in the sample was included to establish the number of boats in compliance with the powering regulation and the significant difference (if any) of power ratios for boats involved in powering and non-powering related accidents.

The following sections discuss the results of the analyses performed in evaluating the current standard.

3.4 Effectiveness Evaluation of the Current Powering Standard

There are several ways in which the current powering regulation may be shown to be effective. It may result in reducing the frequency (number) of powering accidents. It may result in reducing the severity of such accidents, without necessarily affecting their frequency. Finally, it may reduce the powering accident rate; i.e., it may reduce the number of accidents and/or deaths per 100,000 hours of boating activity or per 100,000 boats. On succeeding pages, each of these approaches to current powering standard effectiveness are investigated. Modifications to the current standard are also evaluated. The modifications that are considered represent merely multiplying the rated horsepower by varying constants. Comparisons are made between powering and non-powering data.

An important conceptual distinction is needed in order to fully comprehend the discussions that follow. The distinction is between statistical significance and importance (or practical significance). While there may be a statistically reliable difference in the average distance of a Hank Aaron home run as opposed to a Mickey Mantle home run, the difference is not important (nor practically significant) since the end result of any home run is the same. With respect to the powering accident data, the difference between the chances of having a powering accident with a 10 hp engine as opposed to the chances of having a non-powering accident may be statistically significant with non-powering accidents being much more likely to occur. However, such a difference is unimportant (and not practically significant) because it merely means that powering accidents are unlikely when the boat has a very small engine. Issues such as these will arise in the analyses that follow.

The most important results of the analyses in this section are: 1) the current standard appears to have some potential effectiveness if one looks at boats built prior to 1972 (outboards, less than 20 ft, but pre-regulation), and 2) the effectiveness does not carry over into the post-regulation boats. For boats (outboards, less than 20 ft) built after 1972, the current standard does not relate to accident severity or frequency. Explanations are offered as to why the pre-1972 data indicate that the standard has potential effectiveness and why the post-1972 data indicate that the promulgation of the standard had no noticeable effect on boating accidents.

3.4.1 The Current Standard and Powering Accident Frequency

If the current standard is effective, one might expect that those in compliance with the standard would be less likely to have a powering accident than those not in compliance (assuming similar exposure). Table 3-1 presents the theoretical distribution of data for an "ideal" powering standard, where no one who complies with the standard has a powering accident. The closer the data come to this configuration for the current standard, the more effective it is.

TABLE 3-1. THEORETICAL DATA DISTRIBUTION FOR AN IDEAL POWERING STANDARD

	HAD A POWERING ACCIDENT	HAD A NON-POWERING ACCIDENT
In Compliance	0	X
Not In Compliance	X	X

Table 3-2 presents the data from PRAM for all outboard boats less than 20 ft in length. The data indicate that those boats in compliance with the current standard are less likely to have a powering accident than those not in compliance (corrected $\chi^2_{(1)} = 4.878$, $p < 0.05$). This indicates that compliance with the standard may be effective in reducing powering accidents. If these data are eparated into pre- and post regulation distributions, a somewhat different result is depicted.

TABLE 3-2 PRAM DATA DISTRIBUTION FOR CURRENT STANDARD

	HAD A POWERING ACCIDENT	HAD A NON-POWERING ACCIDENT
In Compliance	118	124
Not In Compliance	62	37

Note: Boats listed as being manufactured in 1972 are omitted.

Tables 3-3 and 3-4 present the same breakdown as Table 3-2, except for the pre-regulation and post regulation (pre-1972 and post-1972) boats. The data for boats made in 1972 are not included because the standard took effect during the year (was a 1972 boat made before or after it took effect?), and many manufacturers anticipated the standard in thier 1972 boats. The data in Table 3-3 show a marginally significant relationship between compliance with the standard and the probability of a powering accident as opposed to non-powering accident (corrected $\chi^2_{(1)}=3.215$, $0.10>p>0.05$). The data in Table 3-4 show no such relationship (Fisher exact p=0.144).* Thus, the overall relationship in Table 3-2 is based primarily upon the standard's effectiveness as measured by pre-1972 boats, and hides the fact that no effectiveness can be demonstrated for post-1972 craft.

* The Fisher exact test is applied in the same situations where a χ^2 test for a 2x2 contingency table is often used. The null hypothesis is the same. The Fisher exact test, however, is more accurate. However, it is cumbersome to compute in cases other than those where the total sample size is small. Wyle has programmable calculators that can compute Fisher exact probabilities for tables that do not exceed the computational capacity of the machines. When that capacity is exceeded, χ^2 tests are used instead. Table 3-4 was the first case in this report where the frequencies were small enough to permit the computation of a Fisher exact probability on an HP-67 or HP-97. The interested reader is referred to Non-Parametric Statistics, by Siegel, referenced earlier.

TABLE 3-3. PRE-1972 DATA DISTRIBUTION FOR CURRENT STANDARD

	HAD A POWERING ACCIDENT	HAD A NON-POWERING ACCIDENT
In Compliance	72	81
Not In Compliance	36	22

TABLE 3-4. POST-1972 DATA DISTRIBUTION FOR CURRENT STANDARD

	HAD A POWERING ACCIDENT	HAD A NON-POWERING ACCIDENT
In Compliance	46	43
Not In Compliance	26	15

The data for Tables 3-2, 3-3, and 3-4 were dichotomized by whether or not the boats in question were in compliance with the current standard. This was determined by computing a power ratio, defined as the mounted engine horsepower divided by the boat rated engine horsepower. A power ratio of 1.0 or less was in compliance with the current standard. The standard could be revised to accept larger or smaller horsepowers by accepting larger or smaller ratios. This would be equivalent to multiplying the current boat rated horsepower by varying constants. Thus, if the power ratio criterion were changed to 0.5, then the mounted horsepower would have to be one-half or less of the current boat rated horsepower (as determined by the formula) to be in compliance.

The data were broken down further (as shown in Tables 3-5, 3-6 and 3-7) to show the changes in the distributions of power ratios for powering and non-powering accidents. If the standard were relevant to the problem of powering accidents, then those boats in powering accidents should have (generally) higher power ratios than those in non-powering accidents.

The results reflect the same phenomena as before. Table 3-5 shows an overall difference in the distributions of power ratios for the powering and non-powering accidents ($\chi^2_{(5)}=21.834$, $p<0.001$). Table 3-6 shows a statistically significant difference in the distributions for the pre-1972 data ($\chi^2_{(5)}=15.113$, $p<0.01$), while

ıle 3-7 reveals no significant difference in the post-1972 data ($\chi^2_{(5)}$ ... ,
).10). This means that there is a tendency for the power ratios for the boats powering accidents to be higher than for those in non-powering accidents for ıts made before 1972, but not for newer boats. The first category in Table 3-6 -0.5) contributed 9.06 to the overall χ^2 for the table.

ıce the standard was passed, it has not differentiated the powering and non-powing accident data by power ratio, or by accident frequency.

TABLE 3-5. POWER RATIO BY TYPE OF ACCIDENT FOR ALL BOATS

	POWER RATIO					
	0-0.5	0.5-0.75	0.75-1	1-1.25	1.25-1.5	Over 1.5
d a Non-Powering Accident	33	33	58	11	16	10
d a Powering Accident	14	50	54	25	13	24

ote: 128 unknowns

TABLE 3-6. POWER RATIO BY TYPE OF ACCIDENT FOR PRE-1972 BOATS

	POWER RATIO					
	0-0.5	0.5-0.75	0.75-1	1-1.25	1.25-1.5	Over 1.5
d a Non-Powering Accident	21	22	38	8	10	4
d a Powering Accident	6	31	35	16	10	10

TABLE 3-7. POWER RATIO BY TYPE OF ACCIDENT FOR POST-1972 BOATS

	POWER RATIO					
	0-0.5	0.5-0.75	0.75-1	1-1.25	1.25-1.5	Over 1.5
d a Non-Powering Accident	12	11	20	3	6	6
d a Powering Accident	8	19	19	9	3	14

ıe analysis above leads to similar analyses for various regulatory criteria using ıe same formula. In other words, does multiplying the formula by a constant equivalent to changing the power ratio criterion for compliance from 1.0 to the ınstant) result in a more effective standard in terms of accident frequency. The ıalyses performed in Tables 3-3 and 3-4 were repeated for varying power ratio ·iteria. In each case, the relationship was observed and compared to the ideal !lationship shown in Table 3-1. Figure 3-2 presents the results of those !peated statistical comparisons, and includes the data presented earlier for ıe current standard. On this figure, the low points (near 0.05 or below on the ·dinate) indicate that the corresponding regulation criterion (abscissa) differ- ıtiates powering and non-powering accidents well.

ıe pre-1972 data in Figure 3-2 indicate that the formula had moderate or stronger ffectiveness at several criteria (0.25, 0.5, 1.0, 1.5, 1.75, 2.0). The low ılues (0.25 and 0.5 to some extent) correspond to severely limiting horsepower ı small boats. Obviously, if horsepowers were severely limited (say to the order f a few pounds of thrust), fewer powering accidents would result. Thus, the tatistical significance of those data points is not important. The upper points 1.75 and 2.0) correspond to regulating only against severely overpowered boats. bviously, if a boater could not meet these lenient criteria, then he would be ery likely to have a powering accident. Here again, the results are statistically ıgnificant, but not important. The data for the current standard, as reported efore, also show moderate effectiveness, and this result is important. It shows hat the observed relationship (in Table 3-3) between the standard and having a owering or non-powering accident was unlikely to have happened by chance.

or the post-1972 data, only one point is in the significant region (0.05 or less), nd that is for the power ratio criterion of 0.25. This corresponds to saying that owering accidents would be prevented if all post-1972 boats were allowed only one- uarter of their rated horsepower. This result is statistically significant, but ot important since such a criterion would be impractical.

inally, if the current standard is effective, then a larger percentage of the re-regulation boats should be in the powering sample than the percentage of ost-regulation boats in that sample. The data in Table 3-8 indicate that such a elationship does not exist in the PRAM data. The breakdowns of pre- and post- egulation boats for the powering and non-powering accident samples were nearly dentical (corrected $\chi^2_{(1)} = 0.315$, $p > 0.5$).

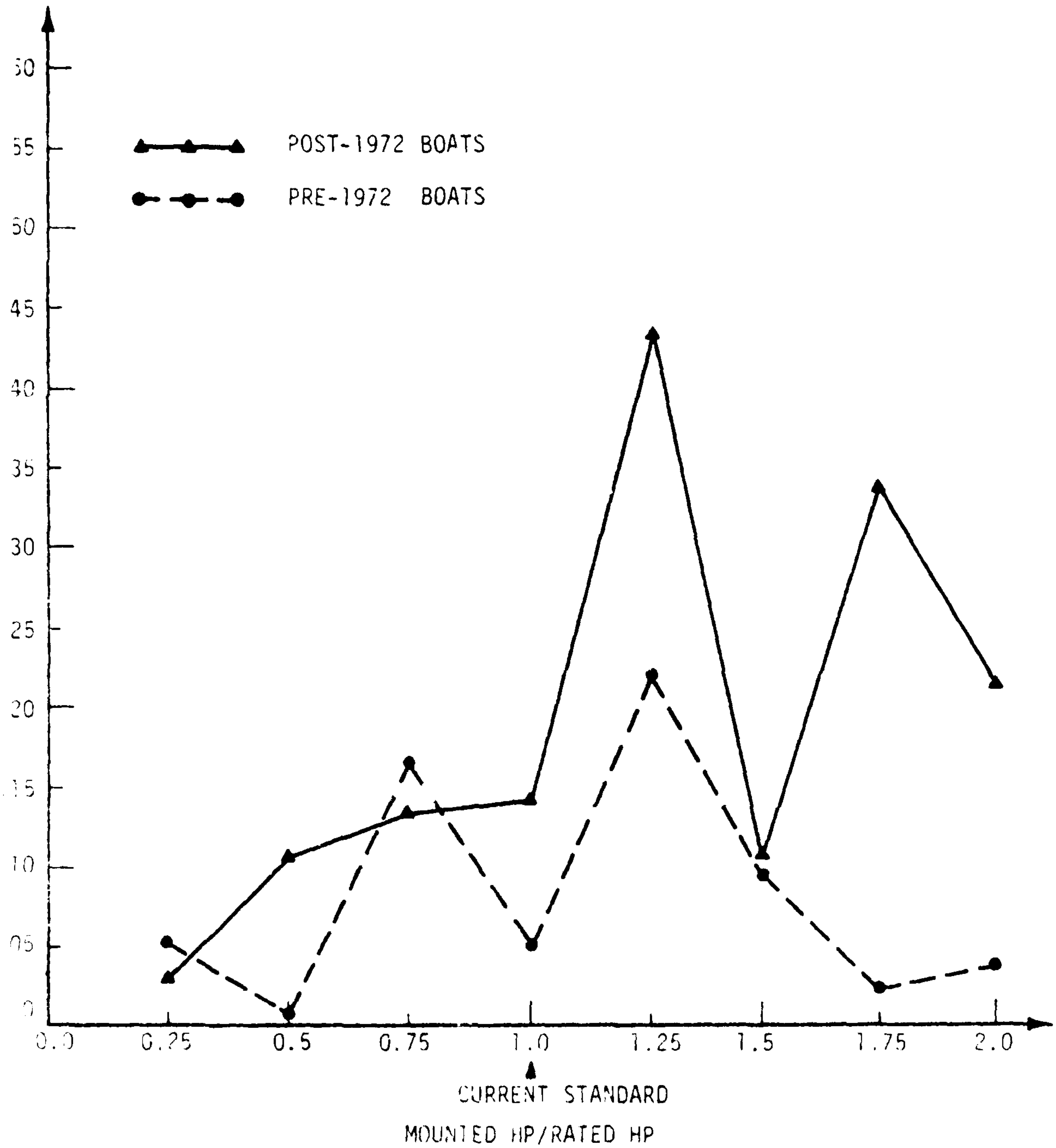


FIGURE 3-2. POWERING/NON-POWERING VS. COMPLIANCE/NON-COMPLIANCE FOR ALL BOATS BY REGULATION CRITERION

TABLE 3-8. TYPE OF ACCIDENT BY AGE OF BOAT

	HAD A POWERING ACCIDENT	HAD A NON-POWERING ACCIDENT
egulation Boats	72	81
Regulation Boats	46	43

: Table considers only those boats with ratio one being less than unity.

, no matter how the criterion is changed, using the present powering standard formula), compliance with the standard does not differentiate powering and powering accident frequency, nor the power ratios for boats in those accis, for boats manufactured after the promulgation of the standard.

3.4.2 The Current Standard and Powering Accident Severity

e from the question of preventing or reducing the frequency of powering dents, the effectiveness of the current standard in reducing the severity of ring accidents must be explored. This issue can be addressed by comparing powering accident severity to the observed power ratio. If the standard mula) correlates well with powering accident severity, then the accidents lving boats with high ratios should be more severe than those involving low os. Ideally, if the standard were a perfect measure of severity, then those comply with it would survive, and those that did not comply would be more ly to die. Table 3-9 presents the theoretical distribution of data for the l standard. The current standard is evaluated in succeeding tables against ideal.

TABLE 3-9. IDEAL DISTRIBUTION OF SEVERITY DATA (IN TERMS OF FATALITIES) FOR POWERING ACCIDENTS

	IN COMPLIANCE	NOT IN COMPLIANCE
Had a Non-Fatal Accident	X	X
Had a Fatal Accident	0	X

hese analyses, severity is dealt with in terms of fatalities. Data were d in PRAM on the property damage, injuries, and other losses associated with ring accidents. However, using a number of $480,000 per life, the nonlity losses amounted to less than the equivalent of two lives lost, while ities for powering accidents in PRAM totalled 204 lives lost. Thus, es other than lives lost represent less than 1.5% of the severity of accidents. Therefore, only fatalities are included in these analyses.

10 shows the distribution of fatal and non-fatal accidents for pre-1972 the PRAM sample that are outboards, less than 20 ft, and in powering s. No statistically significant relationship exists in these data exact p = 0.359). Similarly, Table 3-11 shows the same breakdown for 2 boats. These data are also statistically insignificant (Fisher exact 3).

TABLE 3-10. SEVERITY DATA FOR POWERING ACCIDENTS FOR CURRENT STANDARD FOR PRE-1972 BOATS

	IN COMPLIANCE	NOT IN COMPLIANCE
a Non-Fatal Accident	48	22
a Fatal Accident	24	14

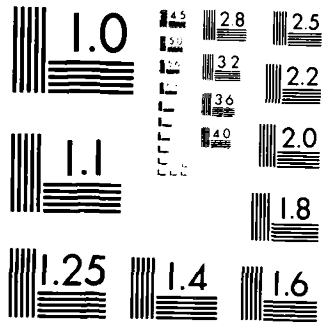
TABLE 3-11. SEVERITY DATA FOR POWERING ACCIDENTS FOR CURRENT STANDARD FOR POST-1972 BOATS

	IN COMPLIANCE	NOT IN COMPLIANCE
a Non-Fatal Accident	29	14
a Fatal Accident	17	12

pens if the regulation criterion is varied? Figure 3-3 shows the statis- nificance (ordinates near 0.05 or below are significant) of using dif- wer ratio criteria in terms of differentiating levels of severity. For 1972 data, the power ratio of 1.25 (= mounted horsepower ÷ formula rated er) correlates well with severity. The boats that exceeded this ratio re-1972 data were much more likely to have a fatal accident than those not. However, no criterion even approaches statistical significance post-regulation (post-1972) data.

ere was some indication that a modification of the current standard ounted hp/rated hp 1.25 as compliance criterion) might provide a good

AD-A152 575 A STUDY TO DETERMINE THE NEED FOR A STANDARD LIMITING 2/3
THE HORSEPOWER OF RECREATIONAL BOATS(U) WYLE LABS
HUNTSVILLE ALA R WHITE ET AL. SEP 78 MSR-78-12
UNCLASSIFIED USCG-D-36-83 DOT-CG-62655-A F/G 13/12 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

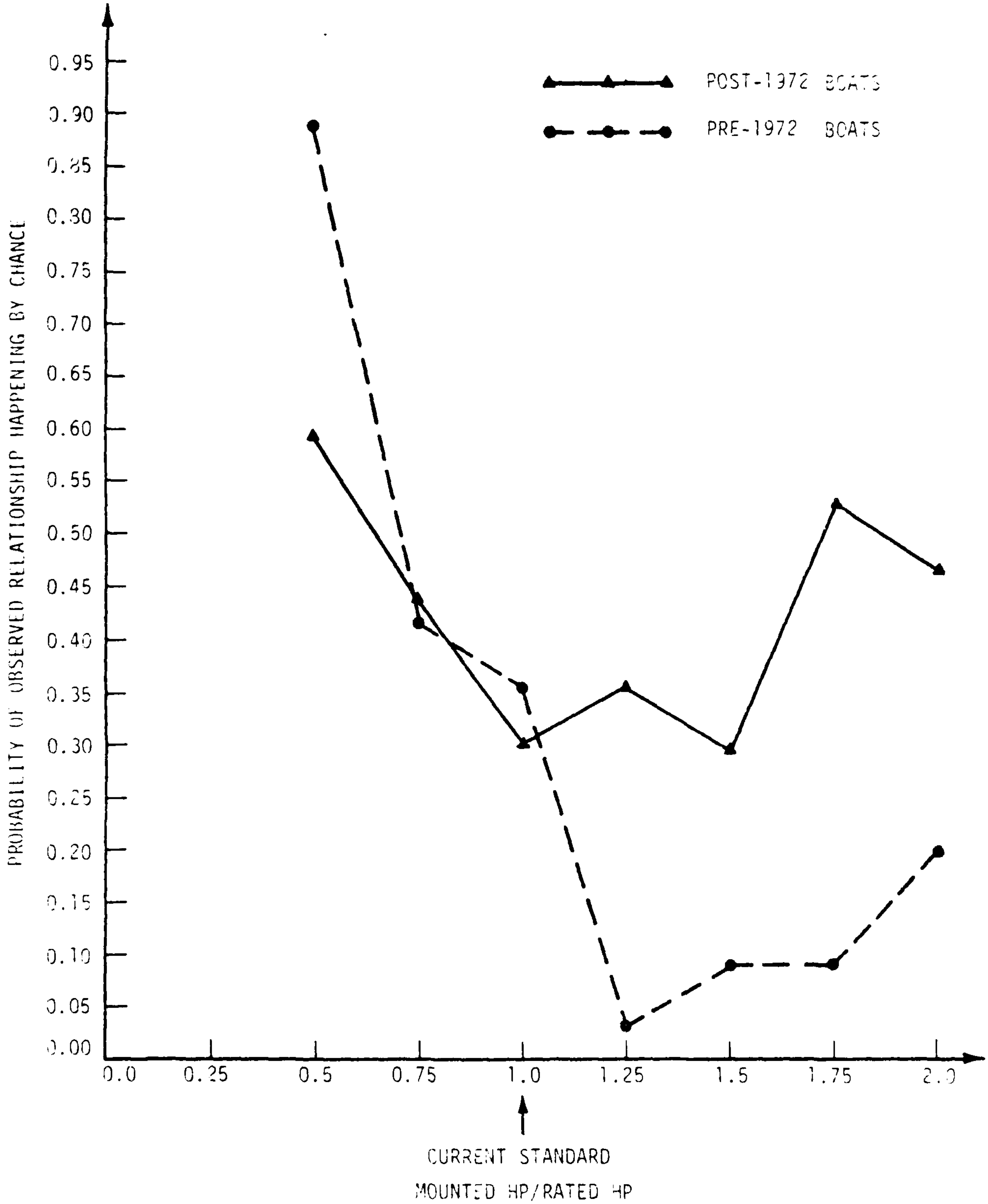


FIGURE 3-3. BOATS IN POWERING ACCIDENTS:
FATAL VS. NON-FATAL (SEVERITY) BY REGULATION CRITERION

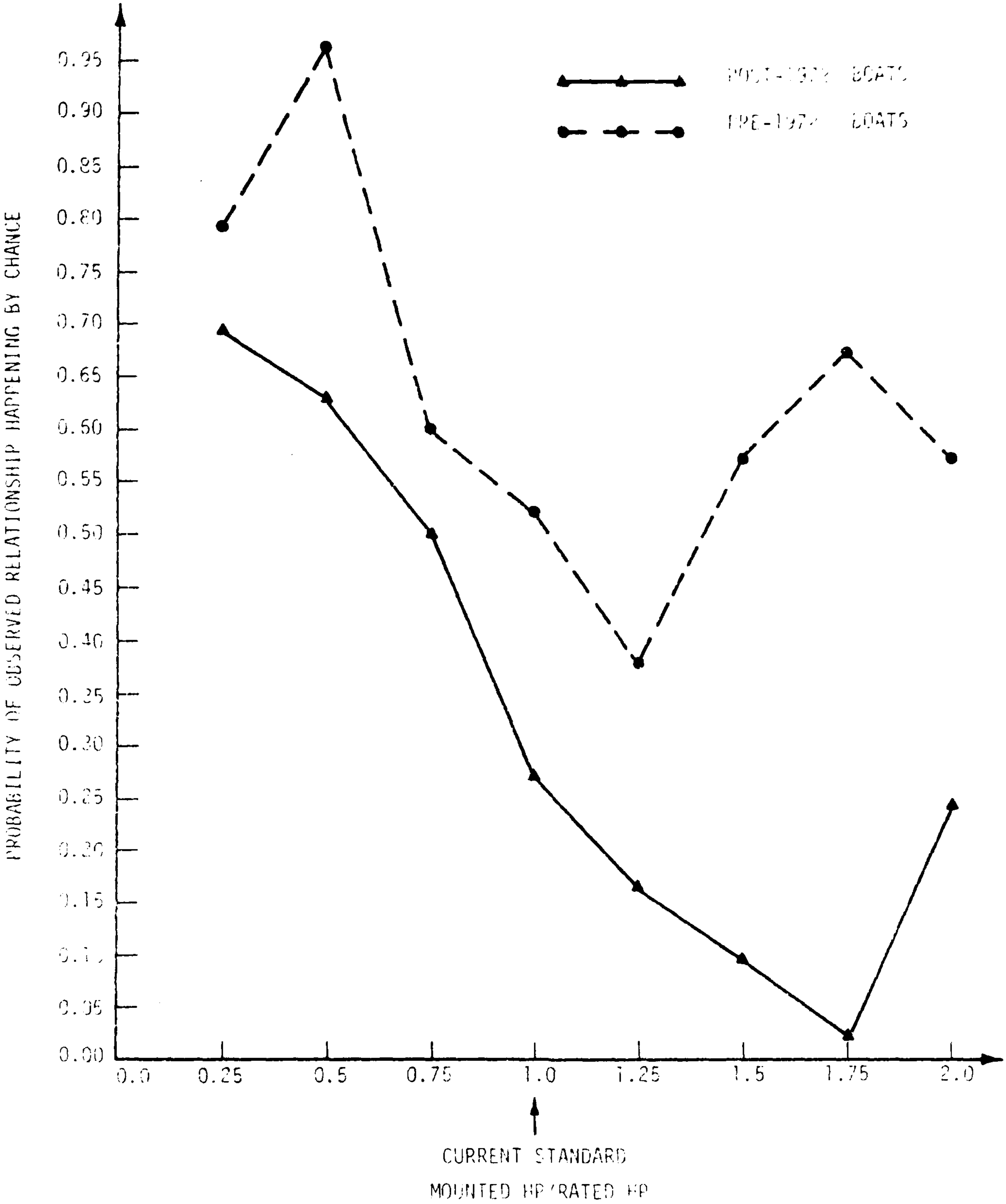


FIGURE 3-4. BOATS IN NON-POWERING ACCIDENTS:
FATAL VS. NON-FATAL (SEVERITY) BY REGULATION CRITERION

relationship with powering accident severity, the same kind of analyses were performed for non-powering accidents. There is no a priori reason to expect any relationship between compliance with a modification of the current standard and non-powering accident severity. Figure 3-6 presents the results of the non-powering accident severity analyses for outboards less than 20 ft in length, for pre- and post-regulation craft. For the post-1972 data, only the criterion of 1.75 generates a statistically significant result (ordinate $\leq$ 0.05). This result is difficult to interpret since a boater who has more than 1.5 times the rated horsepower on his boat may violate other safety precepts which result in his being in a non-powering fatal accident. In any case, there is no relationship between the current standard (a criterion of 1.0) and severity in the pre- or post-regulation data.

Severity and frequency analyses can be combined by analyzing the pre- and post-regulation data for fatal accidents only. Ideally, if the current standard were extremely effective, then there would be no fatal accidents for boats which complied with it, as shown in Table 3-12. The data for pre- and post-regulation outboard boats of 20 ft or less were analyzed by varying power ratio criteria. These data were statistically compared to the i-eal shown in Table 3-12. This was done by comparing the actual 2x2 contingency data with the "ideal" (meaning no fatalities for those in compliance) 2x2 contingency table having the same marginal totals. The test statistic (or measure) used was a χ^2 goodness-of-fit test, where the "ideal" table was considered the null hypothesis (i.e., the "expected" distribution). The results are shown in Figure 3-5, where a low ordinate (near or below 0.05) means that the corresponding criterion (abscissa) has a strong association of the type indicated in Table 3-12 for fatal accidents.

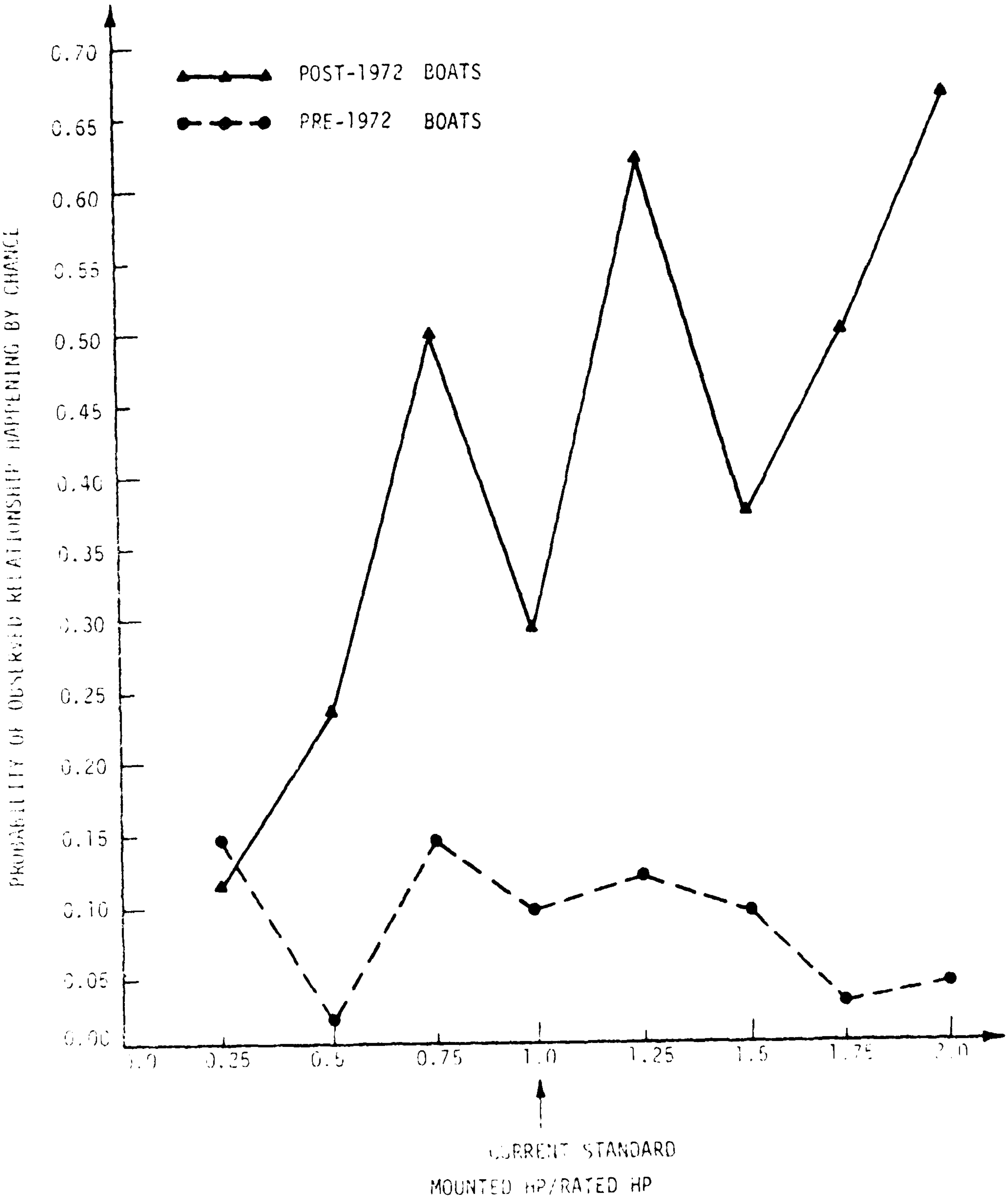


FIGURE 3-5. POWERING/NON-POWERING VS. COMPLIANCE/NON-COMPLIANCE FOR FATAL ACCIDENTS BY REGULATION CRITERION

TABLE 3-12. THEORETICAL FATAL ACCIDENT DISTRIBUTION FOR IDEAL STANDARD

	HAD A POWERING ACCIDENT	HAD A NON-POWERING ACCIDENT
In Compliance	0	X
Not In Compliance	X	X

Figure 3-5 indicates that the current standard has a weak (marginally statistically significant) relationship of the type described in Table 3-12 for the pre-1972 data, and no relationship for the post-1972 data. For other regulatory criteria (0.5, 1.75, and 2.0), stronger associations are indicated in the pre-1972 data. However, as explained previously, these criteria are impractical. Therefore, the statistical significance of their associations is not important. None of the criteria are statistically significant for the post-1972 data.

The conclusion of these analyses is that the current powering standard does not have a significant relationship to severity data (in terms of fatalities) for post-regulation boats. Certain modifications to the standard show some indications of associations with severity for pre-1972 data. These results seem to contradict the results stated in the previous section, where boats in powering accidents which did not comply with the current standard were shown to have a much higher probability of experiencing a fatality. However, that analysis did not break out only those boats covered by the standard (outboards of less than 20 feet in length), and did not differentiate pre- and post-regulation craft. The relationship that was reported previously did not hold up when these additional factors were included in the analyses. The conclusion stated in the first sentence of this paragraph states that the current powering standard does not bear a significant relationship to powering accident fatalities for post-1972 boats. This does not mean, however, that there are not other factors (besides powering problems) which may have contributed to those fatalities that were found in the accident reports. There were powering accident victims who did not wear PFDs, did not know how to swim, etc. Such victims occurred in both the pre-regulation and post-regulation data, and yet, the standard appears to have a significant relationship to severity for pre-regulation boats and not for post-regulation boats.

3.4.3 The Current Standard and Risk

As mentioned earlier, there are several ways to evaluate the effectiveness of the current standard. One of those ways was to analyze the risk associated with different power ratios. In this section, risk will be defined as number of boats in powering accidents per 1,000,000 boat hours at each power ratio, and the number of fatalities in powering accidents per 1,000,000 boat hours at each power ratio. The plots of risk versus power ratio for these two types of risks would then be called risk functions. Regardless of the type of risk, the risk should increase as the power ratio increases if the current powering standard is effective. Figure 3-6 shows some possible relationships between risk and the power ratio (as determined by the formula). Curve C, with the upward bend occurring at or near a ratio of 1.0, would indicate that the current standard is very effective.

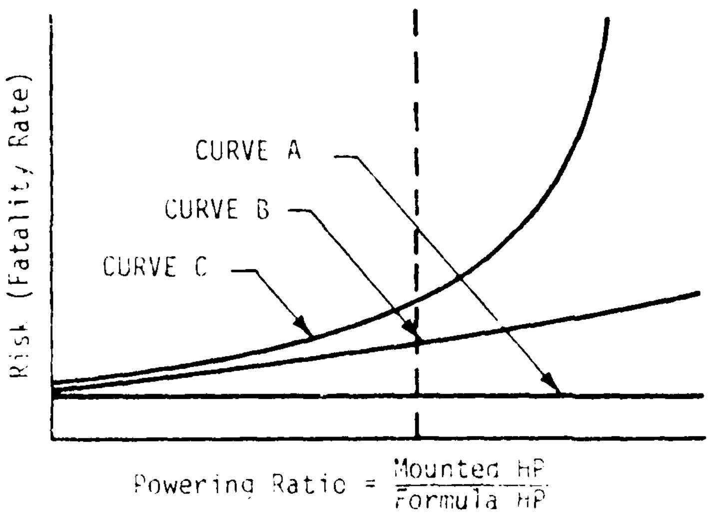


FIGURE 3-6. ALTERNATIVE RISK VS. POWERING RATIO CURVES

The relationship between risk and powering ratio in Figure 3-6 is:

CURVE A - Negligible - Intuition tells us that, for a given boat, there is some point above which the risk of an accident occurring increases substantially with increasing horsepower. However, it is quite possible that people intuitively recognize that limit and only the rare "NUT" approaches it. The other possibility is that even boats which are overpowered into the potentially high risk range under certain conditions are not operated at full power under those conditions by the prudent boating public. Certainly most boats are over-powered in some conditions which are regularly encountered (maneuvering in crowded anchorages), yet most people proceed at less than full throttle in crowded areas.

CURVE B = Positive, but Linearly Increasing with Horsepower - [illegible] possibility is particularly plausible. It could be that the risk of powering accidents increases with increasing power, if for no other reason than the increase in potential for serious damage from collisions at high speeds; yet, due to increasing driver attentiveness and prudence with increasing speed, a dramatic increase in risk never occurs.

CURVE C = Positive, With an Excessive Increase at Some Point - This possibility could be brought on if people "push" their boats into ranges of dynamic instability without consideration of the risks; or if collision accident risk is a function of speed raised to some power higher than one.

The PRAM data were used to generate the number of fatalities and number of boats in powering accidents. The Nationwide Boating Survey for 1973 was used to generate estimates for the total number of boating hours (exposure) for all powered boats, and all outboards under 20 ft in length. The latter number was estimated by adding the exposure data for motorized canoes, outboards, and motorized rowboats and johnboats.

There are several assumptions in these analyses. One is that the 1973 Nationwide Boating Survey exposure data are accurate and that they represent the boats from the PRAM sample. The non-powering accident boats in PRAM were used to estimate the percentage of boating exposure hours at each power ratio in the population, then the NBS data were broken down by power ratio according to the percentages in the non-powering data. This involves two assumptions. One is that the non-powering accident boats are not related to power ratio and reflect population characteristics. This assumption was partially checked in Section 3.4.2 and was not invalidated. Another assumption is that boats with low power ratios are used about as much as those with high power ratios. Such assumptions are required in this effort. It is realized that one or more of these assumptions may not reflect the true nature of the population data, as expressed in the 1973 NBS.

[illegible] powering [illegible] all the [illegible] and [illegible] used to estimate [illegible] values were [illegible] for the former [illegible] and exposure for

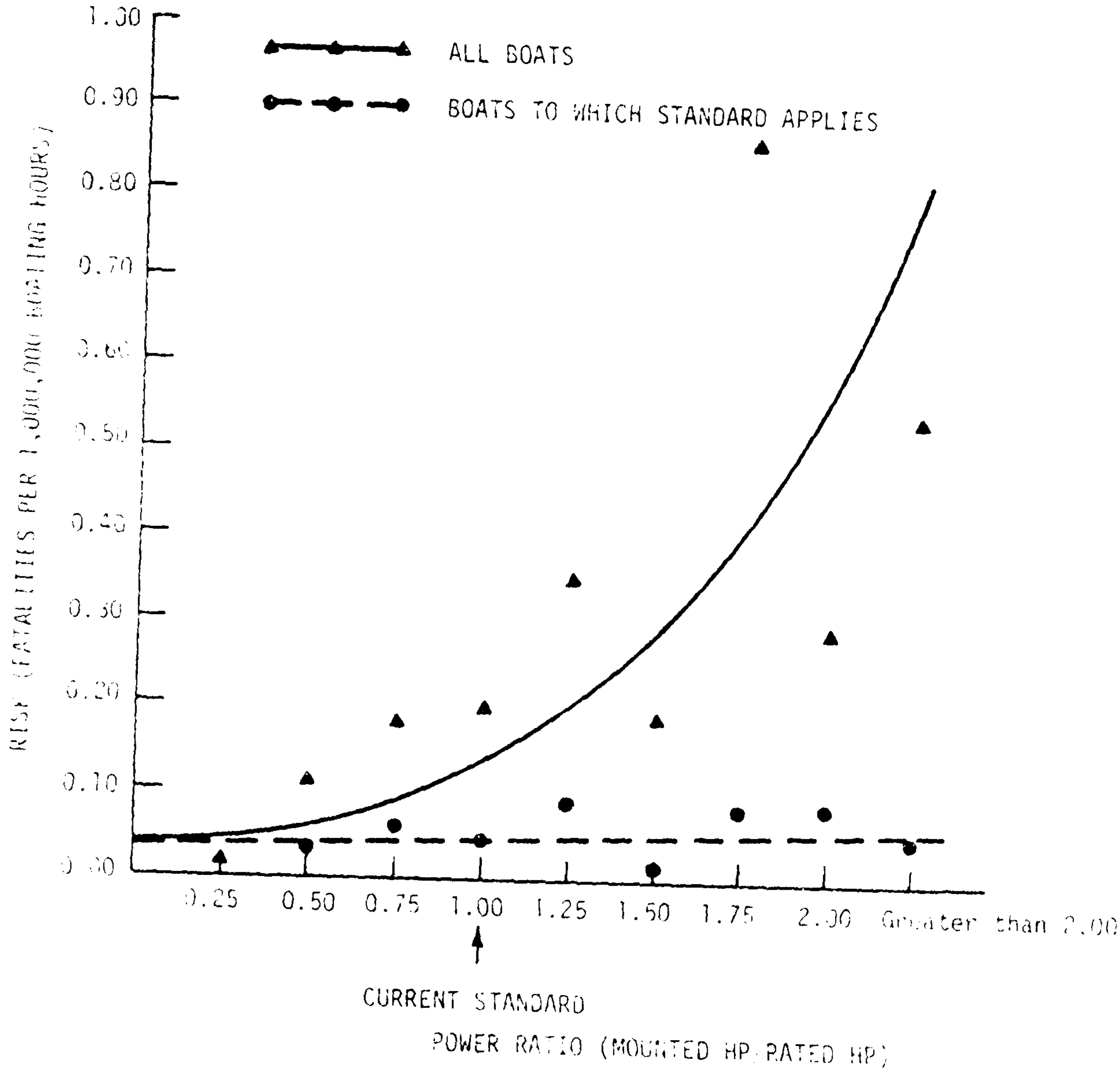


FIGURE 3-7. RISK FUNCTIONS: FATALITIES PER 1,000,000 BOATING HOURS

outboards less than 20 ft in length for the latter curve). The best fitting exponential curve is plotted for each set of points.*

The data show that the risk function for all boats in the powering sample (including pre-1972 boats) is much like curve C in Figure 3-6. It indicates that the standard is effective. The risk function for post-1972 boats less than 20 ft in length is much like curve A in Figure 3-6, indicating minimal, if any, effectiveness. The results in Figure 3-7 agree with previous sections: the current standard has shown no effectiveness since it was promulgated.

Figure 3-8 presents the risk versus power ratio curves for the number of boats in powering accidents per 1,000,000 hours of exposure. As before, the data are shown for all boats in the powering sample and for only outboards under 20 ft in length. The best fitting exponential curves for each set of data are plotted. Figure 3-8 also agrees with all previous results. It shows a strongly increasing risk function for all boats (including pre-1972 boats) and a negligible function for boats to which the standard applies (post-1972 outboards less than 20 ft in length). Figure 3-8 also shows that the current standard has not been effective since federal implementation in 1972.

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* Figures 3-7 and 3-8 contain "best-fitting" curves that were obtained using standard regression analyses, such as might be found in Statistical Principles in Experimental Design, B.J. Winer, New York: McGraw-Hill, 1971; Regression Analysis by Example, S. Chatterjee and B. Rice, New York: Wiley and Sons, 1977; and Introduction to Mathematical Statistics, P.G. Hoel, New York: Wiley and Sons, 1966. As was stated in the Hoel reference (page 175), "If a scatter diagram in the x, y plane indicates that a straight line will not fit a set of points satisfactorily because of the nonlinearity of the relationship, it may be possible to find some simple curve that will yield a satisfactory fit. Since an investigator alwyas strives to explain relationships as simply as possible, with the restriction that his explanation be consistent with previous knowledge, he will prefer to use a simple type of curve. It follows, therefore, that the type of curve to use will depend largely on the amount of theoretical information one has concerning the relationship, and thereafter on convenience." The statistic r^2 is the coefficient of determination and indicates the quality of fit achieved by the regression. This statistic can obtain values between 0 and 1, with the statistic indicating a better and better fit of the regression as it approaches 1. The value of r^2 corresponds to the proportion of the variance in y accounted for by the regression on x. The type of exponential curve that has been fit to the data (using an HP-97 programmable calculator) was $y = ae^{bx}$. In Figures 3-7 and 3-8 the exponential curves gave a better fit to the data than a linear fit, based upon the statistic r^2.

should be noted that none of the curves in Figures 3-7 and 3-8 fit the data ry well; i.e., they do not account for much of the variance in risk values. e trends and differences in the curves are obvious, however. The fact that e computed curve in Figure 3-8 for the boats to which the standard apply approxi- tes a linear relationship with a slightly negative slope should not be inter- eted literally, since the precise values in the regression equation for that irve (or the other curves in Figures 3-7 and 3-8) are not meaningful. What important is the shape of that curve (relatively flat) and the others, and the eaning of those shapes as described above.

3.4.4 Accounting for Differences in Pre- and Post-Regulation Data

iroughout these analyses, it has become very clear that there are vast differ- nces in the effectiveness of the current standard for pre- and post-regulation oats. If one were to look only at the pre-regulation data, then it would ppear that the standard had some potential for measuring the frequency and everity of powering accidents. If one were to look at the post-regulation ata, the standard appears to have little or no relationship with the powering roblem.

here are many possible reasons for the lack of effectiveness of the current tandard on post-1972 boats. Older boats may be used less often or in a differ- ent manner than newer boats. Boaters may have more experience with older boats, and therefore, have fewer accidents. Many similar post hoc explanations can be erived in terms of activity, use, experience, and behavior. However, it is ifficult to conceive of such variables accounting for the large observed dif- erences in a few years.

ne explanation is that engine and boat manufacturers may have found ways to ncrease the horsepower on the boat that were not anticipated in the current tandard. Figure 3-9 shows the same hull with two different deck arrangements. he top set of drawings might represent the boat before the standard was enacted n 1972. The bottom set of drawings might represent the same boat after the tandard was enacted. Although the hull shape is essentially the same for both oats, the lower boat would be rated for a larger engine because of the measure- ents used in the formula (L_1 and W_1). These measurements are increased in the

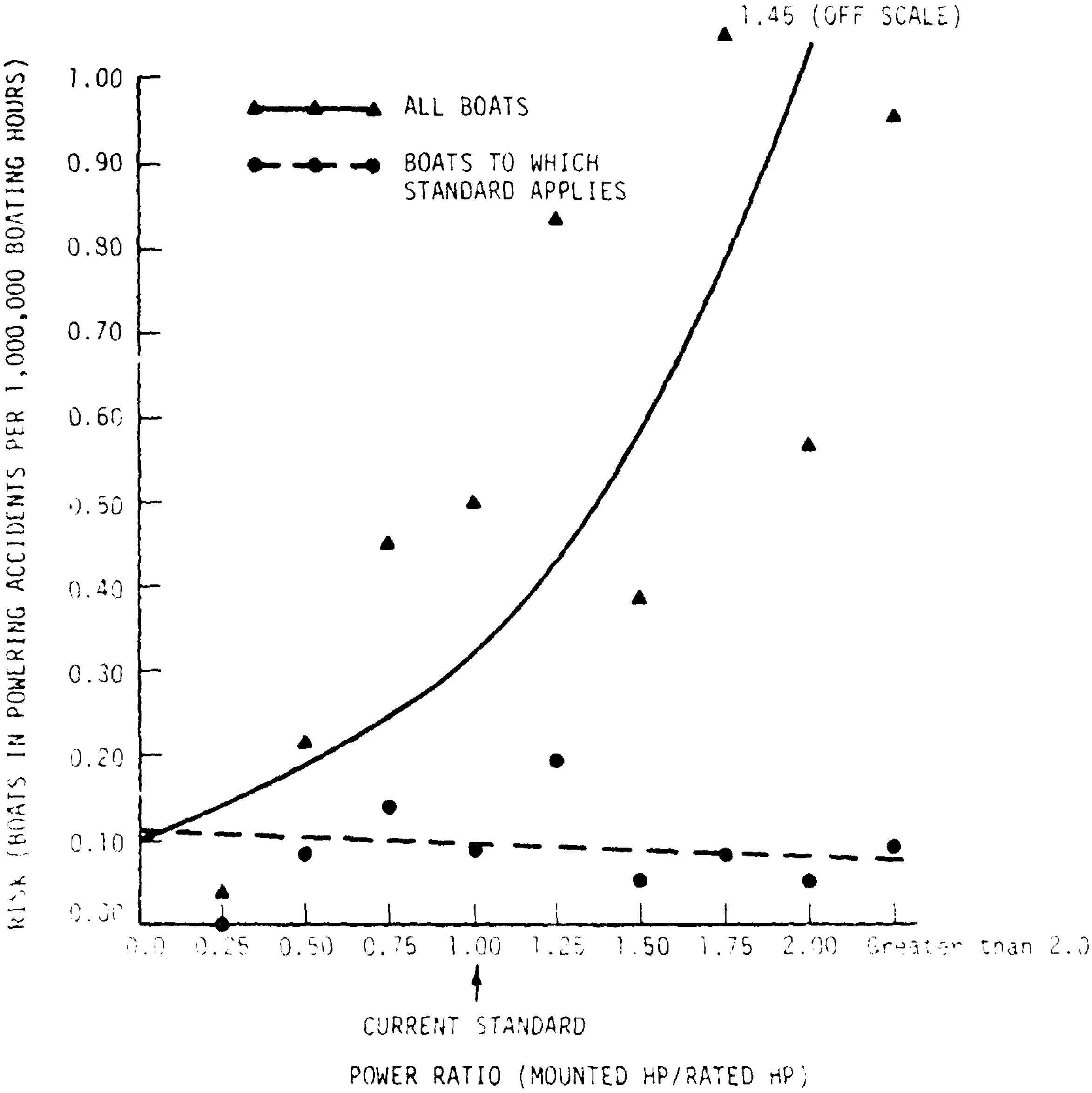


FIGURE 3-8. RISK FUNCTION: BOATS IN POWERING ACCIDENTS PER 1,000,000 BOATING HOURS

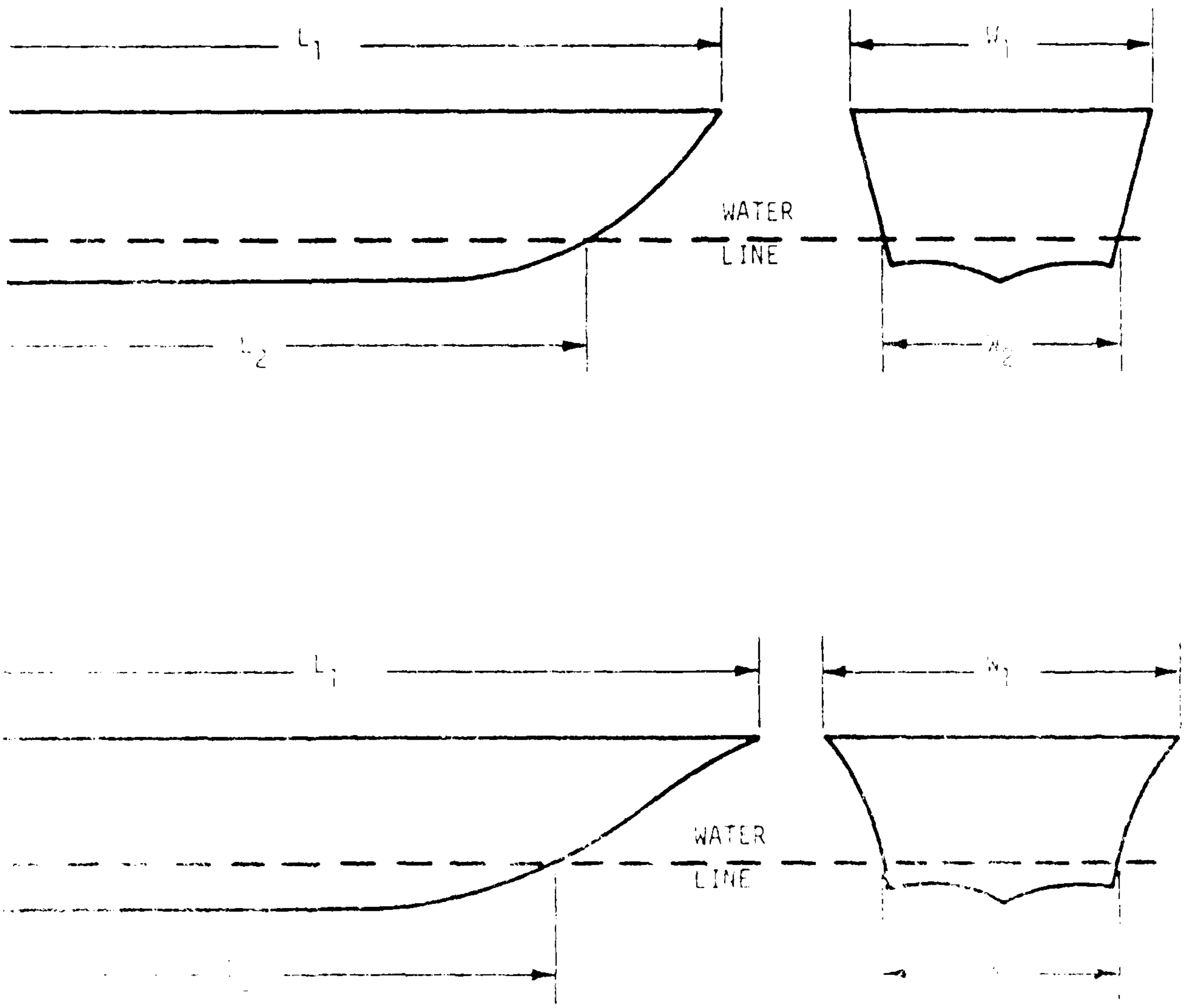
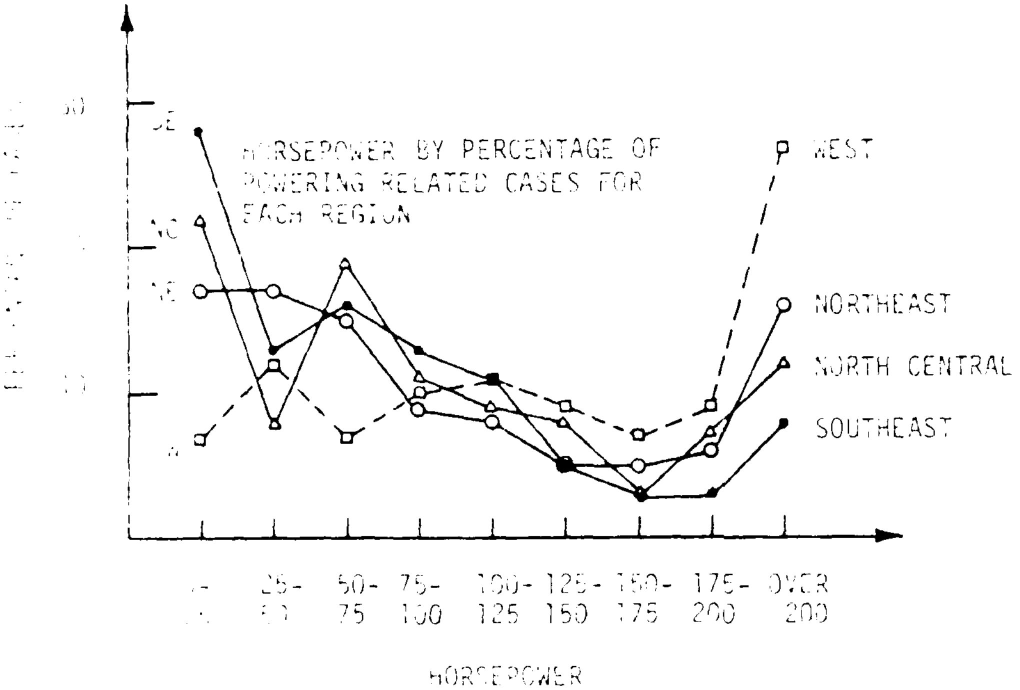
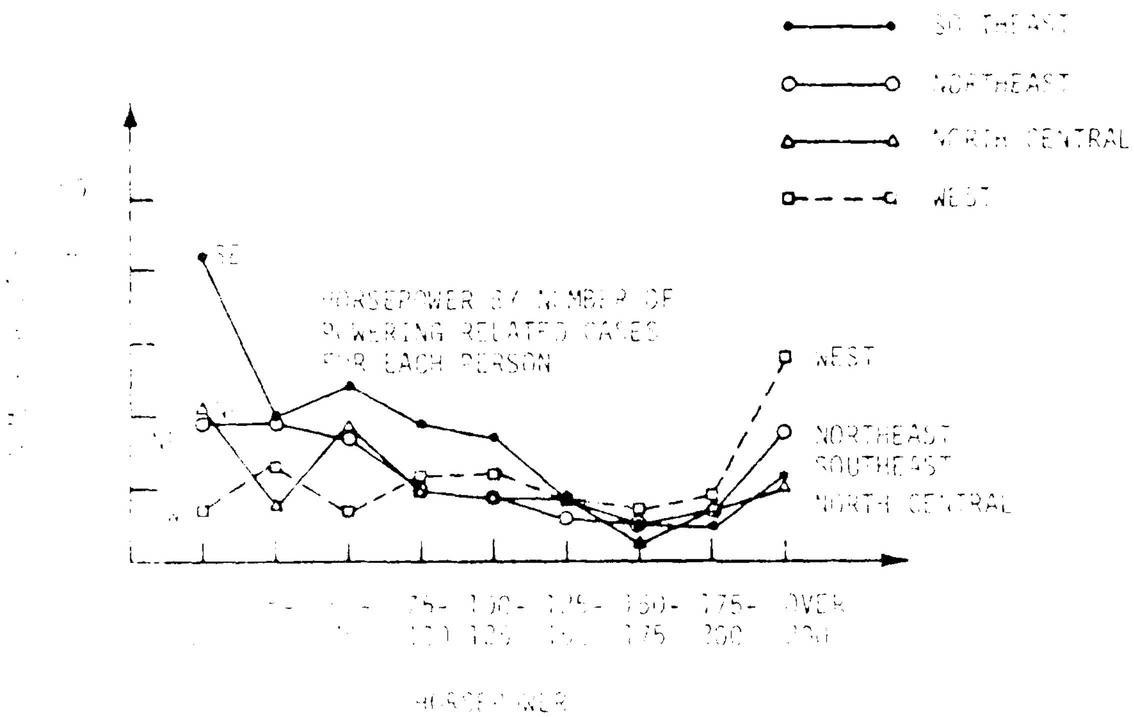


FIGURE 3-4. BOAT DESIGN CHANGES


HORSEPOWER BY PERCENTAGE OF POWERING RELATED CASES FOR EACH REGION
WEST
NORTHEAST
NORTH CENTRAL
SOUTHEAST
50- 75
75- 100
100- 125
125- 150
150- 175
175- 200
OVER 200
HORSEPOWER


NORTHEAST
NORTH CENTRAL
WEST
SE
WEST
NORTHEAST
SOUTHEAST
NORTH CENTRAL
75- 100
175- 200
OVER

[illegible]

4.6 Average Horsepower by Region

Table 4-6 presents the data for the mean horsepower by region in the powering related accident data. The horsepower distribution for each region is shown in Figure 4-6 by percentage of the powering related accident boats in that region and by the frequency (number of cases). The data clearly show that the Southeast powering related accidents involve boats with smaller horsepower much more frequently than in other regions. This is shown by the number of cases where the horsepower was less than or equal to 25 hp and by the percentage of all powering related cases in the region where this was true. The Southeast was the only region in which the mean horsepower of the boats in powering related accidents was less than 100 hp (see Table 4-6). The West is shown to have more highly powered boats in its regional powering accidents. This is shown by the large mean horsepower in the West (see Table 4-6) and by Figure 4-6. Nearly 30% of all the boats that were involved in powering related accidents in the West had horsepowers of over 200 hp.

TABLE 4-6. HORSEPOWER BY REGION FOR BOATS IN POWERING RELATED ACCIDENTS

REGION	NO. OF CASES (KNOWN HORSEPOWER)	MEAN HORSEPOWER	NO. OF CASES ≤ 100 HP	NO. OF CASES ≤ 25 HP
West	106	171.33	36 (34%)	7 (7%)
North Central	95	106.53	51 (54%)	21 (22%)
Northeast	110 (1 unk)	121.35	61 (55%)	19 (17%)
Southeast	152	99.80	102 (67%)	42 (28%)

Note: A total of six boats were not in a prescribed region.

4.5 Fatalities Resulting From Course Changes, By Region

possible reason for regional differences in fatality rates for powering related idents is the type of water being navigated. For small rivers and narrow water-, a larger number of course changes (turns) may result in falls within the boat, ls overboard, and capsizings. It was noted earlier that these types of accidents e very common in the powering related sample. Regional differences could be due some regions having more narrow waterways (run-off waters) and requiring more urse changes.

PRAM fatality data were broken down by region for those accidents which involv- an intentional change of course on the part of the operator (see Figure 4-5). re were 94 such fatalities (nearly half of all powering related fatalities). The theast accounted for over 41% of the powering related fatalities associated with tentional course changes, while the West accounted for less than 11%. This sug- sts that the use of streams, small rivers, and other narrow and winding waterways the Southeast may contribute to the high powering related fatality rate for that gion. The type of boat and activity also play a role in how the intentional change course affects the boat's occupants, but the data are suggestive of the course ange problem.

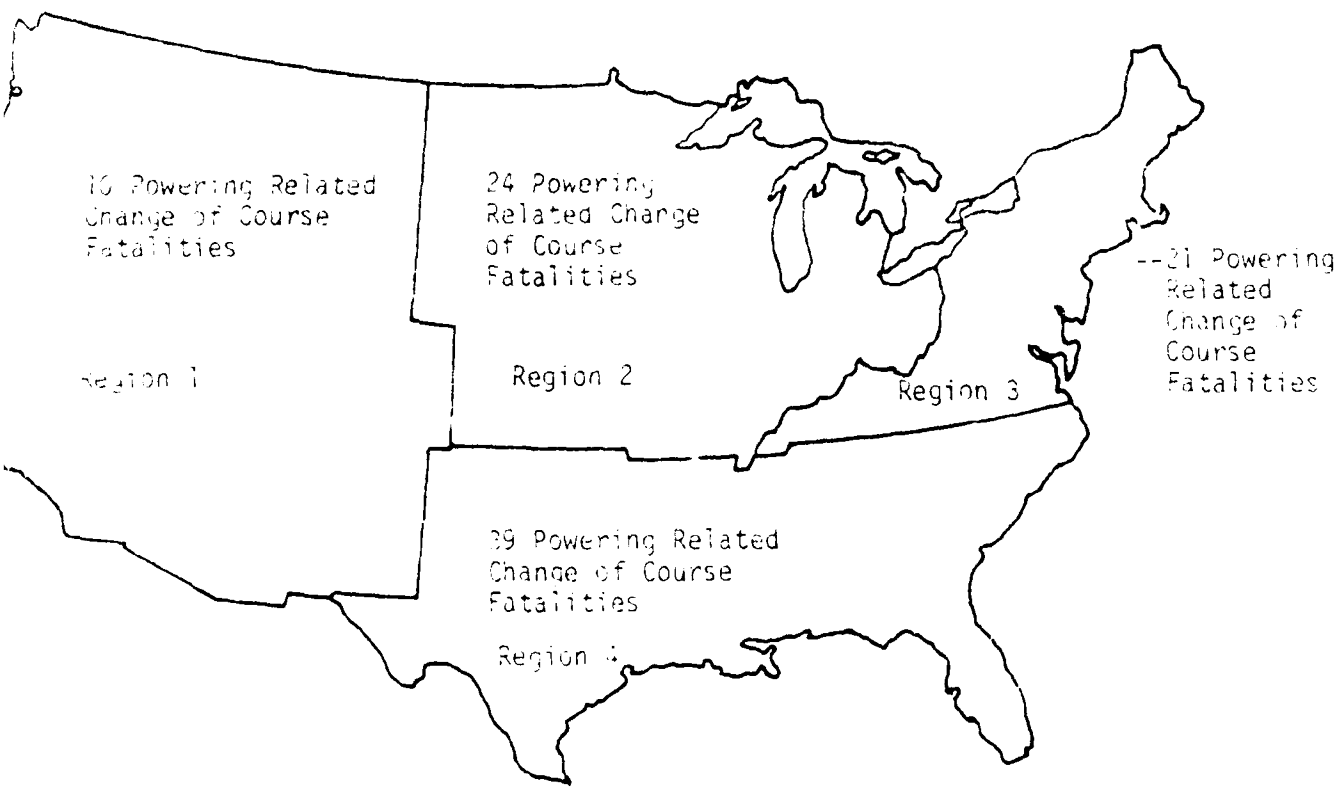


FIGURE 4-5. POWERING RELATED CHANGE OF COURSE FATALITIES BY REGION

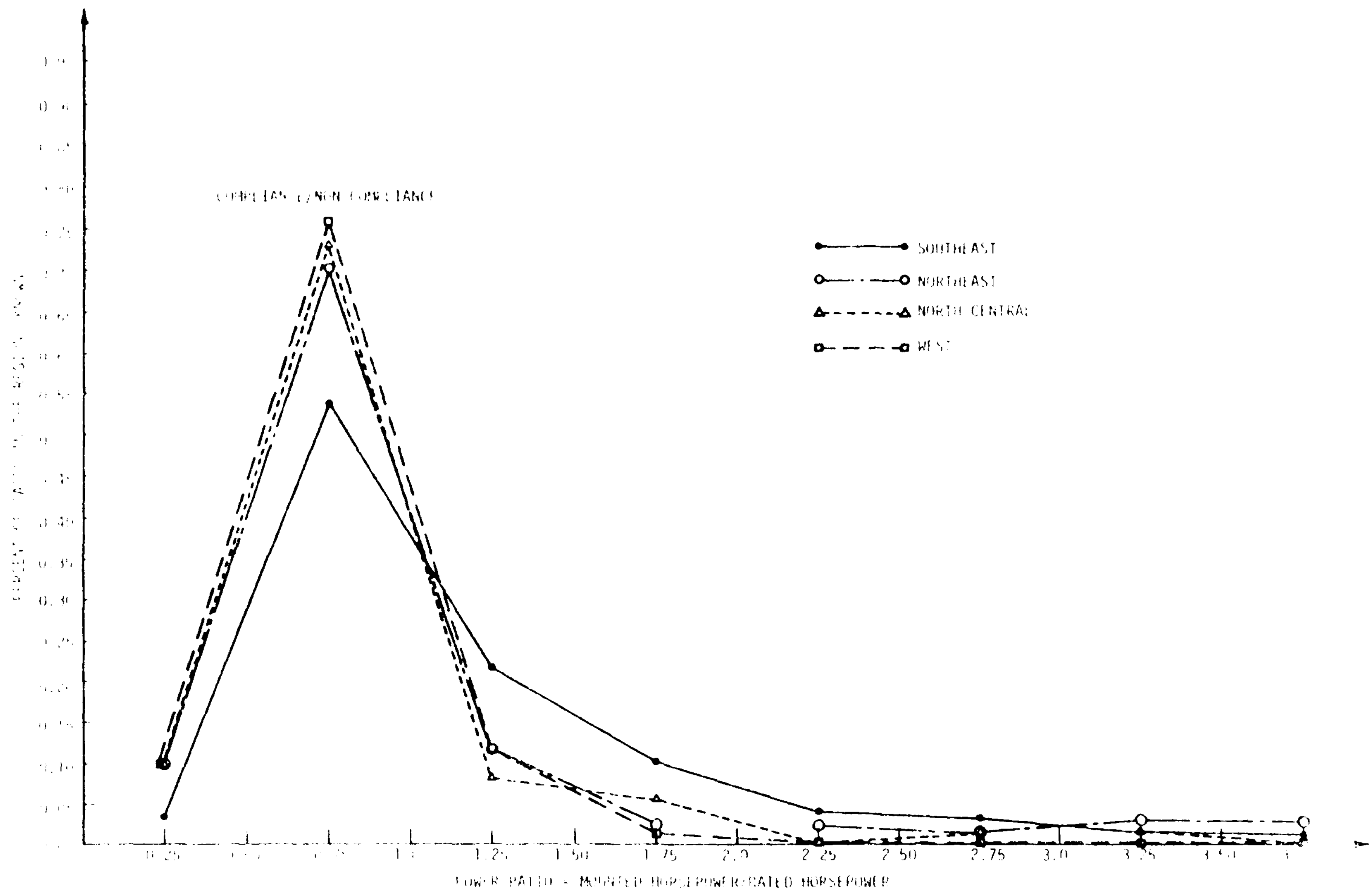


FIGURE 1-4. DISTRIBUTION OF POWER RATIOS BY REGION

4.4 Power Ratio Distributions Within Geographical Regions

Table 4-5 and Figure 4-4 show the ratio of mounted horsepower to rated horsepower (the power ratio) for all boats in powering related accidents (in 1975 and 1976) by geographic region. The West, which had the lowest fatality rate (see Section 4.1), also has the lowest average power ratio. The Southeast, which had the highest fatality rate, also has the highest average power ratio (see Table 4-5). The table also shows that the percentage of boats not in compliance with the current standard increases as one reads down the table from the West to the Southeast. This trend matches the trend in fatality rates shown in Section 4.1.

The graphs in Figure 4-4 show that, for all regions, the most frequent power ratio category for the boats in powering related accidents was 0.5 to 1.0. The most frequent single value was 1.0, which was obtained when the boater had mounted an engine that matched the boat's rated horsepower capacity. The distributions for the West, North Central, and Northeast regions are very similar. The distribution for the Southeast is distinguishable because there were fewer boats in that region in the compliance categories (0-0.5 and 0.5-1.0), and more boats in the non-compliance categories (particularly 1.0-1.5 and 1.5-2.0).

TABLE 4-5. POWER RATIO BY REGION FOR POWERING RELATED ACCIDENTS

[illegible]	NO. OF UNKNOWNS	NO. WHERE POWER RATIO WAS KNOWN	MEAN POWER RATIO	NO. IN COMPLIANCE	NO. NOT IN COMPLIANCE
[illegible]	[illegible]	67	0.836	58 ([illegible])	9 (13)
[illegible]	24	[illegible]	0.913	59 (83)	12 (17)
[illegible]	14	92	1.044	72 (78)	20 (22)
[illegible]	[illegible]	[illegible]	1.098	67 (58)	48 (42)

* [illegible] boats were not in one of the prescribed regions.

TABLE 4-3. POWERING RELATED FATALITIES BY ACCIDENT TYPE

	Number of Powering Related Fatalities	Percent of Total Powering Related Fatalities
Collision/Grounding	26	13%
Swamping/Capsizing/Flooding/Sinking	85	42%
Falls Overboard or Within the Boat	85	42%
Struck by Boat or Propeller	3	1%
All Others	0	0%
Unknown	5	2%
TOTAL	204	100%

TABLE 4-4. ACCIDENT TYPE BY BOAT TYPE FOR POWERING RELATED FATALITIES

Boat Type	Accident Type			
	Collisions	Capsizings/ Swampings	Falls Overboard or Within	Struck by Boat or Prop
Johnboats	1	47	25	0
High Performance Boats	1	1	3	0
Open Powerboats	20	20	41	3
Cabin Motorboats	2	13	5	0
Bassboats	2	2	10	0

TABLE 4-2. POWERING RELATED FATALITIES BY BOAT TYPE

Boat Type	Number of Powering Related Fatalities	Percent of Total Powering Related Fatalities
Johnboats	73	36%
High Performance Boats	5	2
Open Powerboats	84	41%
Cabin Motorboats	20	10%
Bassboats	14	7%
Unknown	8	4
All Others	0	0%
TOTAL	204	100%

The data indicate that over one-third of all the boats involved in powering related accidents are johnboats, which are prevalent in the Southeast. High performance boats, which are prevalent in the Southwest, represent only 2% of the powering related accidents.

4.3 Fatality Distribution by Type of Accident

The fatality data for PRAM were broken down by accident type, as shown in Table 4-3. Falls overboard and capsizings/swampings account for 84% of the powering related fatalities.

Table 4-4 shows the crosstabulation of powering related fatalities by boat type and accident type for those that were known on both variables (196 of the 204 powering related fatalities). The table shows that over half of the powering related capsizings and swampings involve johnboats. Over 43% of the capsizing/swamping and falls overboard accidents combined (the accident types that account for 84% of the fatalities) involve johnboats.

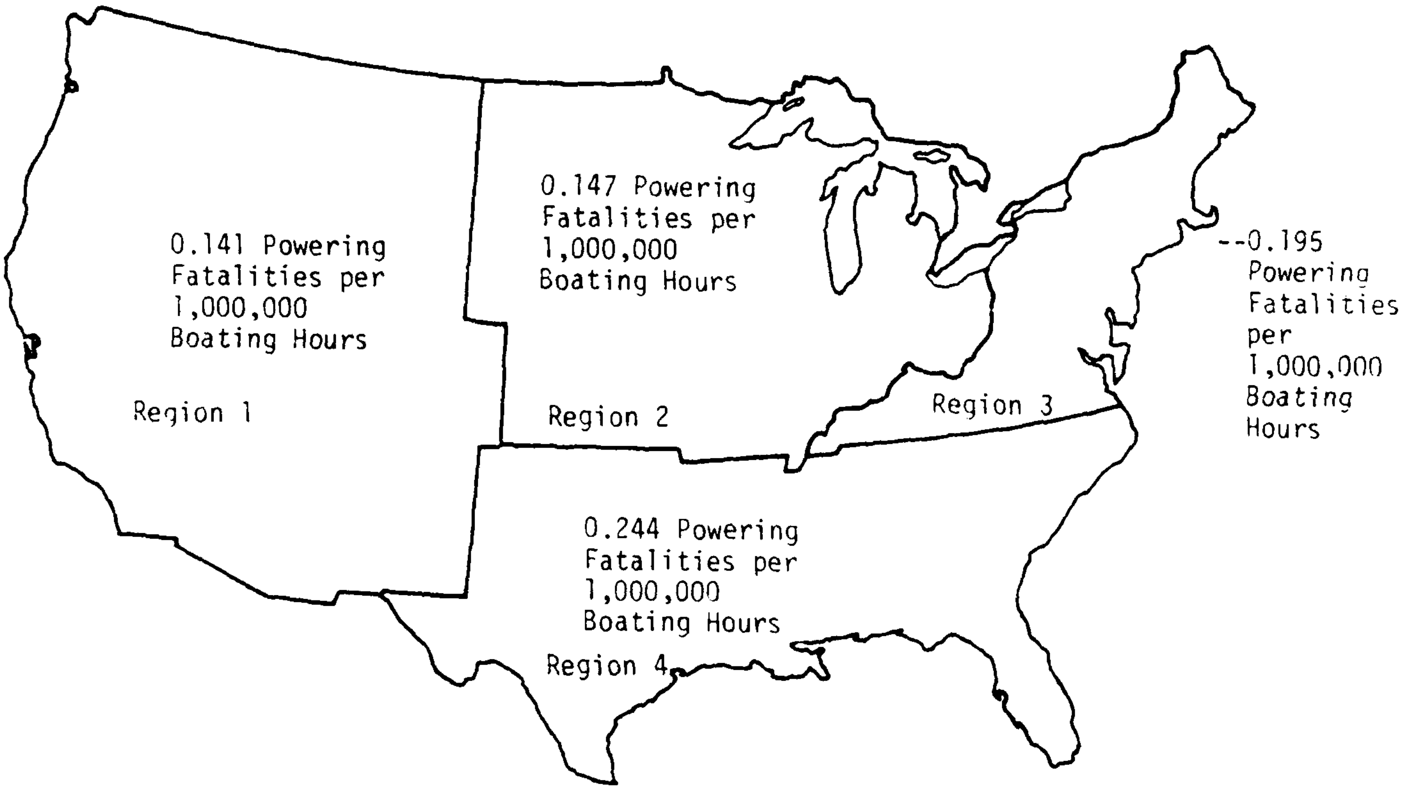


FIGURE 4-3. POWERING FATALITIES PER 1,000,000 BOATING HOURS BY GEOGRAPHIC REGION (USING 1973 NBS DATA FOR EXPOSURE)

Data from other NBS regions were similarly broken down to generate exposure esti-mates for the four regions in this report.

Figure 4-3 shows the resulting powering fatality rates (fatalities per [illegible] boating hours) for each region. The ordering of the regions with respect to fatality rate is the same as it was for fatalities in Figure 4-2 (Southeast was the "worst," West was the "best," etc.). However, the inclusion of exposure data shows that the regional differences are not as great as Figure 4-2 would suggest. That is, one of the reasons that the Southeast experiences so many more powering fatalities than the West is that there is more exposure in the Southeast. The regional differences do persist in Figure 4-3, and the analyses that follow in this section will attempt to demonstrate some of the possible reasons why these regional differences in powering fatalities occur.

4.2 Fatality Distribution by Boat Type

Regional differences in fatality rates in powering related accidents may be due to any of several reasons. Boat types vary by regions (see Table 4-1) and powering related accidents could be more dominant in some boat types than in others. The PRAM fatality data were broken down by boat type. The results are shown in Table 4-2.

TABLE 4-1. BOAT TYPE DISTRIBUTION BY REGION (PERCENT)

Boat Type	Region				Total of All Regions
	Pacific	Great Lakes	New England	S.East	
High Performance	7.6	4.2	2.7	-	3.2
Open Powerboat	61.0	61.1	64.9	61.[illegible]	62.[illegible]
Cabin Motorboat	16.2	7.4	13.5	5.9	10.4
Johnboat	6.7	25.3	16.2	23.0	16.1
Bass Boat	-	1.1	1.8	5.3	2.4
Auxiliary Sail, Powered Canoe/Kayak Houseboat Inflatable (powered)	4.8	1.1	-	0.7	1.5
Unknown	3.8	-	0.9	3.3	2.4
Total No. of Boats in Region	105	95	111	152	463*
Percentage of All Powering Boats	22.7	20.5	23.9	32.8	100.0

* Note: A total of six boats were not in one of the prescribed regions.

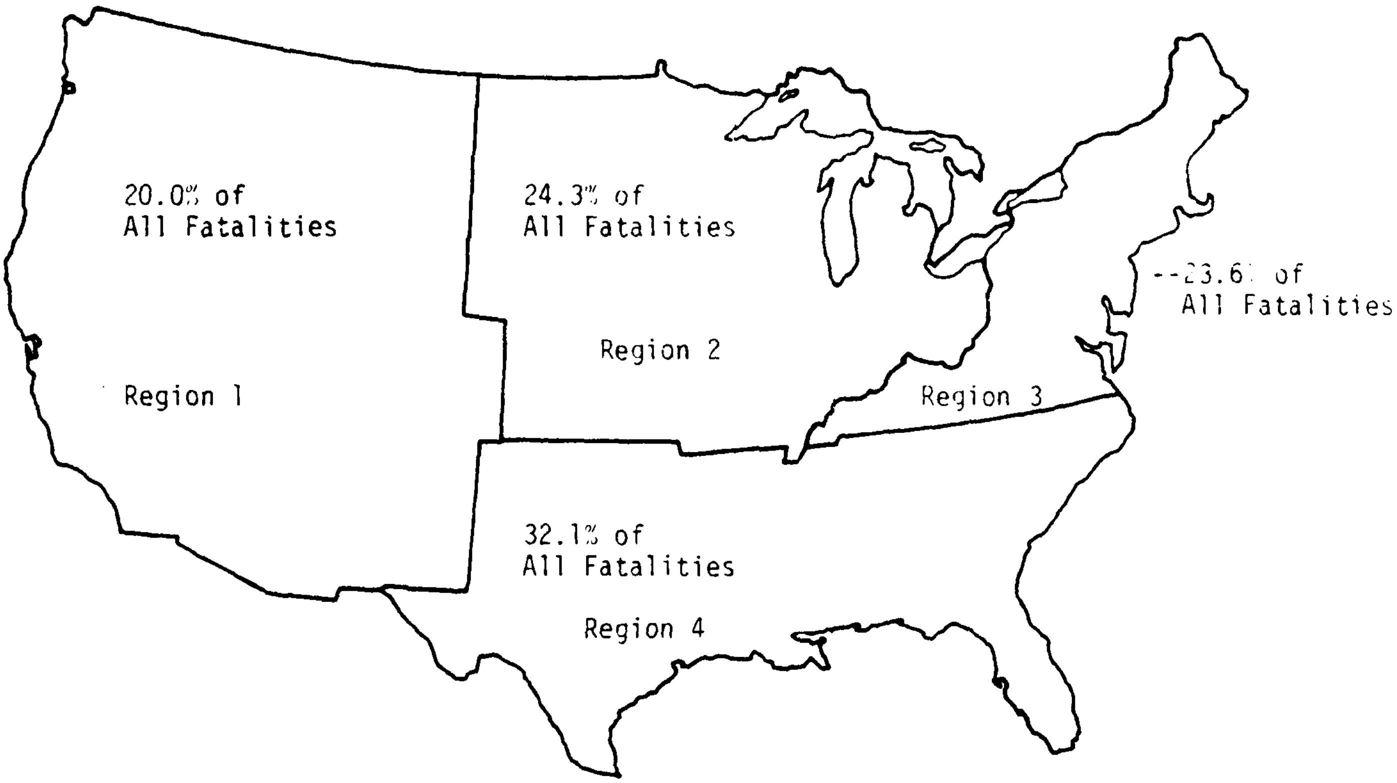


FIGURE 4-1. ALL FATALITIES BY GEOGRAPHIC REGION
(INCLUDES 1975 AND 1976 CG-357 DATA FOR THE 48 STATES)

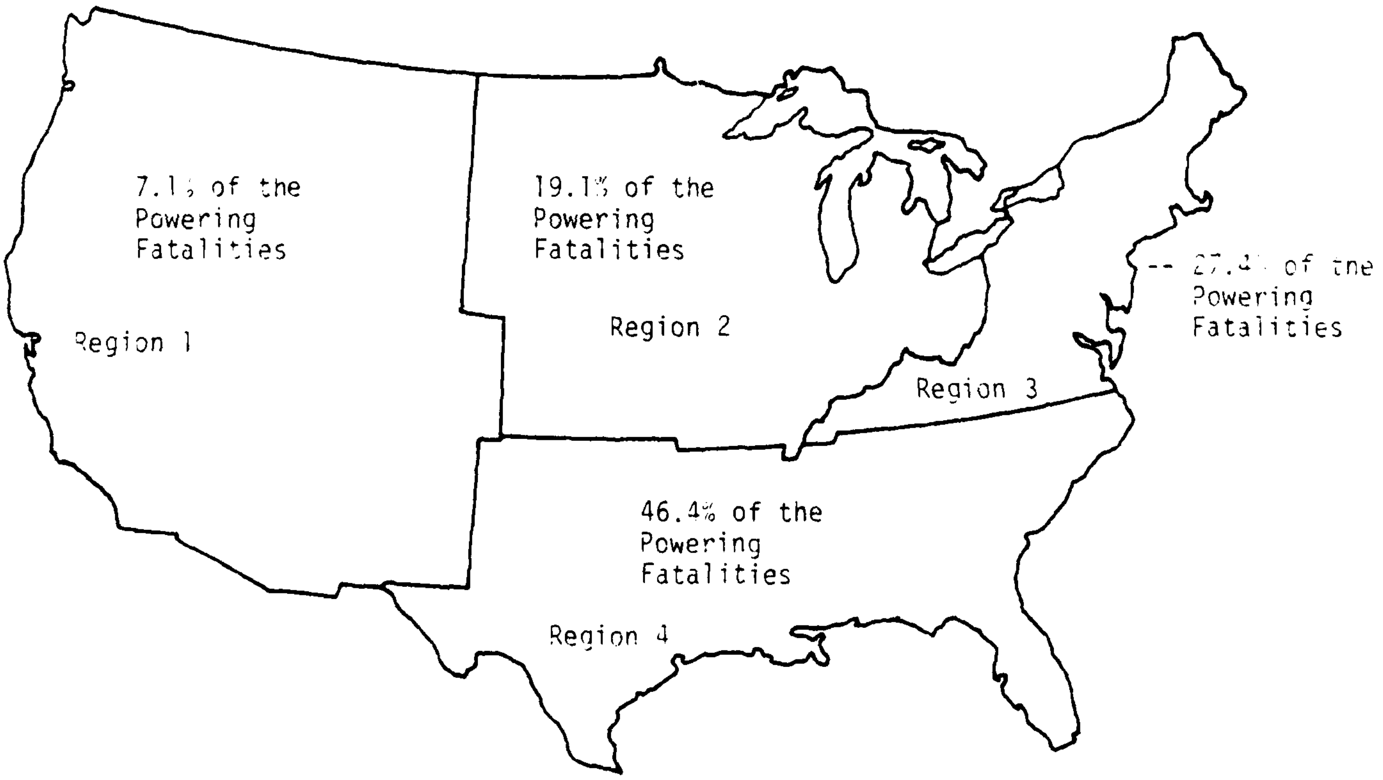


FIGURE 4-2. POWERING FATALITIES BY GEOGRAPHIC REGION
(INCLUDES ALL 1975 AND 1976 POWERING FATALITIES)

4.0 ADDITIONAL ANALYSES AND RESULTS

The results of the Task III effort to evaluate the effectiveness of the current standard formula in predicting risk with increasing mounted horsepower gave rise to several questions. The questions centered on issues related to the fact that the current standard appeared to be more effective for some boat types than for others. The variations in prominent boat types across regions would suggest regional differences in powering accidents. These issues are investigated using PRAM data in this section.

4.1 Fatality Distribution By Region

Figures 4-1 and 4-2 show the distribution of all fatalities (in CG-357) by geographic region, and the distribution of powering related fatalities by geographic region, respectively. The data for two regions are strikingly different in Figure 4-2 than the data for the same regions in Figure 4-1: the West and the Southeast. There are relatively few powering related deaths in the West, considering the percentage of all fatalities that occur there. The Southeast accounts for nearly half of all powering related fatalities, despite the fact that less than one-third of all fatalities occur there.

The exposure data for the geographic regions was obtained from the Nationwide Boating Survey (1973). These data were used to generate fatality rates for each [illegible] region (the number of powering fatalities divided by the number of [illegible] times 1,000,000 = the number of powering fatalities [illegible] in a region). The exposure data that were used were for powered [illegible], and the data were grouped according to the regions as defined in this report. The NBS regions did not always coincide with those used in this report, so the NBS data were adjusted. For example, the NBS region "Mid-Atlantic" [illegible] three states that are in the Southeast region in this report, and six [illegible] in the Northeast region in this report. The number of boats in [illegible] was [illegible] to be proportional to the exposure for each state within [illegible], 60.5 [illegible] of the NBS exposure for "Mid-Atlantic" [illegible] was included in the exposure estimate for the Northeast in this report, [illegible] the "Mid-Atlantic" exposure data from NBS was included in the Southeast [illegible] this report, since those are the percentages of boats in the two areas.

TABLE 3-15. COMPLIANCE VS. TYPE OF ACCIDENT FOR ALL BOATS OF 16 FT OR LESS

	HAD A POWERING ACCIDENT	HAD A NON-POWERING ACCIDENT
In Compliance	92	101
Not In Compliance	58	34

TABLE 3-13. TYPE OF ACCIDENT VS. COMPLIANCE FOR JOHNBOATS

	HAD A POWERING ACCIDENT	HAD A NON-POWERING ACCIDENT
In Compliance	45	59
Not in Compliance	26	19

Note: These data include 1972 boats.

Table 3-14 presents the data for all other outboards less than 20 ft in length (non-johnboats). The data indicate no significant relationship between compliance and type of accident for outboards that are not johnboats (corrected $\chi^2_{(1)}$ = 0.162, p > 0.75). This result, combined with Table 3-13, indicates that the overall effectiveness of the current standard is reflected primarily in its effectivenesss for johnboats, since it shows no relationship in other outboards.

TABLE 3-14. TYPE OF ACCIDENT VS. COMPLIANCE FOR OUTBOARDS LESS THAN 20 FT IN LENGTH THAT ARE NOT JOHNBOATS

	HAD A POWERING ACCIDENT	HAD A NON-POWERING ACCIDENT
In Compliance	90	61
Not in Compliance	43	31

Note: These data include no 1972 boats.

Table 3-15 presents data for all boats less than or equal to 16 ft in length, and shows a statistically significant relationship between compliance and type of accident (corrected $\chi^2_{(1)}$ = 5.307, p < 0.025). This means that boats under 16 ft in length which comply with the current standard are more likely to be in the non-powering sample, while those that do not comply are more likely to be in the powering sample. The relationship for boats under 16 ft is related to the result reported previously for johnboats, since most johnboats are under 16 ft in length. This comparison is very similar to Table 3-2 in Section 3.4.1, which was for boats less than 20 ft in length.

lower set of drawings without changing the boat's performance appreciably. Measures such as L_2 and W_2, however, do not change. Thus, a manufacturer can increase the horsepower capacity of his boat by flaring its bow and transom sides, without changing its performance characteristics. In effect, this circumvents the intent of the formula.

Similarly, engine manufacturers can rate their engines at a non-maximal rpm enabling the boater to buy an engine that is capable of more than the rated horsepower at higher rpm.

Consequently, the passage of the powering standard may have resulted in creating an opportunity to increase power ratings that are not reflected in the formula. The formula would then not be effective for those post-regulatory boats and engines, since it would not apply.

These issues will be discussed briefly in the next section, and in greater detail in the evaluation of alternative concepts.

3.4.5 Current Standard Effectiveness By Boat Type

Previous data analyses have indicated that the current standard is not effective for outboards less than 20 ft in length built after 1972. However, it may be effective for some boat types or lengths and not for others. For example, does the current standard reflect powering accident likelihood for johnboats and other flatbottomed boats?

The data for johnboats were separated from the outboard data. An analysis similar to that in Section 3.4.1 was then performed, where all johnboats were categorized according to whether the boat was in compliance with the current standard and the kind of accident that the boat was in (powering or non-powering). The data are shown in Table 3-13. These data show a statistically significant relationship of the type indicated in Table 3-1 between type of accident and compliance for johnboats. That is, in powering accidents, johnboats are much more likely to have been overpowered (according to the formula) than in non-powering accidents (Fisher exact $p = 0.0279$). Johnboats are not as susceptible to design changes that artificially increase rated horsepower (see Section 3.4.4) as other boat types.

4.7 Risk Versus Power Ratio for Johnboats

Data reported in earlier sections indicated that powering related accidents are more prevalent in the Southeast and on boats with relatively small horsepower (when compared to other boat types). These data suggest that johnboats, which are prevalent in the Southeast, may represent a large portion of the powering related accident problem.

The powering related accident sample was screened to select those accidents that involved johnboats (from all regions). Risk functions for those boats were plotted versus the boats' power ratios (mounted horsepower/rated horsepower). In Figure 4-7, the number of fatalities per 1,000,000 boating hours (from Nationwide Boating Survey, 1973) at each power ratio was plotted separately for johnboats and all boats in the powering related accident sample. The best fitting exponential for the johnboat data is not a very good fit ($r^2 = 0.3$), but it is better than the best linear or logarithmic fit ($r^2 < 0.2$ in both cases - see footnote concerning Figures 3-7 and 3-8). The data points are based upon a relatively small sample of johnboats at each power ratio. Despite the fact that the curve does not account for much of the variation in the data, the risk associated with johnboats in powering related accidents is greater than that for all boats at almost every power ratio. This is particularly true for those johnboats that are not in compliance with the current standard (power ratio > 1.0), which experience several times the risk of an "average" boat at the same power ratio. Since the Southeast contains approximately 40% of the johnboats in the U.S. (Nationwide Boating Survey, 1973), the high powering related fatality risk associated with johnboats may account for the fact that powering related fatalities occur more often in the Southeast. As before in Figures 3-7 and 3-8, the precise parameter values for these curves are not as important as the shapes of the curves, and the differences in shape, which are easily discerned from the figure.

Figure 4-8 presents the risk data for johnboats and for all boats in powering related accidents in terms of the number of boats having a powering related accident per 1,000,000 boating hours. In this case, the accident rate for johnboats exceeds the rate for an "average" boat at every power ratio. As before, the risk goes up significantly for those johnboats that were not in compliance with the current standard.

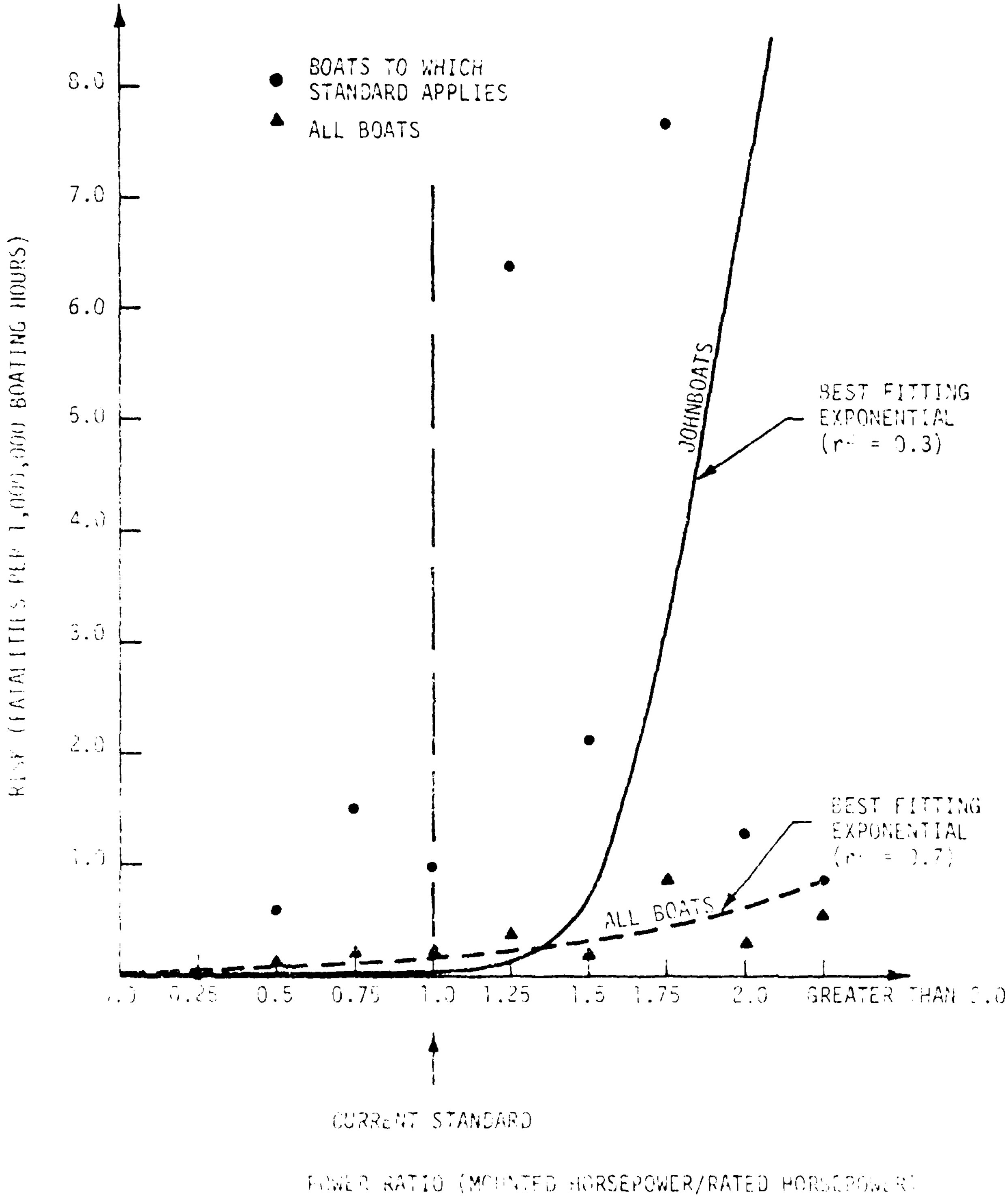


FIGURE 4-7. RISK VERSUS POWER RATIOS FOR JOHNBOATS: FATALITIES

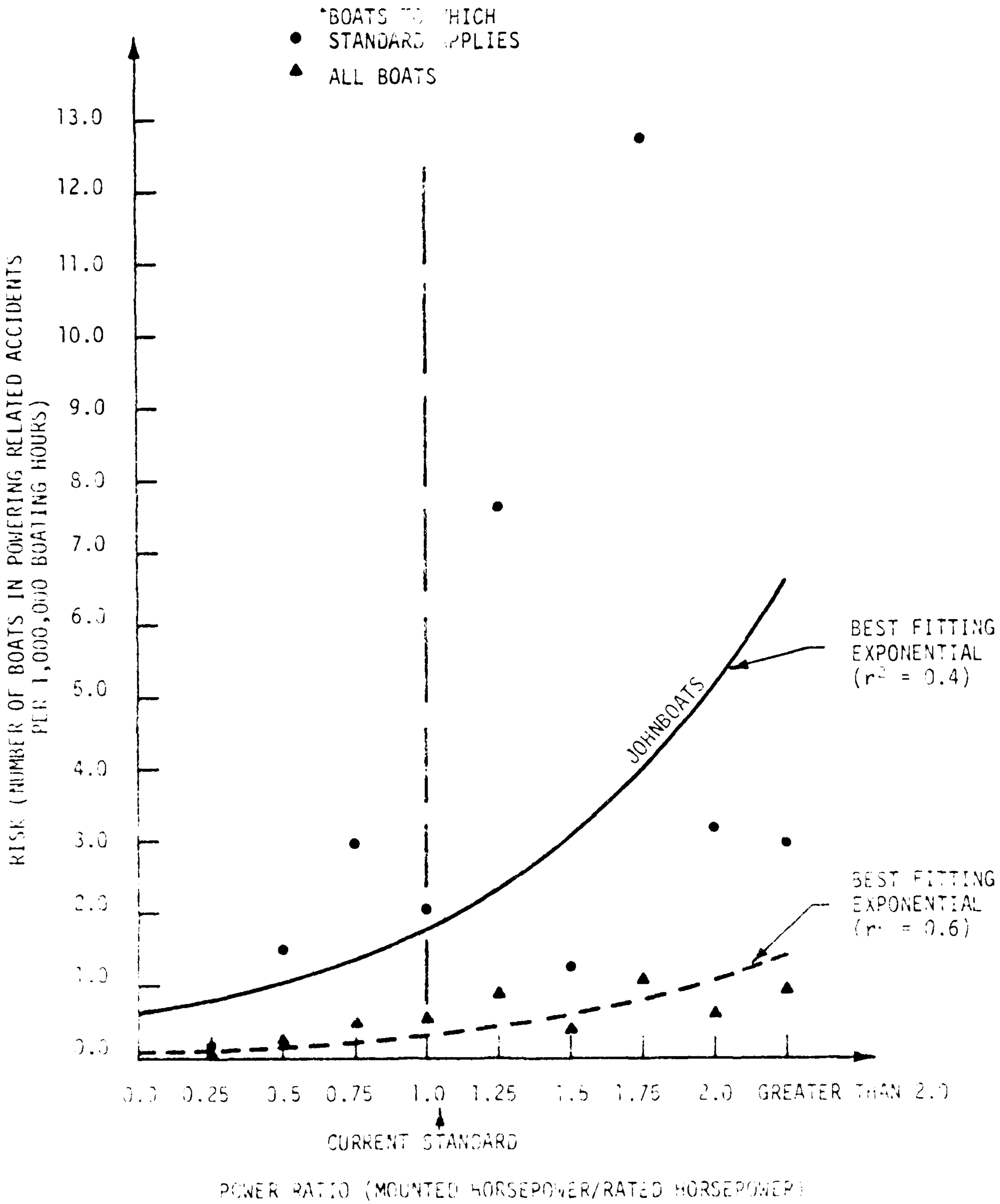


FIGURE 4-8. RISK VERSUS POWER RATIOS FOR JOHNBOATS: ACCIDENTS

4.3 Powering Accident Severity by Power Ratio for Johnboats

The powering related accident data were sorted by boat type and power ratio. Then the severity of each accident was computed (using the lower values for each severity code). Thus, Table 4-7 below shows the total severity of accidents at each power ratio (mounted horsepower/rated horsepower) for each boat type. This table does not present an accurate picture of the severity data, unless it is tempered with exposure data. The severity was divided by the boating exposure at each power ratio for johnboats and all boats combined. The result was the set of graphs in Figure 4-9 (thousands of dollars in severity of powering related accidents per 1,000 boating hours of exposure by power ratio). For these computations, a human life was valued at $480,000. The graphs show a marked increase in severity with increasing power ratio for johnboats. This function was much steeper than the same plot for all boats. In both cases, an exponential curve fit was better than either linear or logarithmic (greater r^2), but still accounted for only about 25 percent of the variation in the data. (See footnote corresponding to Figures 3-7 and 3-8). As before, the general shape and differences in the curves are much more important than the precise parameter values.

TABLE 4-7. SEVERITY (IN $1,000 INCREMENTS) BY BOAT TYPE AND POWER RATIO

[illegible]	[illegible]	[illegible]	0.50-0.75	[illegible]	[illegible]	1.25-1.50	1.50-1.75	[illegible]	Greater Than [illegible]	[illegible]
[illegible]			[illegible]	[illegible]	924	4	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	496	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	0	1,392	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	0	[illegible]	[illegible]	0		[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible] are in $1,000.

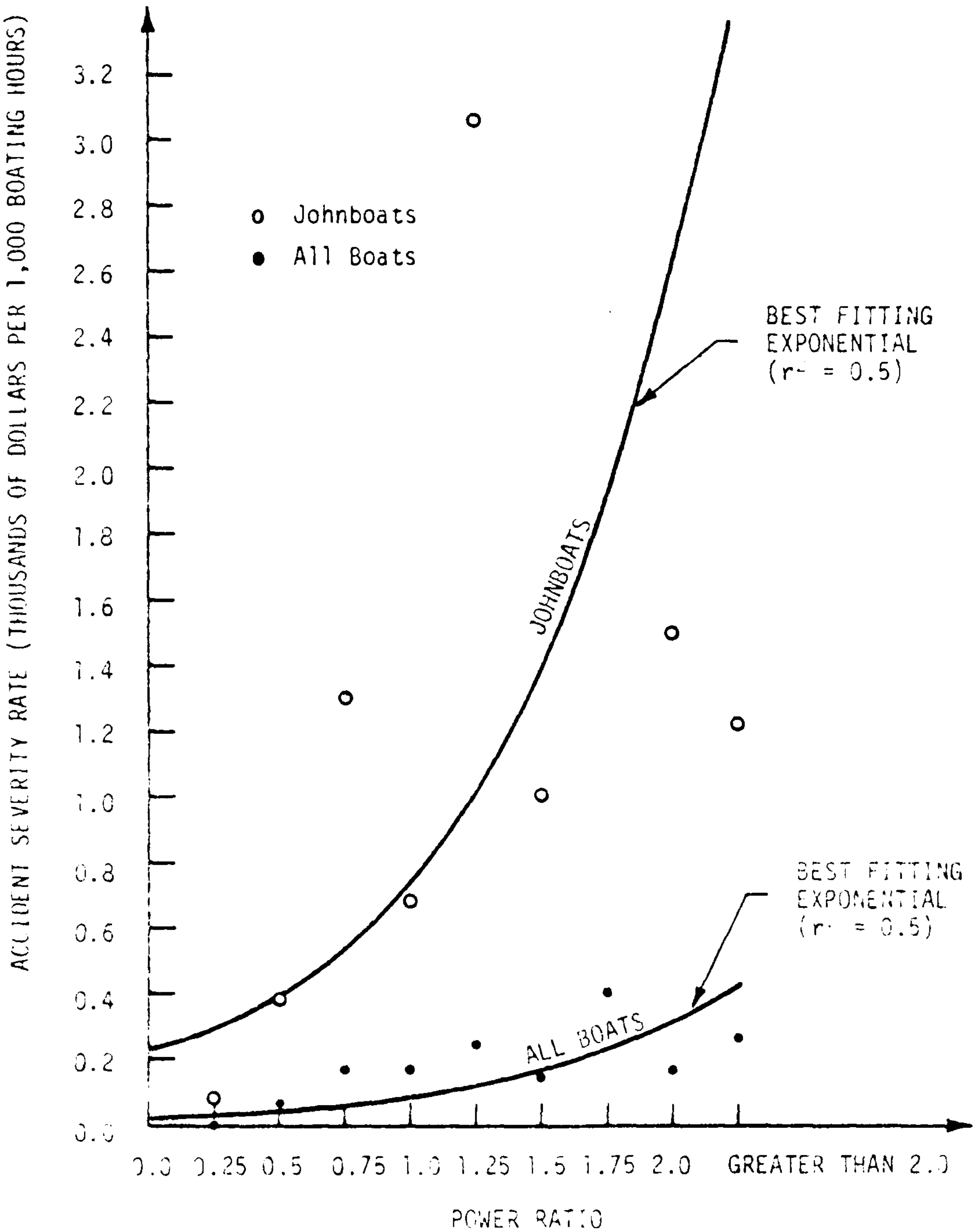


FIGURE 4-9. SEVERITY BY POWER RATIO FOR DIFFERENT BOAT TYPES

4.9 Conclusions to Regional Analyses and Other Results

The preceding pages have shown that regional differences exist in the powering related accident data. Subsequent analyses attempted to account for these regional differences in terms of boat type differences, water type differences (the number of course changes necessary to navigate the waters), and accident type differences. The results were:

- The distribution of powering related fatalities by geographic region is very different from the distribution of all fatalities by geographic region. The West accidents had relatively few powering fatalities while the Southeast accounted for nearly half of the powering fatalities.

- The Southeast had a high powering fatality rate (the number of fatalities per 1,000,000 boating hours) when compared to other regions.

- Johnboats accounted for over one-third of the boats involved in powering related accidents, while open powerboats accounted for over 40 percent.

- Swampings and capsizings (42%) and falls overboard or within the boat (42%) were the dominant accident types in powering related incidents.

- Over half of the powering related capsizings, and over 43 percent of the capsizings and falls overboard (combined) involved johnboats.

- The mean power ratio (mounted horsepower divided by rated horsepower) was the highest in the Southeast, and the mean power ratio for a boat in a powering related accident in the Northeast and the Southeast was not in compliance with the current powering standard.

- The Southeast accounted for over 41 percent of the powering fatalities associated with intentional course changes (turns), while the West accounted for less than 11 percent. Nearly half of the powering related fatalities were in accidents involving intentional course changes.

- The mean horsepowers by region in the powering related accidents were higher in regions with lower [illegible], and lower in regions with higher [illegible]. The Southeast was the only region with mean horsepower under

100 hp. However, different types of boats are used in different regions, and some perform differently than others when equipped with horsepowers above their formula rated horsepower.

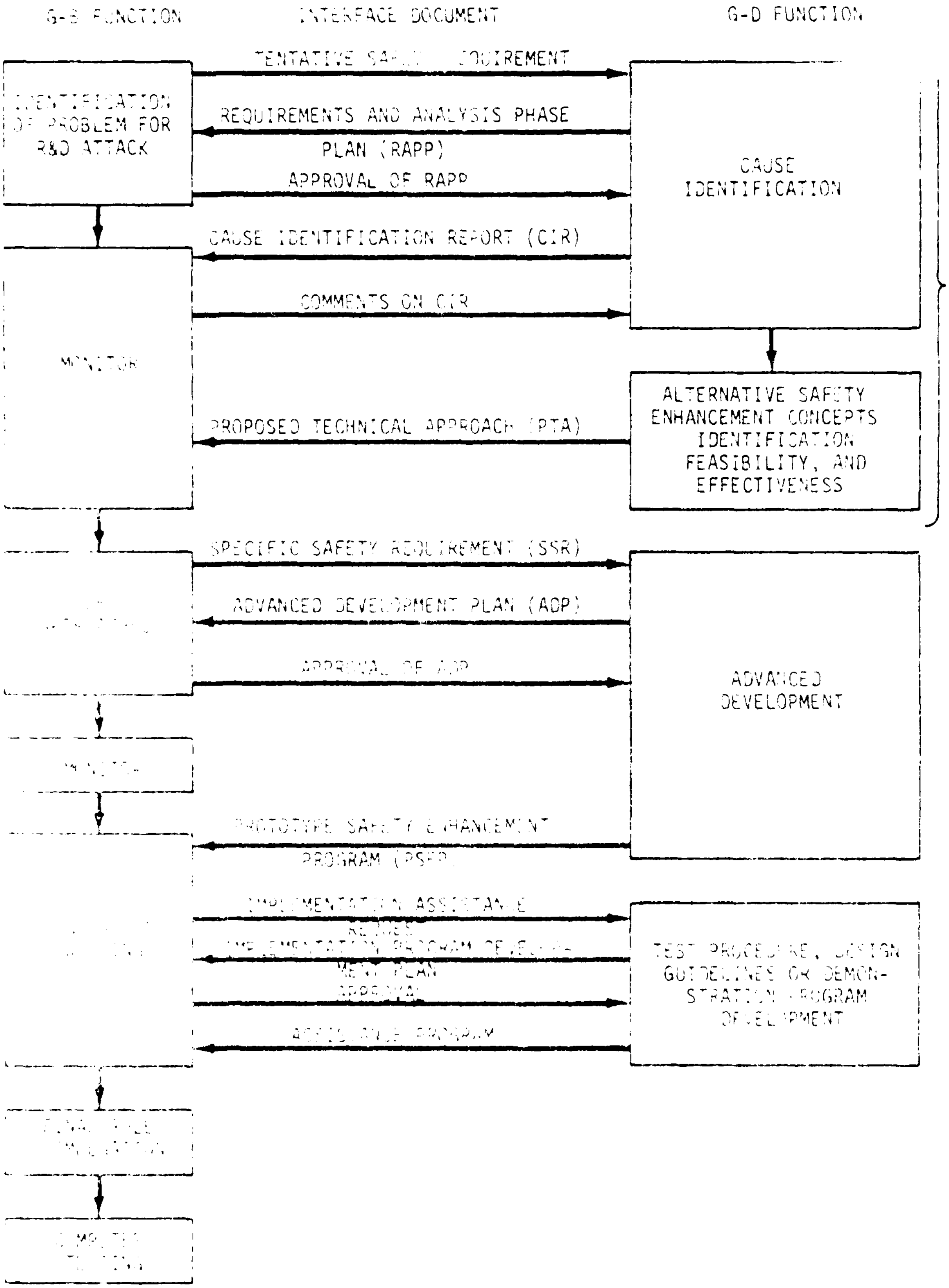
- In terms of risk of an accident, risk of a fatality, and severity of an accident, as the power ratio increases on johnboats in the powering related accidents, the risk or severity increases. The risks (accidents or fatalities per 1,000,000 boating hours) for johnboats were much higher than for an "average" boat in the data base.

5.0 PRELIMINARY IDENTIFICATION OF ALTERNATIVE APPROACHES

The RBS R&D development process, as depicted in Figure 5-1, calls for the identification, feasibility analysis, and preliminary effectiveness analysis of alternate solution concepts after the completion of the cause identification phase. In the present effort, it was decided to include a preliminary identification of alternate approaches task in the cause identification phase, in order to ensure that any concepts identified by the researchers working with the accident data were properly documented for use in the alternative concepts phase of the project. This section documents the concepts we have identified, and provides any readily available data we had concerning the rough magnitude of the accidents to which each idea is applicable.

As a means of structuring this section, Figure 5-2 depicts the interrelationship of the man, the machine, and the environment in an accident situation.

In most accidents, a change in the environment, the operator, or the boat could have "broken" the accident chain and thus prevented the accident. Since there is little that the Coast Guard can directly do to "regulate" the environment, we have organized our alternative concepts into standards concepts aimed at the boat, and possible educational or enforcement approaches aimed at the operator. It should be noted that the choice of approaches is not easy. There is a big difference between promulgating a standard or education program and achieving the "change" in boat or operator performance desired. Factors to be considered include: the "coverage" achieved (while standards, assuming high compliance, can reach nearly all boats of the type under consideration manufactured after a given date, education program coverage is not presently as widespread and has a definite problem reaching "boaters" who are not interested in becoming proficient at their hobby); the [illegible] materials degrade with time; boaters "educated" may well not recall, or choose to disregard, the safety message they received; the cost; and the [illegible] that other factors (additional operator risk-taking, etc.) will partially [illegible] totally negate the effect of the action. Some of these factors mentioned can be quantified through additional study as an aid to management decision making. Others must be decided based solely on management subjective judgment [illegible].



PROGRAM DEVELOPMENT
AND INTERFACE DOCUMENTS

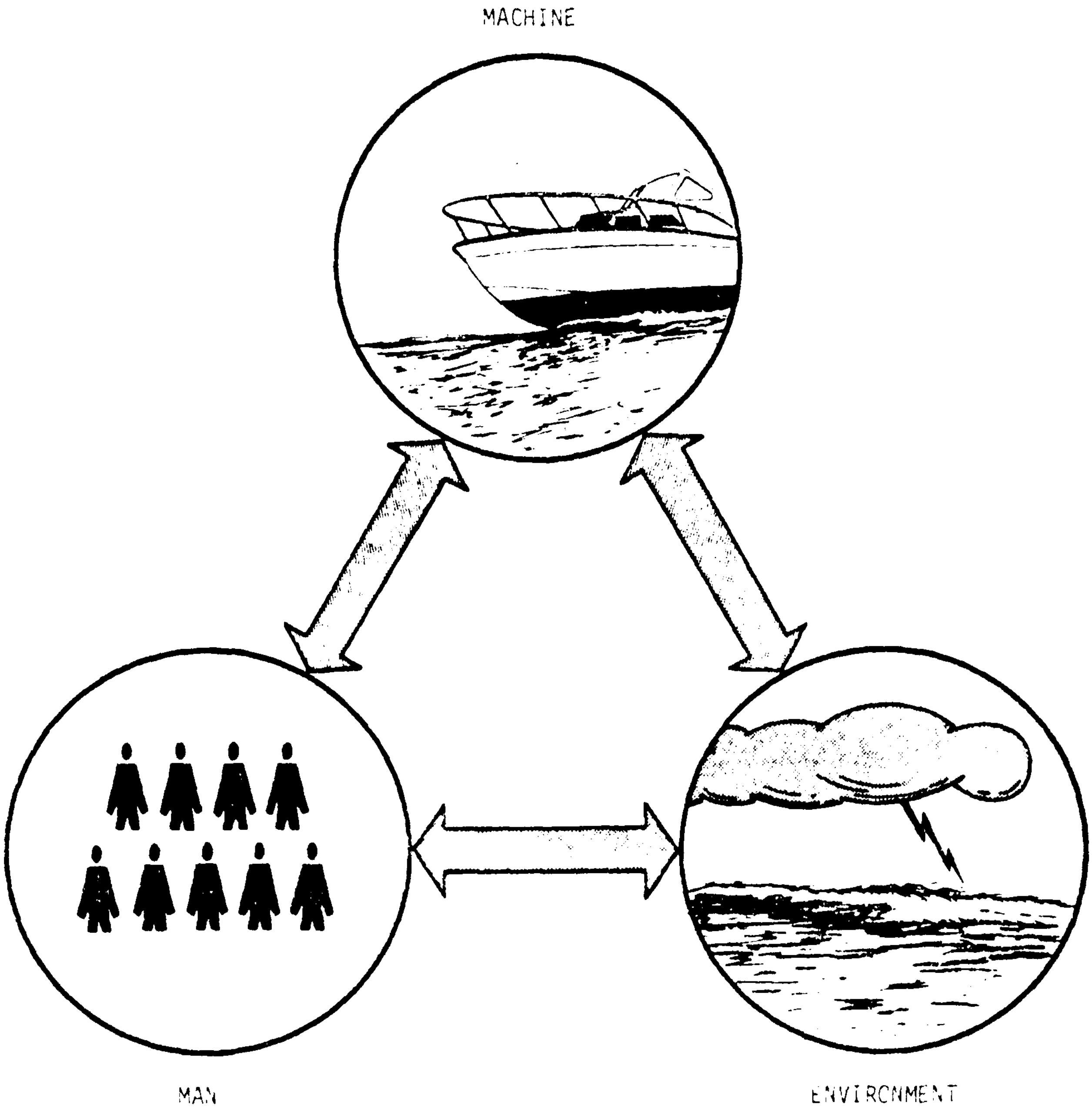


FIGURE 4-2. RECREATIONAL BOATING SYSTEMS AND RELATIONSHIPS

5.1 Standards Approaches

[illegible] section on standards approaches has been subdivided into sections on alterna-[illegible] affecting mounted horsepower and other alternatives to powering related ac-[illegible] prevention, such as start-in-gear protection or non-skid surfaces.

5.1.1 Horsepower Labeling Alternatives

[illegible] going further, some discussion of the present standard and its interrela-[illegible]ship with other boating safety standards is in order. The present standard, [illegible] the federal level of enforcement, is a labeling criteria. It provides informa-[illegible] to the consumer concerning the horsepower capacity of his boat as defined by [illegible] standard. Therefore, it might be more [illegible] identified as an educational [illegible] rather than a standards approach. There is no federal requirement that [illegible] horsepower less than or equal to that appearing on the label [illegible] "overpowering" is considered [illegible] establishing negligence [illegible] accident [illegible] states have [illegible] laws which make it illegal to [illegible] an overpowered boat. The Boating Industry Association [illegible] not to sell [illegible] over the horsepower [illegible] even if requested to do so by the consumer, due to recent [illegible] the courts. We have been told that [illegible] dealer insurance [illegible] prohibit the selling of overpowered rigs. Due to all of [illegible] considerations, the "label information" has in practice provided [illegible] con-[illegible] the mounted horsepower of boats.

[illegible] excepting jonnboats, our research has indicated that the standard [illegible] safe levels of horsepower [illegible] [illegible] The standard fortunately does serve a secondary safety function. Both [illegible] and flotation standards require knowledge of the horsepower that [illegible] boat, in order to establish engine weights for use in [illegible] These standard [illegible] horsepower [illegible] load capacity and flotation [illegible] than be powered in accordance with the label. Fortunately [illegible] board in most accidents with larger boats. Therefore, as a practical matter, even large (≈50%) percentage increases in power, probably do not significantly increase accident or decrease recovery probabilities. Nevertheless, in the absence of federal formulation or other required means of determining horsepower capacity, some provision for consumer information labeling of the safe horsepower or safe engine weight used in determining load capacity and flotation capability would have to be provided.

With the preceding in mind, we have identified the following alternatives for labeling of outboard horsepower capacity for boats other than johnboats (as the present standard appears effective for johnboats):

a. Eliminate the present formula standard but require labeling of manufacturer determined horsepower capacity. This approach would assume that no cost-effective capacity discriminator (test course or formula) could be identified. As the loading and flotation regulations require a horsepower, or engine weight limitation of some sort, safe horsepower capacity information would still be required, but the limit would be set by the manufacturer using any method he chooses. This is essentially the system which presently exists for inboards - the manufacturer establishes his own horsepower limit, but must use the corresponding engine weight in determining load capacity and flotation requirements. The unfortunate outcome of this approach might be that it could result in the de facto continuation of the present formula due to manufacturer product liability considerations.

b. Develop a new standard using test courses. Based on the accident scenarios contained in this report, tentative performance criteria for boats under power would be developed and a test course to measure the corresponding parameters developed. Pass/fail criteria would then be established and the test courses validated for internal consistency and external validity. The latter is easily said, but past experience (Reference 1) indicates that internal consistency across test organizations is difficult and expensive to accomplish.

Once a performance criterion is established, developing a test course and pass/fail criteria to test it is reasonably straightforward. Unfortunately, developing one which minimizes the influence of changes in driver skills and judge's experience is not as easy. One alternative is to use electro-mechanical "drivers" and "judges," but the resulting criteria would essentially require each manufacturer to submit his entire line to a test lab that could afford the instrumentation for testing. The resulting expense of self-certification might well destroy the viability of the approach. This leaves two alternatives:

1. Develop a formula based on the test course results and promulgate it. This will be discussed in more detail later.

2. Develop a conservative formula and a test course, and allow a manufacturer to self-certify by either method, but require him to indicate which he [illegible] compliance test [illegible] down. The label, for instance, would say:

   Maximum horsepower*, 135

   * By test course method

   or

   * By formula method

   [illegible] allow a manufacturer who felt his innovative design [illegible] a higher horsepower than the formula [illegible] the test course method. At the same time, [illegible] interested in boosting his horsepower rating [illegible] the [illegible] and save the expense of undergoing the [illegible] test.

[illegible] new standard based solely on a formula. The new formula [illegible] established by one of two methods:

[illegible] test course. [illegible] was described briefly above. Basically [illegible] and [illegible] of test course results could establish a new [illegible]. However, the formula would have to be [illegible], and [illegible] to [illegible] beating, [illegible] changes [illegible] [illegible] [illegible] [illegible]

[illegible] not in the marketplace, [illegible] sensitivity analysis and expert judgment after the tests were completed and alternative formulas derived.

2) Based on accident data. A formula could, theoretically, be derived by computing various "power ratios" for the powering and nonpowering related accident samples until a valid predictor of risk was uncovered. Unless some theoretical consideration or test course results were used to first identify candidate ratios, this would amount to a "fishing" expedition with little probability of success. The limitations of the accident data also would limit this approach to relatively simple formulations. As in the test course formula approach, an analysis of the susceptibility, or actual validity of the ratio as opposed to simple statistical correlation, of the ratio to "rule beating" or applicability to changing design parameters would have to be investigated.

5.1.2 Other Standards Approaches

There are several possible alternatives that can be pursued to prevent the accidents [illegible] at the various nodes on the decision tree. Some of the alternatives are [illegible] obvious in their identification, but are not effective enough in reality [illegible] significantly reduce the number of fatalities associated with the powering problem.

[illegible] earlier that the major significance in the powering related [illegible] lie in lives lost and not in property damage losses. The [illegible] property damage as indicated in our powering related accident sample [illegible] approximately one (1) life when one estimates the cost of a life at [illegible]. Therefore, all benefit predictions discussed in this section will be [illegible] in lives saved.

[illegible] other hand, we must attach a monetary value on the cost of implementing [illegible] alternative approach. [illegible] investigation, the cost to the manufacturer and [illegible] we must [illegible] the number of lives saved by the [illegible]mentation. We have chosen the $480,000 per life as that cross reference tool.

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ABSTRACT

The powering project will include: defining powering-related accidents, collecting a sample of such accidents and coding them through a powering-related accident model (PRAM), identifying accident mechanisms, and formulating and evaluating powering standard concepts, including the present standard. Progress through the development of PRAM is reported in this technical brief. Operationally, defining a powering-related accident is equivalent to defining the sample to be coded through PRAM. This was accomplished through engineering analysis of the problem in consultation with Coast Guard personnel. A decision tree was developed which is presented and discussed in this report. A preliminary PRAM was developed and tested by the coding of 20 accidents. The results of that coding are presented, along with recommendations for the final form of PRAM, and for the processing of the remainder of the accidents in the total sample.

PREFACE

This document is the first of two volumes constituting a technical brief on the Powering-Related Accident Model (PRAM). Since the coding of the 20 accident sample through PRAM, several new developments in the powering project have occurred, necessitating a second volume. Volume 2 will detail these further developments in the areas of the powering-related accident decision tree, the nature of the total sample in terms of severity, and PRAM. In addition, the data needs for the evaluation of powering accidents will be reviewed in terms of the event and sequencing information that can only be obtained from in-depth investigations, some fatal accident reports, and field studies.

APPENDIX A. THE POWERING RELATED ACCIDENT MODEL
VOLUMES I AND II

WYLE LABORATORIES
MARINE TECHNOLOGY STAFF

TECHNICAL BRIEF 77-5

THE POWERING-RELATED ACCIDENT MODEL

VOLUME I

by

D. Christian Stiehl
Robert L. White

July 1977

Work Performed Under Contract No. DOT-CG-62555-A

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1) What is the rated horsepower capacity stated [illegible] on your boat?

2) What is the horsepower rating of the engine you currently have mounted on your boat?

3) Is your boat classified as a bass boat or fish and ski boat?

4) Were your boat and engine purchased separately or as a package?

- A comprehensive definition of a bass boat and a jonnboat should be developed and the BAR form and NBS questionnaire should be modified to include these as two additional types of boats. The definition should include considerations for future design changes.

- Engines should be dynamometer tested and rated under the same constraints regardless of manufacturer.

- A sensitivity analysis of the safe powering formula should be conducted using test courses related to the powering related accident scenarios for empirical varification. It is possible that the formula can be adjusted to reflect its potential effectiveness as demonstrated in the pre-regulation data.

- The present formula should be retained for establishing the horsepower limit for jonnboats, and possibly other boat types.

- The accident data base should be expanded to include [illegible] accidents in order to determine the effects of large, power-trimmed engines, and the increase in the bass boat population.

- Field investigations within the identified regions should be conducted during popular boating seasons to verify the assumptions made on exposure during this phase of the project (i.e., collect real-world power ratio data). These data should provide valuable input to educational/enforcement concepts as well.

The current standard formula was derived empirically from tests involving classically styled boats running small (less than 80 hp) outboard engines. This inherently indicates non-effectiveness for systems not included in the empirical derivation (i.e., flared-hull boats and/or high horsepower engines).

Test course methods (themselves extrapolated beyond their derivation criteria considerations) do not substantiate the point of "safeness" for outboards less than 20 feet in length. This is substantiated in the results of the tests conducted by the BIA and ABYS in Naples, Florida, in October, 1977 on boats equipped with V-6 outboard motors.

There are regional variances in the probability of having a powering related accident and the probability of having a powering related fatality. The Southeast region was the region with the highest risk. The regional differences can be accounted for in terms of boat types (johnboats, prevalent in the Southeast, having considerably higher powering accident and fatality risk than other boat types) and water types (many powering accidents and fatalities result from intentional course changes, such as might be required on the small streams and rivers of which there are many in the Southeast.

Flat-bottom/hard chine boats with relatively low internal freeboard (passenger compartment floor to gunwale) dimensions are the most frequently encountered boats involved in falls overboard during meaneuvers. The most significant (resulting in the most fatalities) accident mechanisms identified by the sample data involved high longitudinal or lateral accelerations and unexpected boat movements.

Most of the property damages are reportedly due to collisions in which the operator has lost control of the boat. This appears to be a result of accident reporting since, in most cases, insurance claims are involved.

Based on the results of this study, several recommendations are urged:

- The NBS questionnaire should be revised to include several questions that will supply much of the needed but missing boating information. The recommended questions are:

6.0 CONCLUSIONS AND RECOMMENDATIONS

The definition of a powering related accident is a complicated matrix of decisions, each requiring a judgmental decision on power involvement. Such a definition has been derived and applied to all reported accidents for 1975 and to all reported fatal accidents for 1976. Powering related accidents, as we have defined them, account for approximately six (6) percent of all reported accidents. This percentage involves, on the average, the loss of over 100 lives per year on the U. S. waterways. This is a conservative estimate, as the definition filters out such accidents as "grounding" and "hit submerged object." Although these types of accidents are not initiated (in most cases) by excessive power, powering may increase the severity of these types to the loss of life level.

Several comparisons of pre- and post-regulation boats in the sample were made with the data indicating that the ratio of mounted horsepower to formula rated horsepower was the same for pre- and post regulation craft. This indicates that, after being promulgated as a government standard, the present formula had little effect on changing the powering tendencies of the average boater in the accident sample.

It was found that compliance with the current standard was *no more frequent* for experienced boaters than for non-experienced. However, boating safety education was shown to lead to greater compliance.

The current standard formula is not a good predictor of risk (defined as the probability of having a fatality, or the probability of having an accident, for most types of currently designed boats). However, the formula prediction seems to be fairly good for john-type boats. The formula does not predict the impact of boat hull design changes above the water line and allows higher horsepower ratings for flared transom and streamlined boats irregardless of the absence of change in boat to water interfaces.

The current powering standard formula was evaluated in terms of several risk parameters. The comparison showed no increase in risk with non-compliance for post-regulation boats, but considerable increase in risk for pre-regulation boats.

a) If sound labeling criteria are developed and related to powering related accidents either through test courses and/or formulas based on test course results or accident risk data:

   1. Change overpowering to prima facie evidence of negligent operation on federal waters

   2. Encourage states to follow suit on state and joint jurisdiction waters

b) If no sound labeling criteria are developed relative to powering accidents but a labeling criterion remains:

   1. Advise states that federal horsepower limitations are important relative to overloading and flotation only, except for johnboats.

c) For johnboats, in any event:

   1. Encourage states to step up passage or enforcement of overpowering regulations for lightweight, hard chine boats (use definition in powering standards) as most johnboats accidents occur on inland, joint and state jurisdiction waters.

5.2 Education/Enforcement Alternatives

Two sets of education and enforcement related alternatives were identified as part of this effort. The first set are alternatives aimed at maximizing the effectiveness of the powering capacity labeling alternatives, the second set identifies common operator errors in powering related accidents which may or may not be addressed in present education or enforcement programs.

5.2.1 Education Related Alternatives to Enhance Powering Capacity Labeling Effectiveness

The following alternatives were identified under this category:

a) If a sound labeling criterion is developed and related to powering related accidents either through test courses and/or formulas based on test course results or accident risk data and in any event for johnboats:

1. Advise on the dangers of overpowering beyond the capacity stated on the label, including the susceptibility to powering, loading, and flotation recovery related accidents.

2. If a new, relatively simple, formula is developed, advise owners of existing boats on how they can calculate their new, improved, maximum horsepower capacity. Be careful to note dangers of increasing capacity as a result of the calculation due to loading and flotation considerations.

b) If no sound labeling criteria can be developed:

1. Advise on the dangers of having engine weights above those shown on the capacity plates relative to loading and flotation related accidents.

2. Advise on means of avoiding or recovering from "powering related" accidents.

5.2.2 Enforcement Related Alternatives to Enhance Powering Capacity Labeling Effectiveness

The following alternatives were identified under this category:

TABLE 5-7. MATRIX OF POSS[illegible] BENEFITS BY ALTERNATIVE STANDARD APPROA[illegible]

OTHER STANDARD APPROACHES	Accident Accept Modes 5	8	12	14	15	16	17	18	19
	Number of Fatalities [illegible]	11	[illegible]	58	22	15	34	22	24
Speed limits	x	x	x	x		x		x	
Limit on trim angle (this effectively limits net available horsepower)		x				x			
Non-skid passenger compartment surfaces					x	x			
Rail and/or guards				x	x			x	
Greater seat to gunwale dimensions (sides above passenger CG)				x	x			x	x
Variable ratio steering				x					
Spark advance limiter to reduce acceleration rates				x	x				
Thrust vector (lateral) indicator on steering wheel/column					x				
Owner operator to boat system introduction course				x				x	x
Engine start lock-outs (no start-in-gear even if hand cranked)					x				
Control station standards	x	x	x						
Minimum maneuvering space at docks and marinas	x	x	x						
Proportional throttle	x	x	x		x				
Ski observer laws	x	x	x						
No glare surfaces	x	x	x						
Revision to lighting standard [illegible]	x	x	x						
[illegible]				x					
[illegible] turn [illegible]				x					
[illegible] performance [illegible]				x					
[illegible] wake							x		x
[illegible] manner [illegible]									
[illegible]							x		
[illegible] water navigation course									
[illegible] law enforcement									
[illegible]									
[illegible]									
[illegible]									
[illegible] safety education					x	x			
[illegible] of state laws									
[illegible] Measures									
[illegible] usage				x	x			x	
[illegible] boards									
[illegible] swimming [illegible]									
[illegible] equipment [illegible]									
[illegible]									
[illegible]									

For those accidents accepted at node 14, possible approaches other than improved rails and guards can be identified. One possible approach is imposition of proportional steering ratios. This would result in a softer initiated turn and perhaps forewarn the passengers of the forthcoming change in direction allowing them the time to initiate restraining actions. The maximum benefit to be realized from this approach according to our sample is approximately seven lives per year. This means that in order to be cost effective, the one-time cost per boat must be less than $6.90. This approach has some disadvantages in that the avoidance maneuver is hampered by the additional movements required of the operator. This means that any benefits realized here may be offset by an increase in the number of collisions.

A list of several standard approaches that could be investigated in a future effort is presented in Table 5-1 along with the number of possible lives to be saved as indicated in our sample data.

encasement is not the solution. This leaves 29 total lives to be saved in two years.

Now, one must consider that by their nature, guard rails will result in a certain amount of bodily injury to the persons that are being kept in the boat. This must be deducted from the benefit. However, we will disregard this deduction here.

The disadvantage to this alternative lies in the costs to the consumer. An estimate of the cost of adding hand rails (based on wholesale catalog pricing of presently available railing hardware and including nuts, bolts, screws and a nominal labor estimate) runs on the order of $150 to $200 per boat considering an average length of 16 ft. Using the number of boats sold in 1977 as a base, the costs for outboards (per year) is somewhere between $50.4 million and $67.2 million and for inboard/outdrives between $12.6 million and $16.8 million.*

The total cost per year to the consumer is then between $63 and $84 million dollars. The costs would have to be reduced to approximately $16 per boat in order to be cost effective.

If the benefit to society is to be compared to the cost, then both must be expressed in terms of dollars. Various dollar values have been assigned to a human life during various research programs. For the purpose of illustration, a value of $480,000 is chosen.

If the entire population of registered boats is assumed to have the improved rails and guards, then:

$$\frac{\text{(lives saved per year) x (value of life)}}{\text{Boat Population}} = \begin{matrix}\text{Allowable}\\ \text{Cost per year}\\ \text{per boat}\end{matrix}$$

Multiplying this number by the expected life of a boat (15 years), a one-time cost per boat is obtained.

We can apply the above rationale to the fatalities at each node of acceptance and determine the benefits/costs of various other standard approaches.

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* These numbers are based on the Boating Industry Marine Market Survey for 1977.

[illegible] is not to be construed as promoting a theory that lives of boaters are [illegible]portant in a monetary sense only.)

There are two approaches to standard promulgation when attempting to save boaters' [illegible]. Basically standards fall into one of two categories: 1) standards to pre-[illegible] accidents, and 2) standards that preserve the capability to recover from the [illegible]. Both categories have been investigated by the Coast Guard. Obviously, many of the boaters counted as fatalities in the powering related accident sample [illegible] have been saved through recovery measures such as would exist through recovery type standards such as PFD usage, mandatory swimming instruction, level flotation, [illegible] others. However, the primary attention here should be placed on accident pre-[illegible] instead of recovery.

[illegible] prevention category, there are alternative approaches that cross over the [illegible] separation between various nodes of acceptance and may therefore save a [illegible] those lives documented in different nodes. Examples of these are: [illegible] education, 2) improved hand rails/guards, and 3) beverage control laws.

[illegible] education has been addressed earlier. Beverage control is a state enforce-[illegible] problem with extremely high costs.

[illegible] hand rails/guards could be considered a viable alternative. Requiring [illegible] to incorporate these into the design of their boats could possibly [illegible] a portion of those fatalities listed under nodes 14 and 18.

[illegible] sample there were 58 fatalities listed under node 14 and 22 listed [illegible]. Both of these nodes involve falls overboard. However, there are [illegible] at each of the two nodes. The total number of fatalities [illegible] for at both nodes is 80. Also, since the present formula works for [illegible] we subtract those (27 fatalities) from the number. (These cases were [illegible] the formula to become accidents.) Part of those 53 remaining [illegible] the result of capsizings and swampings leaving (43) that could possibly have been saved had they not gone over the side. However, approximately 30% of these [illegible] to their fall by being in a poor position. It must be assumed that [illegible] would not have been helped unless they were "encased" [illegible] way for them to be dislocated. Common sense dictates tha

THE POWERING-RELATED ACCIDENT MODEL

1.0 INTRODUCTION

The objectives of the safe powering project are: 1) to determine the need for a standard limiting the horsepower of recreational boats, and 2) to determine whether there is a need to improve the present standard or develop a new one.

Basically, there are two major work elements in obtaining each of the objectives listed above. First, powering-related accidents must be defined. This type of accident is not as easily defined as others, and this work element is critical in determining the need for a powering standard and evaluating alternative standard concepts. Second, through accident data analysis, the need for a powering standard should be determined. The definition obtained in the first work element is used to define the sample of data to be analyzed. The powering related accident model (PRAM) is developed as part of the second work element. It is an analytical tool to be used to summarize and manipulate the accident data. Provided a significant number of powering accidents do occur, PRAM will enable the description of these accidents in terms of the prominent accident mechanisms.

The two work elements that enable the attainment of the second objective above are: 1) evaluate the effectiveness of the present powering regulation, and 2) evaluate the effectiveness of other possible powering regulations. Through this phase of the project questions such as, "Does the present standard prevent powering accidents?", and "Would another standard prevent powering accidents which might occur under the present regulation?" should be answered.

This technical brief provides an accounting of the progress to date in achieving the first objective, that of determining the need for a powering standard. The development of the definition of a powering-related accident is detailed and the final form of the definition (a decision tree for accepting accidents in the sample for PRAM) is described, including scenarios of accidents that would be included. The development of PRAM is outlined to the point of the coding of 20 accidents to test the model.

The results and implications of the coding of that sample are analyzed. Suggestions and revisions for PRAM are discussed, along with the proposed approach to the coding of the entire powering-related accident sample.

2.0 DEFINITION OF A POWERING-RELATED ACCIDENT

The important first step in the powering project was to define a powering-related accident. This task was complicated by the fact that powering-related accidents occur in many, if not all, of the common accident types (e.g., collisions, falls overboard, capsizings, etc.).

As a start toward the definition of powering-related accidents, a list of situations which were significantly or tangentially related to powering was made. This list is shown below:

Significantly Powering-Related

1. Those accidents where the operator lost directional control of the vessel while it was underway and under power.
2. Those accidents where the boat did not respond to the helm as the operator intended while it was under power.
3. Those accidents where persons fell overboard or the boat capsized or swamped during a maneuver.
4. Those accidents where the boat capsized or swamped and indications exist that its seaworthiness had been degraded by the speed at which it was operating.
5. Those accidents where a sudden application of thrust initiated the accident.
6. Those accidents where the vessel's kinetic energy contributed significantly to the severity of the accident and no other viable regulatory approach appears to exist.

Tangentially Powering-Related

1. Those accidents where kinetic energy was a factor but other viable regulatory approaches exist.
2. Those accidents involving a material or subsystem failure.
3. Those accidents where the operator was unable to detect an object,

and a collision occurred, due to visibility problems involving the vessel's trim or heel angle.

4. Those accidents where the operator was impaired by powering-related stressors.

<u>Not Powering-Related</u>

All others.

2.1 Initial Sorting of the 1975 Accidents

Through consultations with the Coast Guard and further analysis of the problem, a decision tree was developed for the sorting of the 1975 boating accidents reported to the Coast Guard into the potentially powering-related accidents and all others. This tree is shown in Figure 1. It rejects a large number of accidents at the top of the tree that are not powering-related (those involving boats that were not powered or were not underway, etc.). The later decisions in the tree involve the accident mechanisms and the involvement of speed, power, and thrust in those mechanisms. This tree was used to perform an initial sort of the 1975 accident data, and to select the potentially powering-related accidents from those data.

In order to minimize the number of accidents to be read and sorted, the Coast Guard's computerized data system was used to cull those accidents which were easily eliminated from consideration. If the boat had no engine, or horsepower was unknown, or (in some cases) the boat was not underway, then the computer could eliminate these accidents from consideration quickly.

Wyle personnel applied the decision tree shown in Figure 1 to the accidents that survived the computer sort. A sample of approximately 1200 accidents were "accepted" from the initial population (before the computer sort) of approximately 6300 reported cases. Records were kept of the number of accidents accepted/rejected at each node.

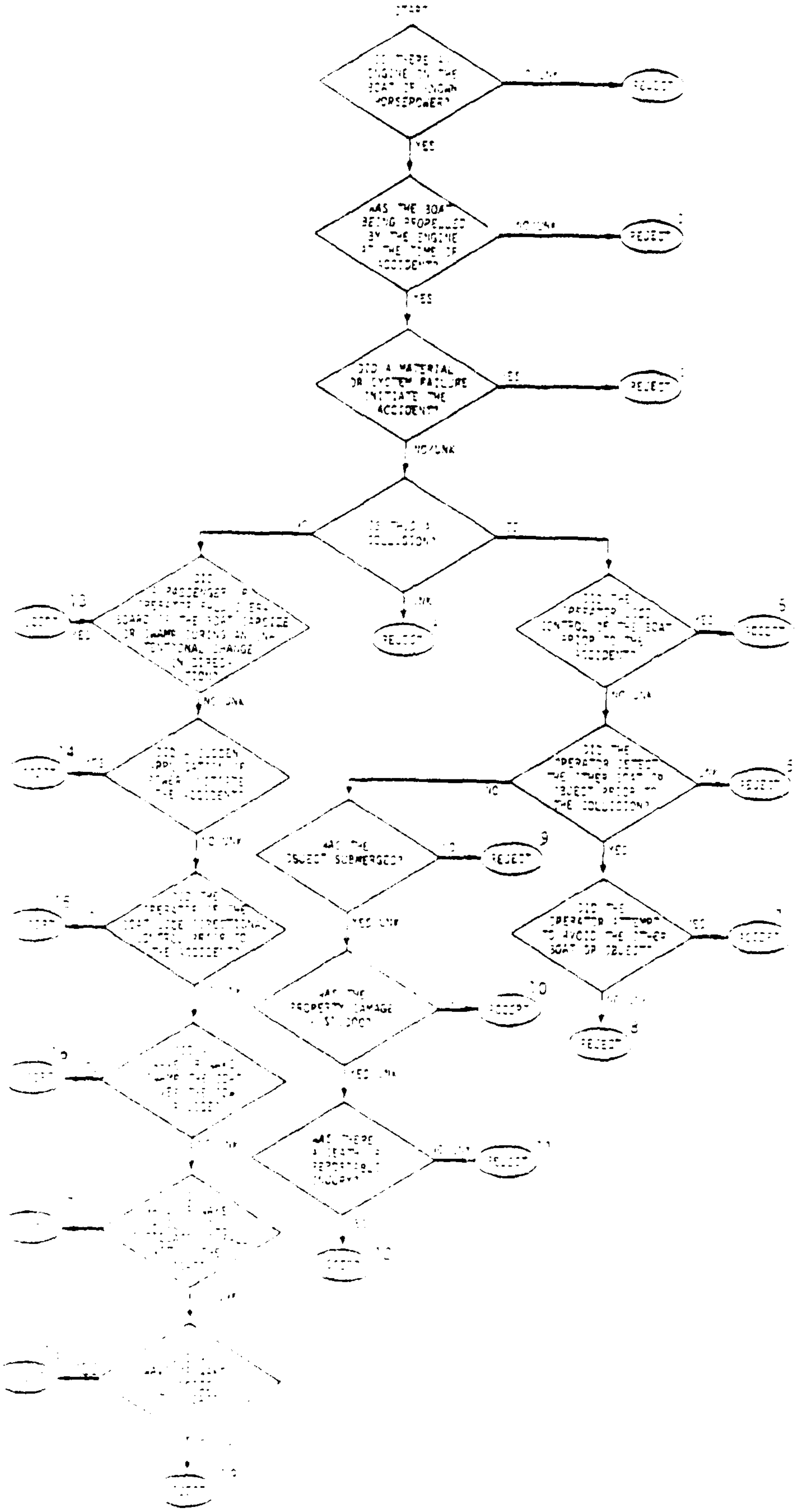


FIGURE 1. POTENTIALLY POWERING-RELATED ACCIDENT DECISION TREE

2.2 The Final Definition of a Powering-Related Accident

Upon further analysis and consultation with USCG personnel, it was decided that the definition of a powering-related accident needed further refinement; i.e., the sample needed to be reduced further, particularly in the areas of collisions and loading-related accidents where the involvement of powering was tangential or secondary in nature.

The result of the further analysis was the final definition of a powering-related accident. The final decision tree is shown in Figure 2. Any accident which is processed to an "accept" node in this decision tree is considered a powering-related accident.

The differences between Figure 1 and Figure 2 are subtle. The first four decisions in the tree are not different. On the non-collision branch (node 13 and below), the change in Figure 2 was the addition of the top decision in that branch. This was inserted to reject those accidents where underpowering may have been a significant causal factor, and other accidents that were not related to overpowering. Note that accidents involving boats operating at less than half throttle <u>can</u> be included in the sample, but only if their horsepower per foot of boat length ratio is high. Thus, a small boat with a large engine, which could experience a powering problem at low throttle settings, <u>is</u> included in the sample; i.e., it can be accepted.

For the collision branch of the tree, several changes were made. The concept behind the decisions in the tree in Figure 2 was to include those accidents where: 1) the operator theoretically had a chance to avoid the collision (he detected the other boat, etc.), and 2) his speed (lack of time) precluded the execution of an effective avoidance maneuver. Cases where the operator lost control of the boat are still accepted. Cases where the object of the collision was not detected, or the operator did not respond in time because of alcohol or other stressors, or where the environment (waterway, etc.) precluded avoidance were collisions which the decision tree rejected. It should be noted that the decision tree allows for some engineering judgment in cases where the decisions can be surmized but are not directly known.

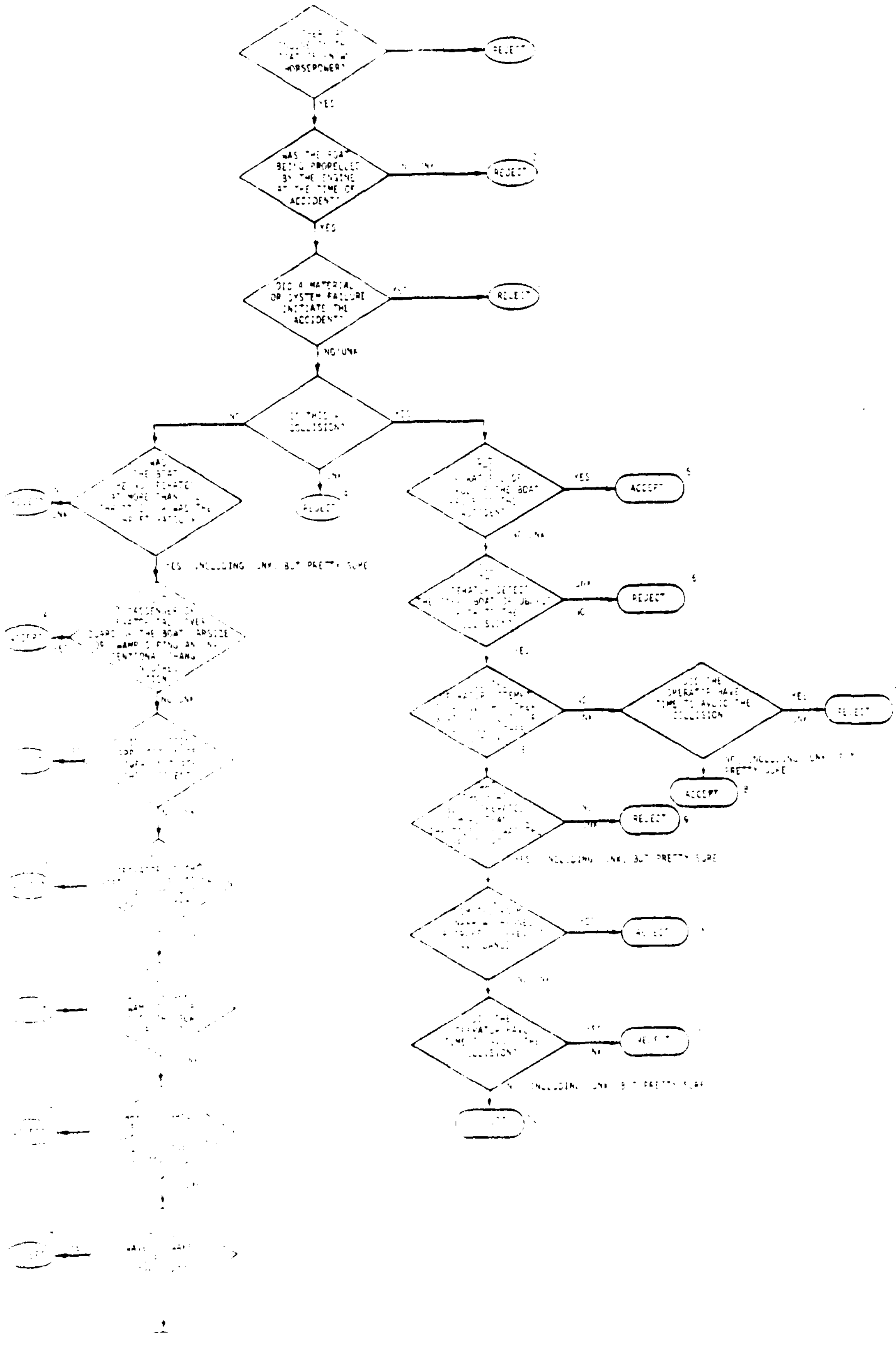


FIGURE 2. FINAL POWERING RELATED ACCIDENT DECISION TREE

This decision tree (Figure 2) was used to code the node of acceptance for the 20 accidents in the PRAM evaluation sample (see next section) and will be used prior to and during the coding of all accidents reviewed by the analysts for PRAM.

2.3 Accident Scenarios Which Would Be Accepted

Example scenarios have been developed for each of the "accept" nodes in the decision tree (Figure 2). These are listed below in order to illustrate the meanings of each of the decisions in the tree. The examples are not intended to be all-inclusive but illustrative.

NODE 5: A motorboat was proceeding at a fast rate of speed. While attempting to pass a boat which it was overtaking it hit the wake of the other boat, causing the overtaking boat to go out of control and strike the boat that was being overtaken.

NODE 8: A boat enters a marina area at 3/4 throttle. While proceeding past several docked boats, the operator notices one vessel backing out of its dock, directly in his path. Before he can react to the situation, the collision occurs.

NODE 12: A motorboat was proceeding up a river at a fast rate of speed. As it rounded a bend in the river, the operator noticed another boat heading towards him. Both boats attempted to turn away from the impending collision, but could not. The boats collided as the turns were being executed.

NODE 14: An operator is proceeding up a narrow waterway at high speed. He rounds a bend and finds a boat in his path. In turning to avoid the other boat, he loses control and capsizes. One occupant drowns or extensive property damage occurs.

NODE 15: An operator applies full throttle suddenly while a passenger is shifting from one seat to another. The passenger falls overboard and drowns before the operator can return to pick him up.

NODE 16. An operator is proceeding at high speed across a lake. He hits a wave and loses control of the boat, which goes into "dynamic instability" and capsizes. One occupant drowns either due to "sudden drowning," being a non-swimmer, or being hit on the head during the capsizing.

NODE 17: A boat proceeding at high speed encounters a large wave which enters over the bow and swamps the boat. One or more occupants drown prior to rescue.

NODE 18: A boat is on plane, and while it is traversing a large wave at an angle, one passenger is knocked down, causing a severe head injury.

NODE 19: A boat proceeding at high speed encounters a wave or wake which capsizes the boat. One or more occupants drown prior to rescue.

3.0 PRELIMINARY PRAM

Upon the completion of the sorting of the 1975 accidents, the powering-related accident model (PRAM) was developed. This model was designed to summarize the accident data in an organized fashion to allow for the identification of powering-related accident mechanisms and the evaluation of the potential benefits attributable to alternative powering regulation concepts.

Through a review of the powering accident decision tree and the resulting sample of 1200 accidents, as well as several consultations with USCG personnel, several key decisions were made as to the content, form, and purpose of PRAM. PRAM was built using analytical techniques similar to those used in previous successful data modeling efforts (CAM - the collision accident model, and ARM - the accident recovery model). Three purposes were identified for PRAM: 1) to summarize/organize powering-related accident data and provide scenarios of common powering-related accidents, 2) to identify the dominant mechanisms of these accidents, and 3) to provide statistics and probabilities on all relevant factors and combinations of factors in these accidents in order to facilitate the estimation of potential benefits attributable to alternative powering regulation concepts. In reviewing the accident data and purposes of PRAM, it was determined that sequential dependencies in powering-related accidents would be difficult to identify, if they were present. This suggested that PRAM should be a matrix-like model, concentrating on the conditions surrounding the powering-related accidents and their interrelationships, rather than upon sequential dependencies (a more tree-like approach).[1] Thus, from the outset, PRAM was conceived as a model with many variables coded as separate entities and relationships indicated by the ability to organize the data in many ways. This approach allows PRAM to be flexible in the ways that information can be categorized, which should prove to be beneficial when the benefit estimations are performed.

After additional analysis of the accident data and further consultations with USCG personnel, a preliminary PRAM (including coding instructions) was designed. This model included information in each of the following areas:

Accident Identification Number	Speed (at the time of accident)
Coder (Wyle analyst)	Trim Tabs? (yes or no)
State	Motorwell? (yes or no)
Month	Helm Location
Year	Type of Steering Controls
Time (of the accident)	Type of Throttle Controls
Boat Type	Type of Propeller
Boat Length	Motor Manufacturer
Boat Width	Horsepower (in use)
Hull Shape	Motor Weight
Year of Manufacture of the boat	Maximum Engine RPM
Type of Power	People on Board
Body of Water	Activity (at the time of accident)
Water Conditions	Rated Horsepower

---

[1] For detailed discussions of these two approaches to accident data models, the reader is referred to: Personal Flotation Devices Research-Phase I, by T. Doll, S. Stern, M. Pfauth, and R. MacNeill, report to USCG for contract No. DOT-CG-42333-A, T.O. [illegible], July 1976, pages 1-1 to 1-32; and, Regulatory Effectiveness Methodology-Phase II Research, Interim Report, by S. Cohen, [illegible], report to USCG for contract No. DOT-CG-42333-A, T.O. [illegible], March 1977, pages 2-27.

Visibility	Rated Weight of People on Board
Wind	Rated Total Weight
Number of Survivors	Rated Motor Weight
Number of Fatalities	Powering Ratios: HP: 1/10 ft.
Operator Skill/Experience	HP: 10 lb. Boat Wt.
Operator Fatigue/Stress	HP: 10 lb. Total Wt.
Weight of Gear on Board	HP: Rated HP

Course Tree (a decision tree to code information on course changes prior to and during the accident).

Powering Behavior Tree (a decision tree to code information on throttle settings used prior to and during the accident).

Load Distribution Tree (a decision tree to code information about possible loading problems and the engine's involvement in them).

Node of Acceptance (the node in Figure 2 which was the "accept" node for this accident).

This information was to be coded using the computer coding sheet shown in Figure 3. Instructions for the proper ways to code each of these variables can be found in the PRAM Analyst's Guide (Appendix A). This guide includes the powering-related accident decision tree, a copy of the coding sheet, and detailed instructions on the coding of each variable. The version of PRAM that is found in Appendix A was used in the trial coding of 20 powering-related accidents.

4.0 CODING OF 20 ACCIDENT SAMPLE

A trial sample of 20 powering-related accidents was processed through the preliminary PRAM in order to test the appropriateness of the model. It was anticipated that the preliminary PRAM would need to be refined in order to model the accident data. Some variables may have requested information that was simply unavailable in the data base. The sample of 20 accidents was processed in order to identify those areas where PRAM should be revised.

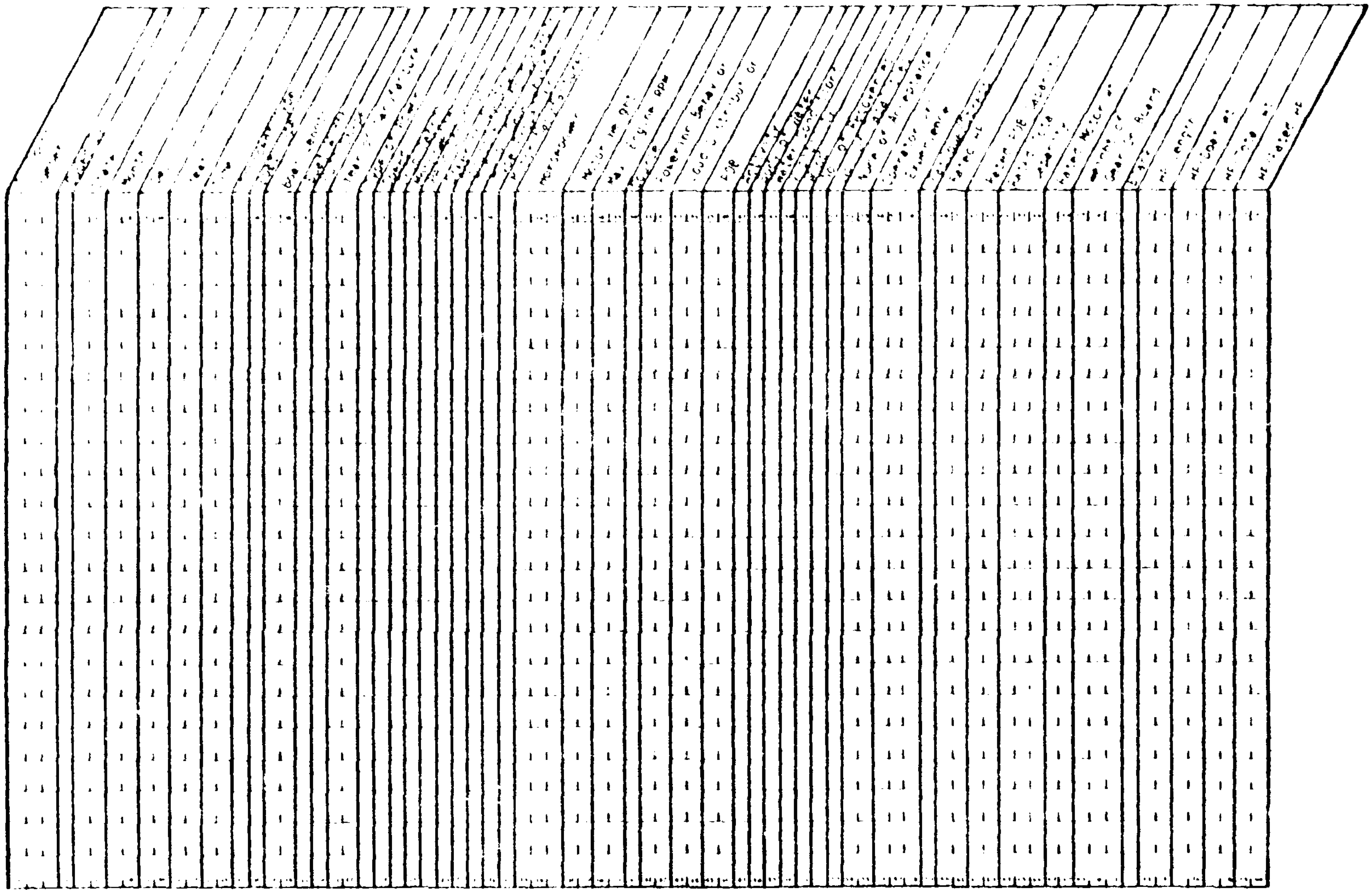


FIGURE 3. PRELIMINARY PRAM CODING SHEET

Results of the coding of these 20 accidents are reported below, and their implications for PRAM are outlined in the next section (5.0 The Powering-Related Accident Model).

Preliminary PRAM Results

Number of Accidents Coded: 20

Computer Column(s)	Variable				
05-06	States:	Alabama	1	New York	4
		Arizona	1	North Carolina	3
		Illinois	1	Oregon	2
		Indiana	1	Pennsylvania	2
		Iowa	1	Tennessee	1
		Massachusetts	1	Virginia	2
07-08	Months:	March	1	July	5
		April	1	August	6
		May	1	September	3
		June	3		
11-12	Year:	20 from 1975			
13-14	Time:				
		00:01-03:00	0	12:01-15:00	8
		03:01-06:00	1	15:01-18:00	7
		06:01-09:00	0	18:01-21:00	3
		09:01-12:00	1	21:01-24:00	0
[illegible]	Accident Type:				
		Collisions	17	Struck by Boat or Prop.	1
		Falls Overboard	2		
16	Boat Type:				
		Open Power	19	Cabin Cruiser	1

Computer Column(s)	Variable				
17-18	Boat Length:				
		14 ft.	12	17 ft.	1
		15 ft.	1	18 ft.	2
		16 ft.	4		
19	Boat Width:				
		0-3 ft.	1	6 ft.	1
		4 ft.	8	unknown	7
		5 ft.	3		
20	Hull Shape: 20 Unknown				
21-22	Year of Manufacture:				
		1959-63	3		
		1964-68	7		
		1969-73	7		
		unknown	3		
23	Type of Power: 20 Outboards				
24	Speed:				
		20-30 mph	1		
		Unknown, but increasing	4		
		Unknown	15		
25	Did the boat have trim tabs? 20 unknown				
26	Did the boat have a motorwell? 20 unknown				
27	Helm Location: 20 unknown				
28	Steering Controls: 20 unknown				

puter umn(s)	Variable
29	Throttle/shift Control Levers: 20 unknown
30	Type of Controls: 20 unknown
31	Type of Propeller: 20 unknown
32	Motor Manufacturer:

Mercury	3	Chrysler	1
Johnson	2	Unknown	9
Evinrude	4	Other	1

-35 Horsepower:

0-30	5	91-120	1
31-60	6	121-150	1
61-90	7	151+	0

36-37 Motor Weight:

88-100 lbs.	1
150+ lbs.	7
Unknown	12

[illegible] Maximum Engine RPM:

5500	2
4800	2
Unknown	16

4[illegible] Course: Did operator attempt to change course?

Unknown	[illegible]
No	9
Yes	7...

Did operator lose control?

Yes 7...

Loss of control due to:

Too difficult a manuever	[illegible]
Unknown	2

Cols	Variable Name	Description and Coding Instructions
1 2	Year	Enter the last two digits of the year in which the accident occurred.
3 4	Time	Code the two digits (in military time; i.e., 00-24 hours) corresponding to the time, to the nearest hour, that the accident began. Code the time of the capsizing, for example, when a boat capsizes and the people are not recovered for 10 hours.
5	Accident Type	Code the primary (first) accident type. For example, if there is a collision causing someone to fall out of the boat, all people on board are coded as victims of a collision, not a falls overboard. Similarly, if a personfalls out of a johnboat causing it to capsize, throwing a second person into the water, both victims are coded as falls overboard, since that was the primary cause of the accident. Occassionally more than one accident happens consecutively in time. A person might fall overboard, and a second person (coming to his aid) might be struck by the boat or prop. These two incidents would best be coded as separate accidents. These types of accidents will require judgment, and other analysts should be consulted if there is any doubt. 1 = collisions/groundings 2 = swampings/capsizings/floodings/sinkings 3 = fires and explosions 4 = falls overboard/falls within the boat 5 = struck by boat or propeller 6 = other
6	Boat Type	Code the single digit that corresponds to the best description of the boat involved. 1 = high performance boat 2 = open powerboat 3 = cabin motorboat 4 = auxiliary sail 5 = canoe/kayak (powered) 6 = houseboat 7 = inflatable 8 = unknown 9 = other
7 8	Boat Length	Code the length of the boat as a two digit number (measured to the nearest foot). For all accidents, code "boat data" for the appropriate boat. For falls overboard, this would be the boat that the victim left. For hit by the boat or prop, this would be the boat that did the hitting.
9	Boat Width	Code the one digit number that corresponds to the boat's maximum width (measured to the nearest foot) 0 = 0-3 ft. 5 = 8 ft. 1 = 4 ft. 6 = 9 ft. 2 = 5 ft. 7 = 10 ft. 3 = 6 ft. 8 = unknown 4 = 7 ft. 9 = greater than 10 ft.

PRAM Coding Instructions

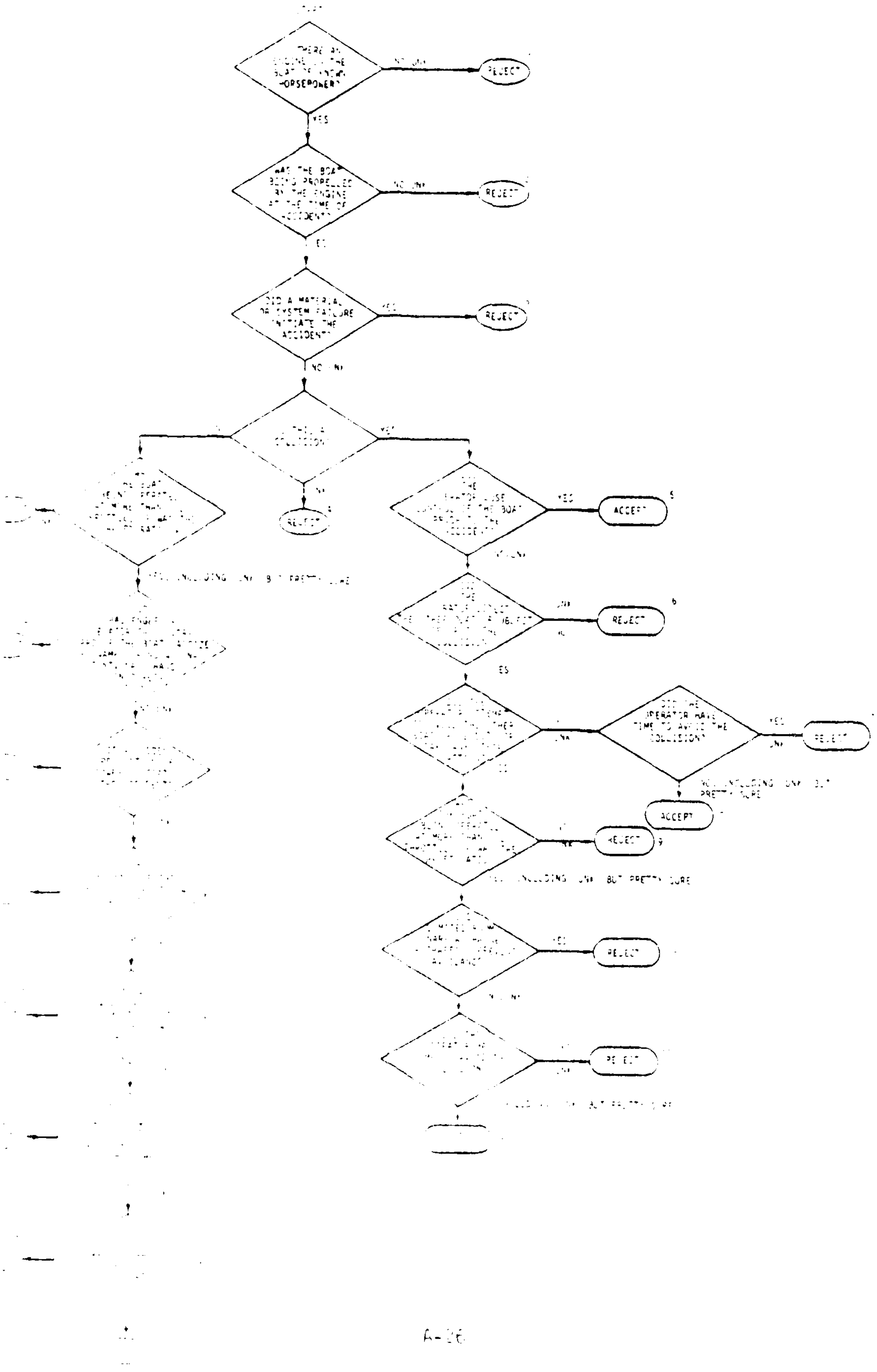
Once you have decided that [illegible] ident is acceptable for PRAM, [illegible] row on the coding sheet complet[illegible] for that accident using the [illegible] tructions.

umn(s)	Variable Name	Description and Coding Instructions
01 02 03	Accident #	This is the number of the accident in our sample. It is used to identify the accident in case we should ever need to refer to it again. The first accident coded into PRAM will be "001," and the next will be "002,"etc., until all of the appropriate accidents have been coded. Each time an acceptable accident is found, it should have the next sequential accident number written on it in bold black printing.
04	Coded By	The analyst who codes each particular accident should enter his personal one digit code here. Codes are: 0= Mark Perry 4= Bob White 1= Stuart Burrell 5= Jack Bowman 2= Benny Smith 6= Olivia Corder 3= Chris Stiehl 7= Nona Whatley
05 06	State	Enter the appropriate two digit code for the state where the accident occurred, according to the list below:

Alabama	01	Alaska	02	Arizona	04
Arkansas	05	California	06	Colorado	08
Colorado	[illegible]	Connecticut	09	Delaware	10
Dist. of Columbia	11	Florida	12	Georgia	13
Hawaii	15	Idaho	16	Illinois	17
Indiana	18	Iowa	19	Kansas	20
Kentucky	21	Louisiana	22	Maine	23
Maryland	24	Massachusetts	25	Michigan	26
Minnesota	27	Mississippi	28	Missouri	29
Montana	30	Nebraska	31	Nevada	32
New Hampshire	33	New Jersey	34	New Mexico	35
New York	36	North Carolina	37	North Dakota	38
Ohio	39	Oklahoma	40	Oregon	41
Pennsylvania	42	Rhode Island	44	South Carolina	45
South Dakota	46	Tennessee	47	Texas	48
Utah	49	Vermont	50	Virginia	51
Washington	53	West Virginia	54	Wisconsin	55
Wyoming	56				

07 08	Month	Enter the appropriate two digit code for the month when the accident occurred (01=January, etc., 12=December). NOTE: FOR ALL TIME ORIENTED VARIABLES, CODE THE TIME THAT THE ACCIDENT BEGAN.
09 10	Day	Enter the appropriate two digit code for the day of the accident (01=the 1st of the month, etc.) Don't forget the 0.

For all applicable variables code unknown as 8, 88, or 888. For some of the trees 8 does not correspond to unknown.



WAS THE BOAT BEING PROPELLED BY THE ENGINE AT THE TIME OF ACCIDENT?
DID A MATERIAL OR SYSTEM FAILURE INITIATE THE ACCIDENT?
DID THE OPERATOR HAVE TIME TO AVOID THE COLLISION?
YES
NO/UNK
REJECT
ACCEPT
UNK
YES (INCLUDING UNK BUT PRETTY SURE)
NO (INCLUDING UNK BUT PRETTY SURE)

APPENDIX A

P.R.A.M.* ANALYST'S GUIDE

June 1977
USCG 61700

C. Christian Stiehl

(* an abbreciation for Powering-Related Accident Model)

The pages that follow contain much of the information you will need to analyze accidents for PRAM and fill out the code sheets.

The first page has a decision tree that you should use to decide whether an accident should be coded in PRAM or not. Whatever your decision may be, you should write "rejected at node ____" or "accepted at node ____" on the front of the BAR. If the accident was rejected, set it aside. If the accident was accepted, then continue coding the information for that accident until the coding has been completed.

Succeeding pages show you exactly how to code all of the information required by PRAM. A row on the coding sheet is to be filled out for each accident coded into PRAM. The first page of this section is a reduced sample coding sheet for PRAM.

The last couple of pages show the quality assurance procedures for PRAM. These should be read and understood before coding begins.

project leaders, and 3) has all the necessary information to do his job. It should also be noted that all accidents (BARs) are retained, including those that are not accepted by the powering-related accident decision tree. The rejected accident reports are retained, and the node of rejection is recorded. This is done so that particular kinds of accidents may be used in future comparisons with PRAM data, and so that an overall comparison of powering-related accidents to other kinds of accidents can be made. PRAM will have many uses, even beyond those described in this technical brief. The major conclusion of this phase of the powering project is that a viable Powering-Related Accident Model has been constructed and modified through engineering judgment and test on the data. Once the approval of the Coast Guard is obtained, PRAM will be complete and the coding of the overall sample will commence.

The motorwell and steering control coding instructions will be changed to allow the judgment of the analysts to be used. For example, it is unlikely that a twelve foot johnboat has a motorwell. Similarly, it is very likely that the steering controls for an outboard of over 50 HP will be remote. The new codings will be:

	Code
Did the boat have a motorwell?	0 = No 1 = Yes 2 = Unknown, but pretty sure "No" 3 = Unknown, but pretty sure "Yes" 8 = Unknown

Steering Controls   Code the Appropriate One-digit Code

0 = Controlled from engine
1 = Remote Steering Wheel (push-pull type of connection)
2 = Remote Steering Wheel (other)
3 = Tiller
4 = Other
5 = Unknown, but pretty sure "Remote"
6 = Unknown, but pretty sure "Controlled from engine"
8 = Unknown

Finally, all accidents involving more than one boat, wherein more than one boat will be processed through PRAM, will be numbered starting from 900. All other accidents coded into PRAM will be numbered from 001.

These changes and amendments will be incorporated into the PRAM Analyst's Guide (see Appendix A). Upon the approval of the final version of PRAM by the Coast Guard, the coding of the entire data base of powering-related accidents will proceed.

The quality assurance procedures for the PRAM coding can be found at the end of the PRAM Analyst's Guide (Appendix A). Briefly, these procedures assure that the analyst: 1) is well-trained, 2) is checked by qualified

Speed (Column 23) now has the following codes:

0 = 0-10 miles per hour
1 = 11-20 mph
2 = 21-30 mph
3 = 31-40 mph
4 = 41-50 mph
5 = 51-60 mph
6 = greater than 60 mph
7 = unknown, but increasing speed
8 = unknown
9 = unknown, but decreasing speed

The instructions for coding the motor weight capacity have been revised to include representative weights for outboards that are given in the Coast Guard's level flotation test procedures. The analysts will be instructed to code the motor weight capacity as before, if it is known. If the motor weight capacity is unknown, but the horsepower capacity (outboard) is known, then the following codes will be used:

Horsepower Capacity	Motor Weight Capacity	Code
0.1 to 2	25	03
2.1 to 3.9	35	04
4.0 to 7.0	55	06
7.1 to 15.0	75	08
15.1 to 25	100	10
25.1 to 45	155	16
45.1 to 80	240	24
30.1 to 150	135	32
150.1 to 250	420	42

The instructions for coding the motor weight have also been revised. The new codes are as follows (engines weighing 87 lbs. or less are coded as before, see Appendix A):

98 = unknown
89 = 88-100 pounds
90 = 100-150 pounds
91 = 150-200 pounds
92 = 200-250 pounds
93 = 250-300 pounds
94 = 300-350 pounds
95 = greater than 350 pounds
99 = not applicable (I/O, or Inboard)

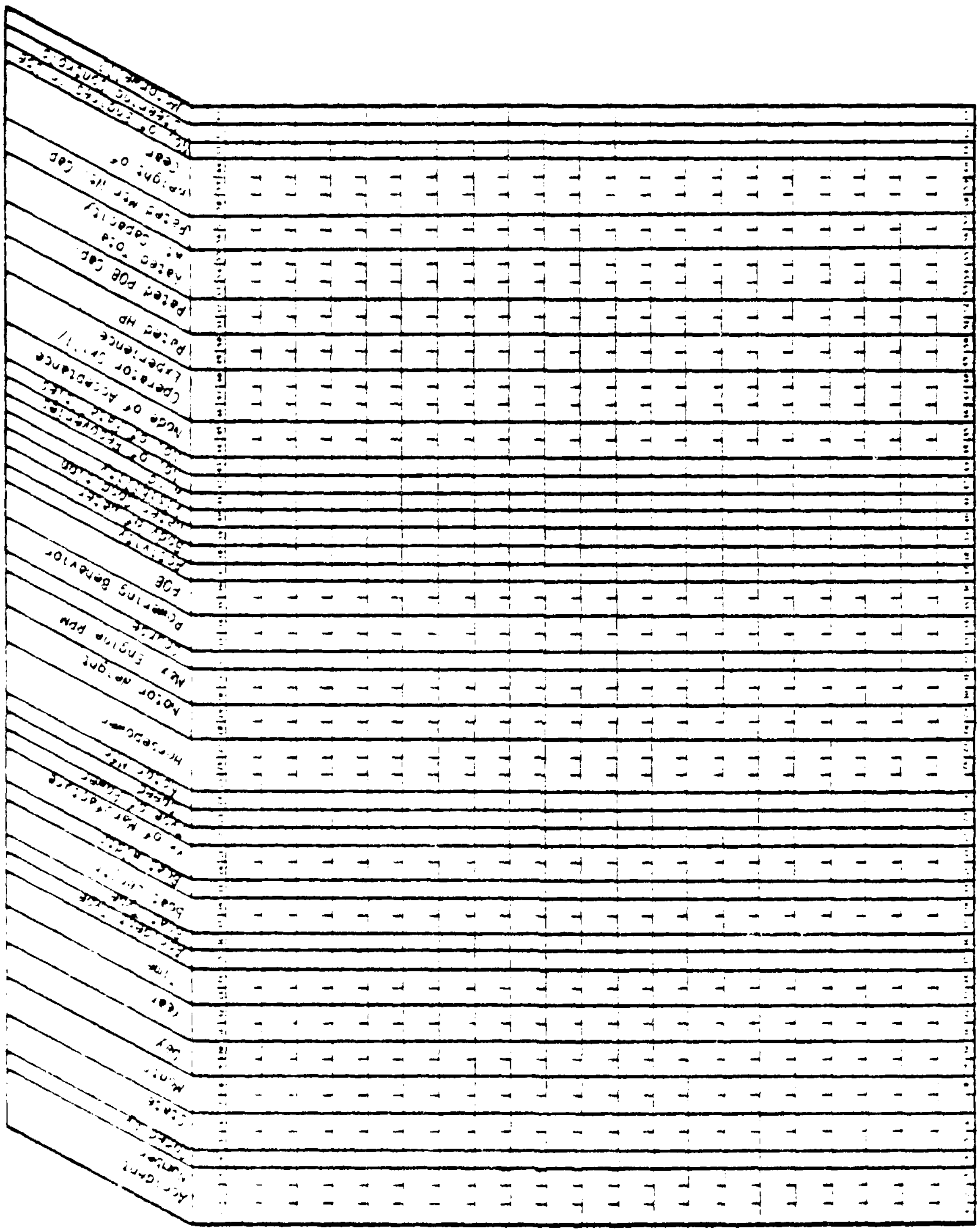


FIGURE 4. REVISED PRAM CODING SHEET

New coding procedures have been developed for these two variables. If the new procedures do not result in fewer unknowns, then these two variables may be deleted in the future.

The objectives for this project include not only the evaluation of the present powering standard, but also the evaluation of alternative concepts. This is why several powering ratios are included in PRAM. One may prove to be a more predictive indicator of the potential for a powering-related accident than the others. All powering ratios will be calculated (all listed in the preliminary PRAM) for each accident by the computer, when the relevant information is available. Thus, the ratios will no longer be calculated or coded by the accident analysts.

Transom height and maximum transom width were considered as variables which could be added to PRAM. However, a quick inspection of the 20 sample accidents revealed that these variables would be unknown in all cases. Also, the number of engines in use at the time of the accident will be added to PRAM.

The coding of speed will be changed to allow incrementing the speed by 10 mph up to 60 mph. The coding of motor weights will be revised to agree with current standardized criteria by horsepower; i.e., 150 HP = 310 lb. The course variable tree will be revised to include information as to why the operator lost control of the boat. Finally, accidents involving more than one boat, when two (or more) of these boats will be included in PRAM, will be numbered in a special way. The specific coding changes are shown below.

Changes in PRAM Coding

Since several variables have been deleted from the preliminary PRAM, fewer columns of the computer coding sheet are needed to code all of the information. The final PRAM coding sheet is shown in Figure 4 with the columns labeled appropriately. For most of the variables that remain, from the preliminary PRAM, the coding instructions are the same as they were previously; however, some have been modified.

The new variable of "Number of Engines In Use" (Column 61 on the coding sheet) is coded as follows: 1 = 1 engine in use, 2 = 2 engines in use, 3 = 3 or more engines in use, [illegible] = unknown.

FORMAL BOATING EDUCATION

		None	Aux.	Red Cross	Other	Unknown
POWERING RATIO (HP/Rated HP)	0.5 - 0.60	3	2	0	0	0
	0.7 - 0.80	2	0	0	1	1
	0.9 - 1.00	2	0	0	0	0
	1.5 - 1.60	0	1	0	0	0
	3.3 - 3.40	1	0	0	0	0
	Unknown	4	0	1	2	0

involving associations between variables. The next section will describe the final version of PRAM, after modifications suggested by the Coast Guard and by the processing of the sample of 20 accidents.

5.0 THE POWERING-RELATED ACCIDENT MODEL

The variables listed below were included in the preliminary PRAM, but little or no information was available in the boating accident reports for these variables:

- Hull Shape
- Trim Tabs
- Helm Location
- Throttle/Shift Levers
- Load Distribution
- Rated Total Weight Capacity
- Rated Motor Weight
- Powering Ratio HP/.1 lb. Total Wt.
- Speed
- Motorwell
- Steering Controls
- Type of Propeller
- Fatigue/Stress
- Rated Persons Capacity
- Powering Ratio: HP/.1 lb. Boat Wt.

Since the coding of information with respect to these variables requires time and effort on the part of the analysts, without significant return (in terms of usable information), most of them will be deleted from the final version of PRAM. Speed, Rated Persons Weight Capacity, Rated Total Weight Capacity, and Rated Motor Weight will be retained. These variables are of paramount importance in understanding the powering problem, and in computing powering ratios. Also, the motorwell and steering control variables will be retained, at least for the coding of the first one hundred accidents.

Computer Column(s)	Variables					
73-74	Powering Ratios:					
	HP/10 ft.	0.1	2	0.5	1
		0.2	4	0.6	2
		0.3	3	1.0	1
		0.4	7		

Computer Column(s)	Variables		
75-76	HP/.1 lb. Boat Weight	Unknown	17
		0.9	1
		1.0	1
		1.2	1
77-78	HP/.1	Unknown	18
		0.3	1
		0.6	1
79-80	HP/Rated HP	Unknown	7
		0.5 - 0.6	5
		0.7 - 0.8	4
		0.9 - 1.0	2
		1.5 - 1.6	1
		3.3 - 3.4	1

The purpose of this section was to present the preliminary PRAM and show the results of the coding of a sample of 20 accidents. It is not intended that any meaning be ascribed to the results based upon such a small sample, other than their meaning in terms of the appropriateness and usefulness of the model. Cross tabulations on two or more variables are easily accomplished using PRAM. An example is shown below, using the fourth powering ratio (HP/rated HP) and the operator's formal boating education as the cross-tabulated variables. Such a table might be used to evaluate the effects of different types of boating safety education on the tendency to be overpowered (HP/rated HP>1) and in a powering-related accident. In this manner, PRAM can provide tabulations of data that relate to many questions, particularly those

Computer Column(s)	Variable		
56-58 (continued)	Formal Boating Education:	none	12
		Auxiliary Course	3
		Power Squadron	0
		Red Cross	1
		State	0
		Other	3
		More than One	0
		Unknown	1

59 Operator Fatigue/Stress:

Unknown 18 None 2

60-61 Rated Horsepower:

Unknown	7	121 - 150	0
0 - 30	1	151 - 180	1
31 - 60	7		
61 - 90	2		
91 - 120	2		

62-63 Rated Weight Capacity of POB: 20 unknown

64-66 Rated Total Weight Capacity: 20 unknown

67-68 Rated Weight Capacity of the Motor: 20 unknown

69-71 Weight of Gear on Board (estimate):

1000 - 1100	2
1101 - 1200	10
1201 - 1300	5
1301 - 1400	2
1401 - 1500	1

Computer Column(s)	Variable
50	Visibility:

Good 17
Fair 1
Poor 2

51	Wind:

None 7
Light 8
Moderate 5

52	Number of Recoveries:

0 - 0
1 - 2
2 - 7
3 - 8
4 - 3

53	Number of Fatalities: 0 - 20 (No fatalities)
54-55	Node of Acceptance:

5 - 12
8 - 2
12 - 3
15 - 1
18 - 2

56-58	Operator Skill/Experience:

With this Boat:	under 20 hrs.	3
	20-100 hrs.	3
	100-500 hrs.	3
	unknown	11
With Boats of this type:	under 20 hrs.	4
	20-100 hrs.	3
	100-500 hrs.	2
	over 500 hrs.	6
	unknown	5

Computer Column(s)	Variables
41-42	Powering Behavior: Did the operator change the throttle?

Unknown 13

No 3 — Final throttle setting was..unknown 3

Yes 4 —
- Operator increased power, final throttle setting was...unknown 2
  - high 1
- Operator decreased power, final throttle setting was...unknown 1

43-44 Load Distribution: 20 unknown

45-46 People on Board:

1 - 2	3 - 8
2 - 7	4 - 3

47 Activity:

Pleasure Cruising	13
Water Skiing	4
Docking	1
Leaving dock, getting underway	2

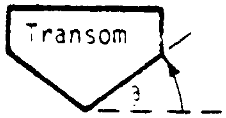
48 Body of Water:

River, Creek, Channel	10
Lake, Swamp	7
Bay, Inlet, Harbor	2
Unknown	1

49 Water Conditions:

Calm 12	Choppy/Rough 8

Column(s)	Variable Name	Description and Coding Instructions
20	Hull Shape	Code the one digit that best corresponds with [illegible] shape of the boat's hull, using the figure below.



0 = Deep V (θ greater than 18°)
1 = Semi V (θ less than 18°)
2 = Cathedral or tri-hull
3 = Flatbottom
4 = Roundbottom
5 = Other
6 = Unknown

21 22	Year of Manufacture (of boat)	Code the last two digits of the year that the boat was manufactured(model year).
23	Type of Power	Code one digit corresponding to the type of power in use.

0 = Other   1 = Outboard   2 = I/O   3 = Inboard

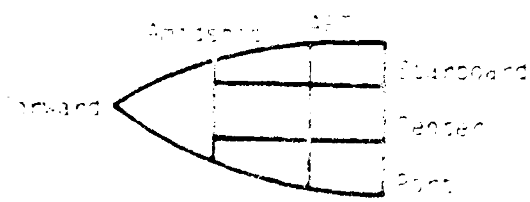
24	Speed	Code one digit which best corresponds to what is known about the boat's speed.

0 = 0-10 miles per hour	5 = Unknown, but greater than 20mph
1 = 10-20mph	6 = Unknown, but reducing speed
2 = 20-30mph	7 = Unknown, but increasing speed
3 = 30-40mph	8 = Unknown
4 = greater than 40mph	9 = Unknown, but changing speed

25   Did the boat have trim tabs?   Code 0 = No   1 = Yes   8 = Unknown

26   Did the boat have a motorwell?   Code 0 = No   1 = Yes   8 = Unknown

27	Helm Location	Using the figure below, code the one digit which best describes the location of the helm station that was is use. Note that the figure divides the boat into thirds, and divides the [illegible] and aft sections of the boat into thirds. Flybridges are [illegible] [illegible] "other."



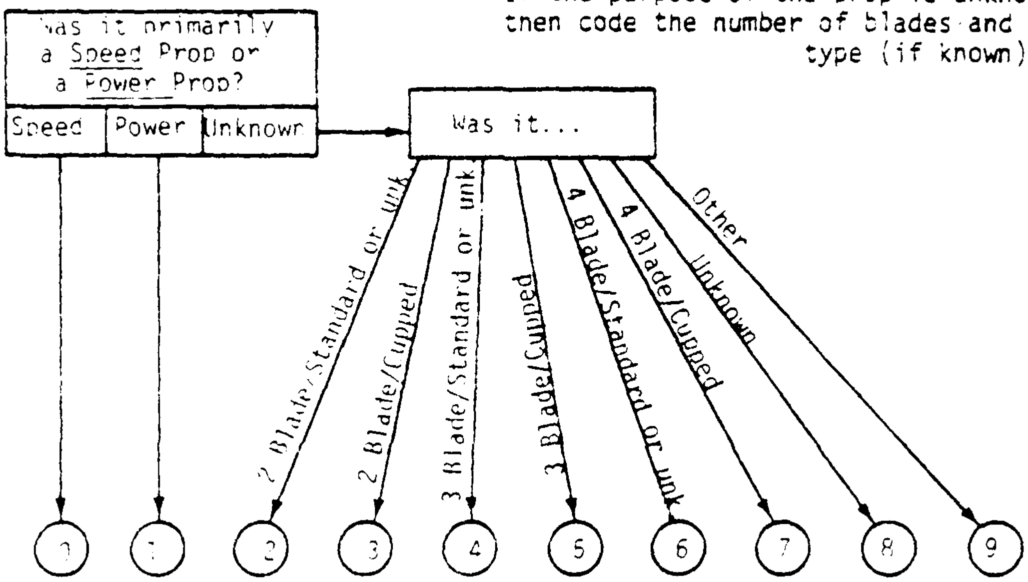
0 = Forward
1 = Amidship starboard
2 = Amidship center
3 = Amidship port
4 = Aft, starboard
5 = Aft, center
6 = Aft, port
7 = Amidship, lateral position unknown
8 = Unknown
9 = Other (flybridge, etc.)

28	Steering Controls	Code the appropriate one digit code

0 = Controlled from engine
1 = Remote steering wheel (push pull type of connection)
2 = Remote steering wheel (other)
3 = Tiller
4 = Other
8 = Unknown

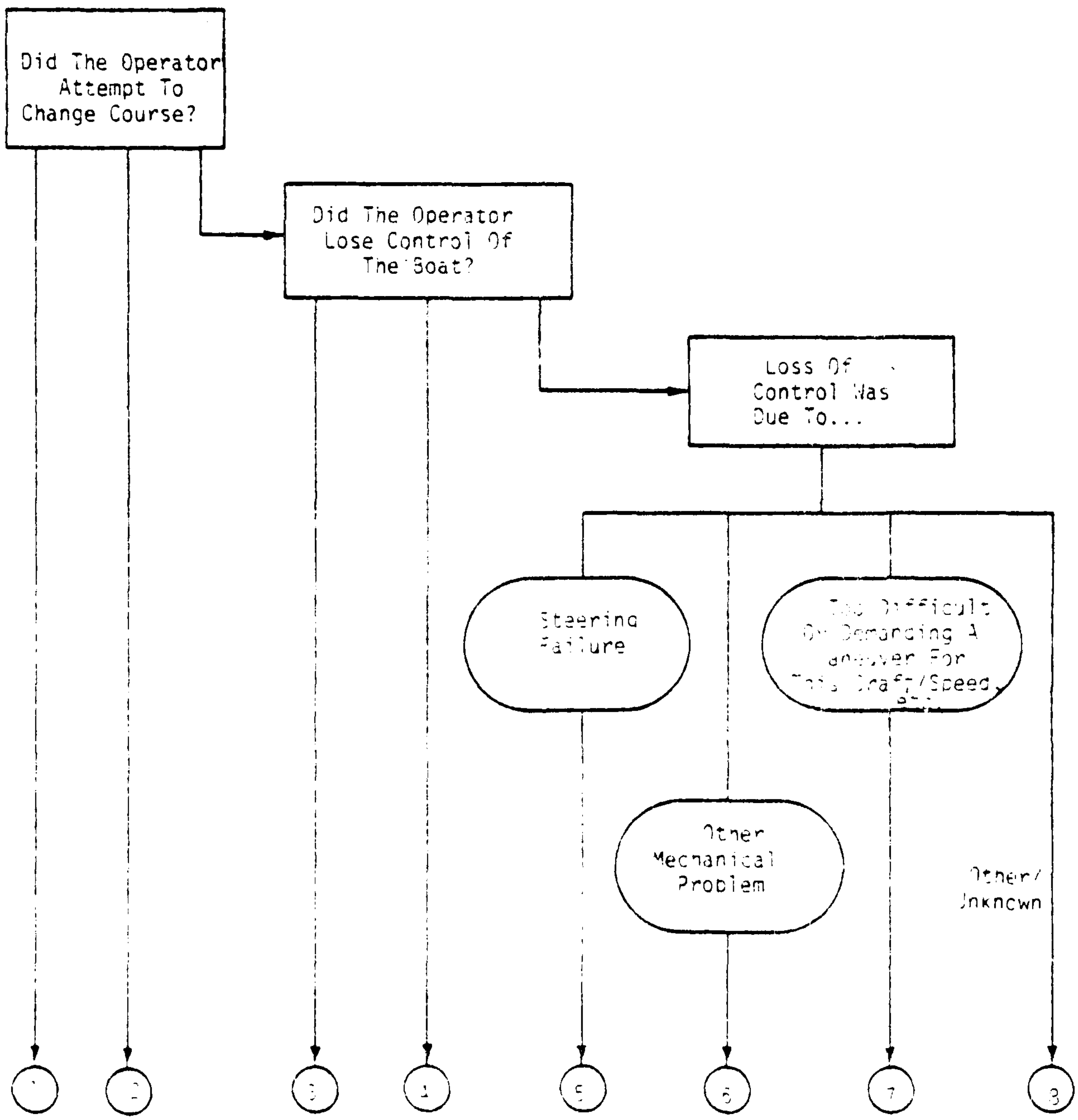
29   Throttle and shift controls on the same lever?   Code 0 = No   1 = Yes   8 = U[illegible]

Column(s)	Variable Name	Description and Coding Instructions
30	Throttle/Shift	Code the one digit which best describes the throttle and shift controls. 0 = Manual 1 = Electric 2 = Hydraulic 3 = Other 9 = Unknown
31	Type of Propeller	Code the one digit which best describes the type of propeller in use, using the decision tree shown below. If the purpose of the prop is unknown, then code the number of blades and blade type (if known).



Column(s)	Variable Name	Description and Coding Instructions
32	Motor Manufacturer	Code the one digit that corresponds to the motor manufacturer. 0 = Mercury Marine(Mercruiser) 1 = Johnson 2 = Evinrude 3 = Chrysler 4 = OMC 5 = Clinton or McCulloch 6 = Eska 7 = Volvo Penta 8 = Unknown 9 = Other (including Sears, etc.
33 34 35	Horsepower	Code the horsepower of the engine(s) in use. If more than one engine was in use, then code the combined horsepower.
36 37	Motor Weight	Code the weight of the motor (in pounds). Remember that "88" means unknown. For this variable, codes (weights) above 87 shall be used as follows: 88 = Unknown 89 = 88-100 pounds 90 = 101-150 pounds 91 = greater than 150 pounds 99 = not applicable (I/O, or I.) Note: Code the combined weight if more than one engine was used.

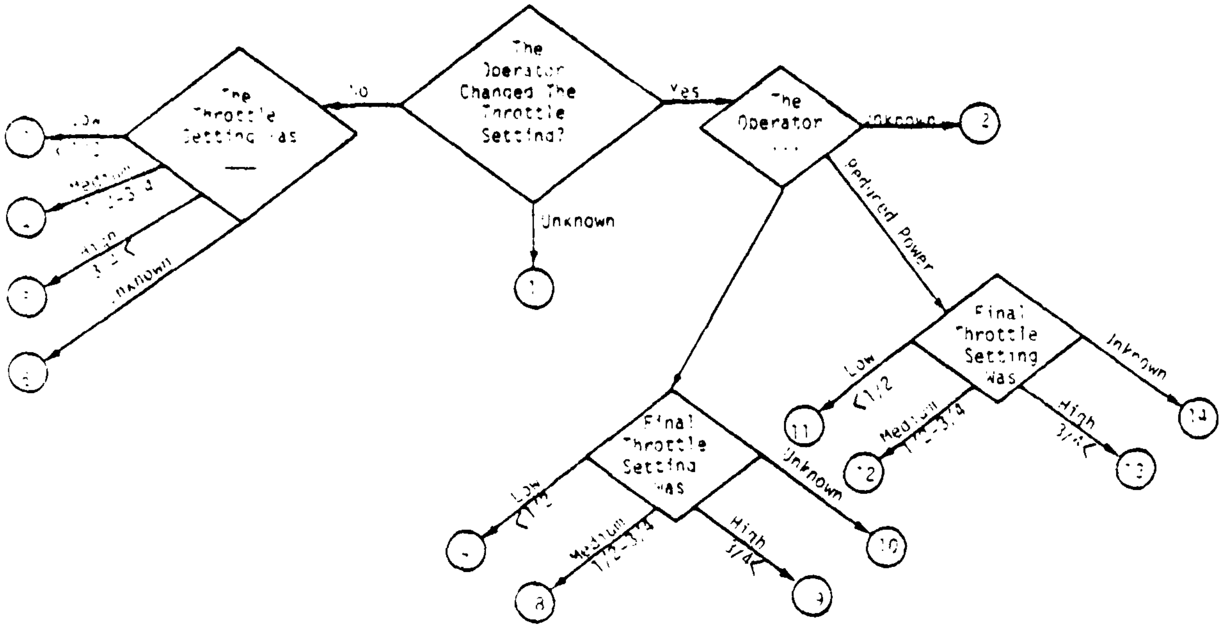
Column(s)	Variable Name	Description and Coding Instructions
38 39	Maximum Engine RPM	Code the maximum engine rpm as a two digit number by determining the maximum engine rpm and then dividing it by 100. Remember that "88" is unknown. For any maximum rpm over 8700, use the following codes: 8701 - 10,000 use 89 greater than 10,000, use 90
40	Course	Choose the appropriate one digit code from the decision tree shown below:



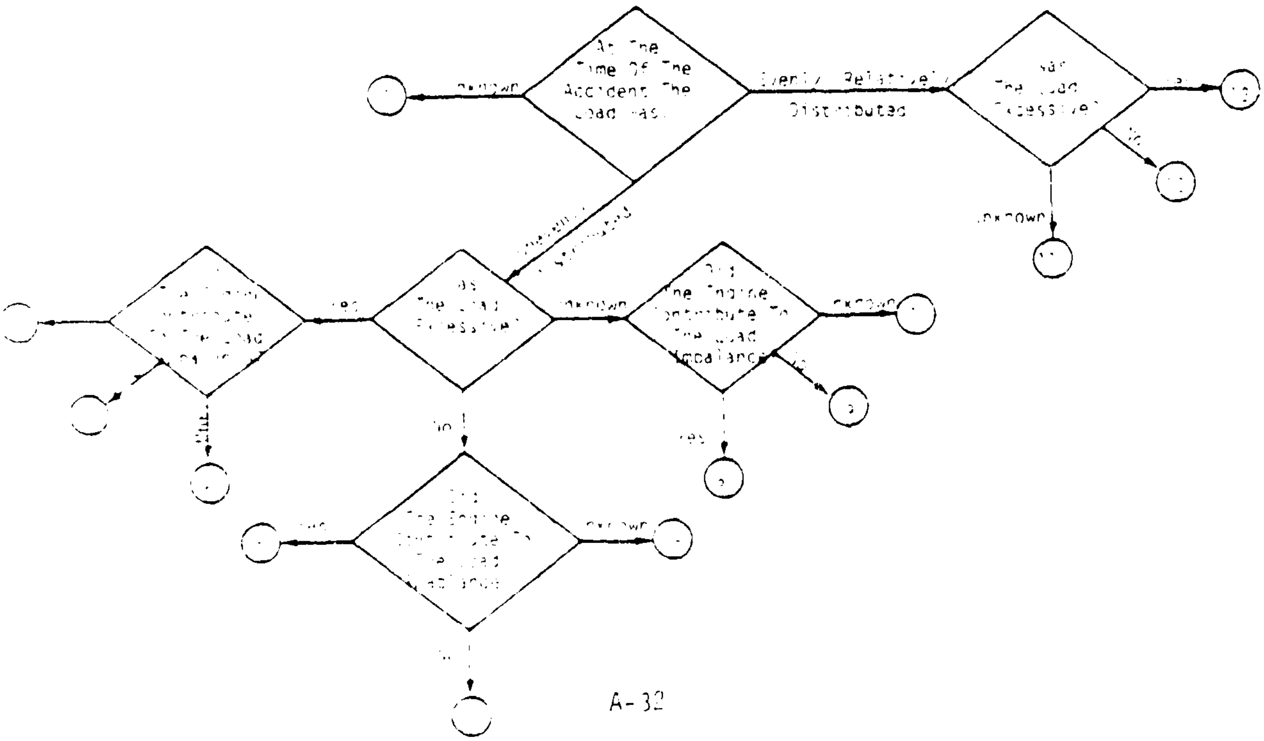
Columns Variable Name Description and Coding Instructions

41 Powering Behavior Choose the appropriate two digit code from the decision
42 tree shown below:

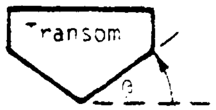
Powering Behavior Tree



Load Distribution Choose the appropriate code from the decision tree shown below:



Column(s)	Variable Name	Description and Coding Instructions
20	Hull Shape	Code the one digit that best corresponds with the shape of the boat's hull, using the figure below.



0 = Deep V (θ greater than 18°)
1 = Semi V (θ less than 18°)
2 = Cathedral or tri-hull
3 = Flatbottom
4 = Roundbottom
5 = Other
6 = unknown

21 22	Year of Manufacture (of boat)	Code the last two digits of the year that the boat was manufactured(model year).
23	Type of Power	Code one digit corresponding to the type of power in use.

0 = Other   1 = Outboard   2 = I/O   3 = Inboard

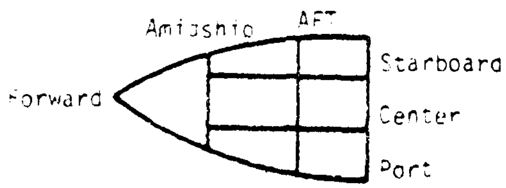
24	Speed	Code one digit which best corresponds to what is known about the boat's speed.

0 = 0-10 miles per hour	5 = Unknown, but greater than 20mph
1 = 10-20mph	6 = Unknown, but reducing speed
2 = 20-30mph	7 = Unknown, but increasing speed
3 = 30-40mph	8 = Unknown
4 = greater than 40mph	9 = Unknown, but changing speed

25 Did the boat have trim tabs?   Code 0 = No   1 = Yes   8 = Unknown

26 Did the boat have a motorwell?   Code 0 = No   1 = Yes   8 = Unknown

27	Helm Location	Using the figure below, code the one digit which best describes the location of the helm station that was is use. Note that the figure divides the boat into thirds, and divides the mid and aft sections of the boat into thirds. Flybridges are coded as "other."



0 = Forward
1 = Amidship/starboard
2 = Amidship/center
3 = Amidship/port
4 = Aft/starboard
5 = Aft/ center
6 = Aft/ port
7 = Amidship, lateral position unknown
8 = Unknown
9 = Other (flybridge, etc.)

28 Steering Controls   Code the appropriate one digit code

0 = Controlled from engine
1 = Remote steering wheel (push/pull type of connection
2 = Remote steering wheel (other)
3 = Tiller
4 = Other
8 = Unknown

29 Throttle and shift controls on the same lever ? Code 0 = No 1 = Yes 8 = Un

Column(s) Variable Name Description and Coding Instructions

if the operator had 50 hours of experience on boats of this type, 150 hours of experience on other boats, and had had no formal boating safety courses, then he would be coded "120."

For Experience (both types):	For Education:
0 = Under 20 hours	0 = None
1 = 20-100 hours	1 = USCG Auxiliary Course
2 = 100-500 hours	2 = Power Squadron Course
3 = Over 500 hours	3 = Red Cross Course
4 = Exact number unknown, but operator is known to have considerable experience	4 = State Course
	5 = Other Course
	6 = More than one course
8 = Unknown	8 = Unknown

59 Operator Fatigue/stress Choose the one digit code from the list that best describes the environmental conditions to which the operator had been exposed.

0 = No known stressors	5 = Fatiguing activities (swimming, etc.) on the boating outing
1 = High noise levels	6 = Fatiguing activities before the boating outing
2 = Three hours or more exposure to the sun.	7 = Other
3 = some amount of alcohol ingested	8 = Unknown
4 = Considerable shock & vibration	9 = More than one of the stressors listed above in 1-6.

60
61 Rated Horsepower Code two digits corresponding to the rated horsepower divided by 10.

62
63 Rated Weight Capacity of POB Code two digits corresponding to the rated rated weight of the people on board (persons capacity) divided by 10, up to a code of 88. "88" is used for unknown. "89" for this variable means a persons capacity of from 1001 to 1500 pounds. "99" stands for not applicable (boats which are not rated).

64
65
66 Rated Total Weight Capacity Code three digits corresponding to the rated total weight capacity of the boat, divided by 10. Recall that "888" stands for unknown, and "999" means not applicable (boats which are not rated). "889" is used for boats whose total weight capacity exceeds 8870 pounds.

67
68 Rated Weight Capacity of the Motor Code two digits corresponding to the rated weight of the motor divided by 10. Recall that "88" stands for unknown, and "99" stands for not applicable (I/O, inboards).

69
70
71 Weight of Gear On Board Code the weight of the gear on board divided by 10 as a three digit number. Include the weights of all items on board other than the people and the motor. As examples: (ESTIMATE)

Full gas tank (approx. 40 lbs.)
Small ice chest-full (@ 10-25 lbs.)
Large ice chest-full (@ 30-50 lbs.)
Anchor (@ 20 lbs.)
Battery (@ 45 lbs.)
Anchor line and other line
Ski equipment
Fishing equipment/hunting equipment and catch
PFDs and Navigational Aids (compass, flashlight, charts, etc.

Column(s)	Variable Name	Description and Coding Instructions
72 Blank		
73 74	Powering Ratio #1	Code the appropriate digits for each of four powering ratios as shown below. <u>For all of the powering ratios "88" is unknown</u>, and "89" means a value greater than 8.749. Code horsepower per 0.1 ft as a two digit number where the decimal point is between the two coded numbers. For example, a 90 hp engine on a 12 ft boat would be: $\frac{90}{12} \times \frac{1}{10} = 0.75$ and gets coded "08" The same engine on an 8 ft boat would be coded "11". The code for horsepower per 0.1 ft should be written in columns 73 and 74.
75 76	Powering Ratio #2	Horsepower per pound of boat weight is coded in columns 75 and 76, where the horsepower per 10 pounds of boat weight. Code this information as a two digit number, where a decimal point is between the two numbers. For example, if a 120 hp engine were on a bass boat which weighed 850 pounds (boat weight only), then: $\frac{120}{850} \times \frac{10}{1} = 1.41$ which would be coded "14" Similarly, if the same engine were on a boat which weighed 1500 pounds, it would be coded "08." Recall that "88" is used to code unknown, and "89" codes any number greater than 8.749.
77 78	Powering Ratio #3	Horsepower per total boat weight and gear/engine/people weight is coded in columns 77 and 78. Code this information by dividing the horsepower by the total boat+etc. weight and multiplying by 10. For example, for the 120 hp engine used above, the boat may weigh 850 pounds, be carrying 300 pounds of gas and gear, and 400 pounds of people. Thus. $\frac{120}{1550} \times \frac{10}{1} = 0.77$ which would be coded "08" On the 1500 pound boat, with the same 700 pounds of gear, gas and people on board, this ratio would be 0.55 and would be coded "06". Recall that "88" is unknown, and "89" means a ratio greater than 8.749.
79 80	Powering Ratio #4	Finally, the ratio of the actual horsepower in use to the rated horsepower for the boat is coded in columns 79 and 80. So, if the boat had a 120 hp outboard on it, and was rated for a 100 hp engine, this ratio would be $\frac{120}{100} = 1.2$ and would be coded "12" Recall that for all of these ratios, "88" stands for unknown, "89" is used for any ratio greater than 8.749, and "99" is used when this ratio is not applicable - such as when coding information for a boat which has no horsepower rating or limitation (therefore, no actual/rated horsepower ratio).

PRAM Quality Assurance Procedures

The accidents that are coded into PRAM will be processed by one analyst. That is, each individual accident report will be coded by only one person. At the early phases of coding (for approximately the first 20 accidents) the analysts' work will be thoroughly reviewed by the project leaders (R. White and C. Stiehl) for quality and adherence to the intent and instructions of the model. Thereafter, a sample of five from each group of fifty accidents that are coded will be reviewed by the project leaders.

When all of the accidents have been coded, two decks will be independently keypunched. These two decks will be compared using Wyle's "Check Decks" program to find keypunching discrepancies. The discrepancies will be reviewed by the project leaders and analysts to arrive at a consensus coding. Then both decks will be corrected. The final product of this procedure will be a complete set of coded data, relatively free of keypunching errors. The only way that a keypunching error could survive this procedure would be if the exact mistake were made twice independently. The diagram on the next page depicts the entire process.

Coding Steps for PRAM

If you are the analyst, about to code data for PRAM, you should:

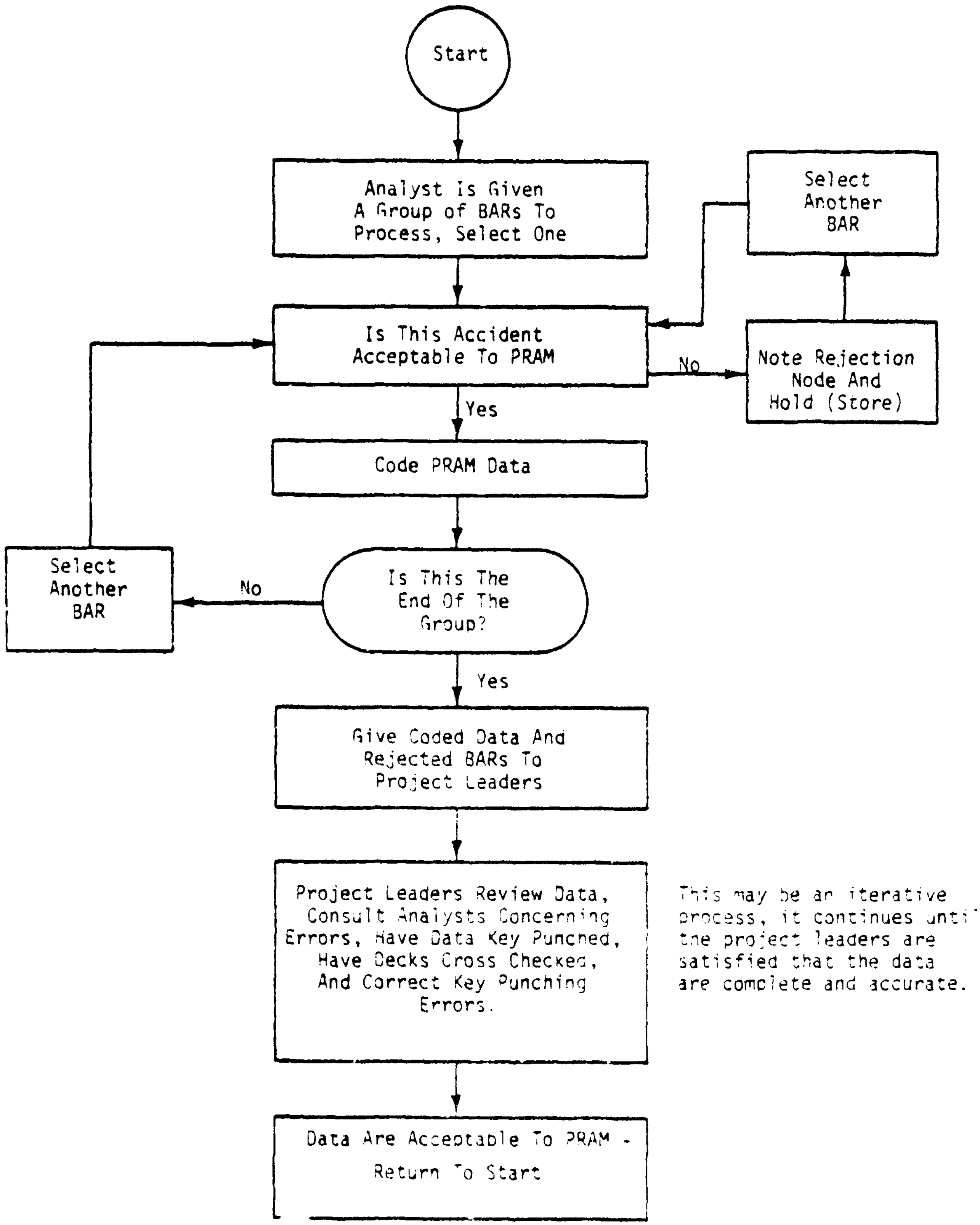
1. Check with the project leaders to make sure you have the correct sample of accidents to code.

2. Check each accident against the decision tree for acceptance. If the accident is rejected, write the node of rejection on it. If it is accepted, write the next sequential accident number in the PRAM sample on it, and the node of acceptance.

3. Code all of the required information on the data sheet for the accident, according to the instructions on previous pages, and consulting with the project leaders if any questions arise.

4. When you have completed a group of accidents to be coded, take the completed data sheets and the BARs that were accepted to the project leaders for review. Then proceed with the next group of accidents to be processed.

5. When errors are made (either in coding or keypunching) the project leaders will review these with the analyst in order to make sure that the correct information is coded on the computer cards. This may require some rereading of the BARs on your part, and perhaps some recoding.


Start
Analyst Is Given A Group of BARs To Process, Select One
Select Another BAR
Is This Accident Acceptable To PRAM
No
Note Rejection Node And Hold (Store)
Yes
Code PRAM Data
Select Another BAR
No
Is This The End Of The Group?
Yes
Give Coded Data And Rejected BARs To Project Leaders
Project Leaders Review Data, Consult Analysts Concerning Errors, Have Data Key Punched, Have Decks Cross Checked, And Correct Key Punching Errors.
This may be an iterative process, it continues until the project leaders are satisfied that the data are complete and accurate.
Data Are Acceptable To PRAM - Return To Start

WYLE LABORATORIES
MARINE TECHNOLOGY STAFF

TECHNICAL BRIEF 77-5

THE POWERING-RELATED ACCIDENT MODEL

VOLUME II

by

C. Christian Stiehl

October 1977

Work Performed Under Contract No. DOT-CG-62655-A

PREFACE

This document is the second of two volumes constituting a technical brief on the Powering-Related Accident Model (PRAM). It details further developments in the powering-related accident decision tree and PRAM, after the initial coding of a sample of 20 accidents. Severity variables and other information needs for PRAM are discussed, along with the sequential event trees which have been developed.

ABSTRACT

The powering project will include: defining powering-related accidents, collecting a sample of such accidents and coding them through a powering-related accident model (PRAM), identifying accident mechanisms, and formulating and evaluating powering standard concepts, including the present standard. Additional progress in the development of PRAM since the first volume of this technical brief is reported in this document. Operationally, defining a powering-related accident is equivalent to defining the sample to be coded through PRAM. This was accomplished through engineering analysis of the problem in consultation with Coast Guard personnel. A decision tree was developed in Volume I, which is amended and discussed in this report.

Significant improvements in PRAM are discussed in this volume, including: the addition of accident severity information, the inclusion of sequential event trees for accidents and other detailed accident scenario information, the enlarging of the PRAM sample to include 1976 fatalities, and the improvement of the quality assurance procedures.

TABLE OF CONTENTS

THE POWERING-RELATED ACCIDENT MODEL

1.0 INTRODUCTION

The objectives of the safe powering project are: 1) to determine the need for a standard limiting the horsepower of recreational boats, and 2) to determine whether there is a need to improve the present standard or develop a new one.

As part of attaining the first objective, powering-related accidents were defined using a decision tree. Most of the development of this tree was discussed in Volume I. Volume II will present some minor modifications to the decision tree and discussion of the reasons for these changes.

Data are presented concerning the nodes of the decision tree where fatal and non-fatal accidents from 1975 tended to be accepted. The fact that 96 fatal accidents (involving 117 deaths) and 285 non-fatal accidents were accepted, indicates that there is a significant potential benefit to be gained by reducing these accidents. It remains to be determined if (or how) limiting horsepower might play a role in the reduction of these accidents.

The Powering-Related Accident Model (PRAM) has been devised in order to model the powering accidents, allow for the development of scenarios that describe significant numbers of these accidents, and provide data to allow benefit estimations for alternative powering regulatory concepts. This report shows that significantly more information is available concerning the fatal accidents. In order to be useful in providing the direction for engineering solutions to the powering problems, PRAM must include some accounting of the dynamics of the accidents, beyond the description of the circumstances. The bulk of this type of information will be gathered primarily from fatal accidents.

AD-A152 575 A STUDY TO DETERMINE THE NEED FOR A STANDARD LIMITING THE HORSEPOWER OF RECREATIONAL BOATS(U) WYLE LABS HUNTSVILLE ALA R WHITE ET AL. SEP 78 MSR-78-12 3/3

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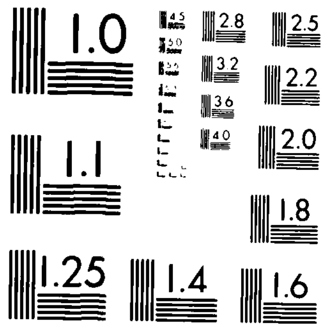


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

2.0 THE POWERING-RELATED ACCIDENT DECISION TREE

Figure 1 shows the powering-related accident decision tree as shown in Volume I of this technical brief. A problem exists in this tree in the decisions made in the vicinity of nodes 13 and 9. The decisions (as shown in Figure 1) are based upon throttle setting and horsepower per foot of boat length. The intent of these nodes was to allow those boats that were operating at more than half throttle and those involving boats which were at less than half throttle but perhaps overpowered to be passed on through the tree. The basic thought was to include heavily overpowered boats even though they might be at less than half throttle. The problem with the decision tree shown in Figure 1 is that it might reject accidents that should be included.

Consider the following two cases:

Case 1	Case 2
12 ft johnboat	12 ft johnboat
10 hp engine	20 hp engine
full throttle	slightly less than 1/2 throttle

Case 1 would be accepted by the tree in Figure 1, and Case 2 would be rejected. However, Case 2 probably represents a more severe powering problem. To correct this, the tree has been changed to: 1) still accept all those greater than 1/2 throttle, 2) if less than 1/2 throttle, then check to see if horsepower in use is greater than 1/2 of rated horsepower (accept if "yes"), 3) if throttle setting is unknown, then accept if mounted hp: rated hp > 1. This makes the tree more complicated at this point, but solves the problem illustrated by the example. Figure 2 shows the changes that would be incorporated at node 13. Figure 3 shows the changes to be incorporated in the vicinity of node 9.

The new decision tree calls for the analyst to use a pocket-sized computer in some cases. These are accidents where the throttle setting was known to be less than 50% throttle. The critical decision then is whether or

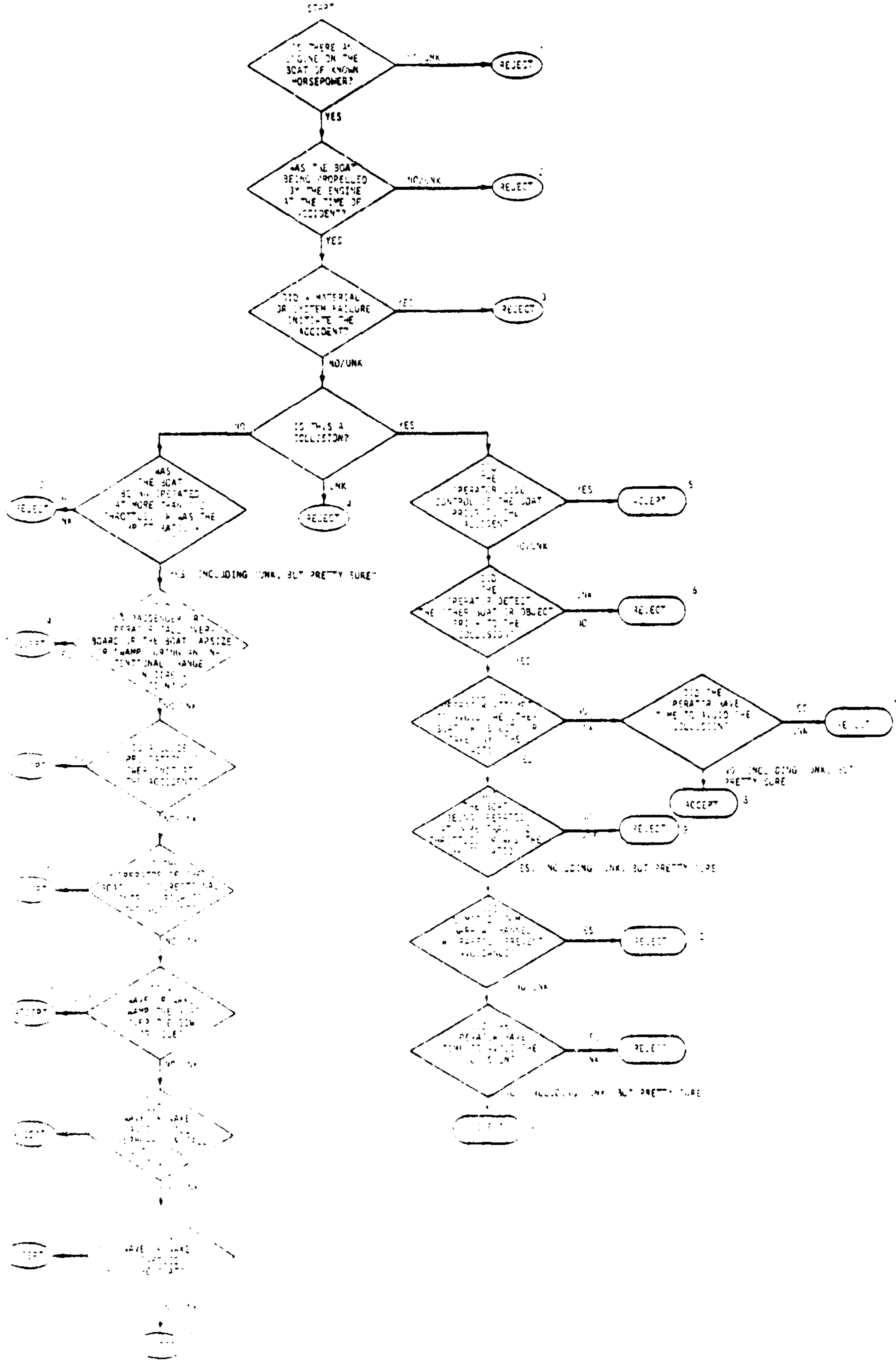


FIGURE 1. POWERING-RELATED ACCIDENT DECISION TREE

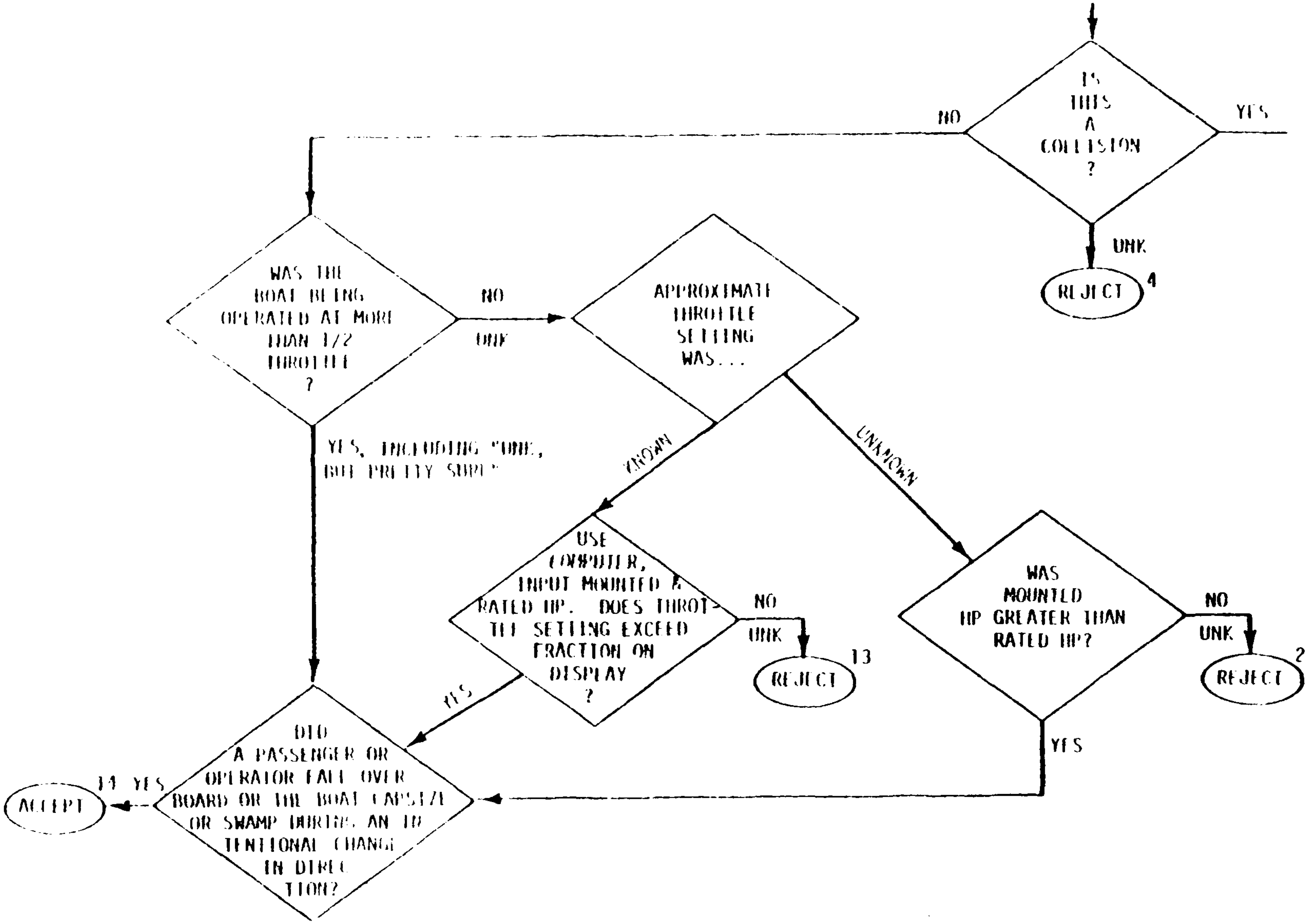


FIGURE 2. CHANGES AT NODE 13

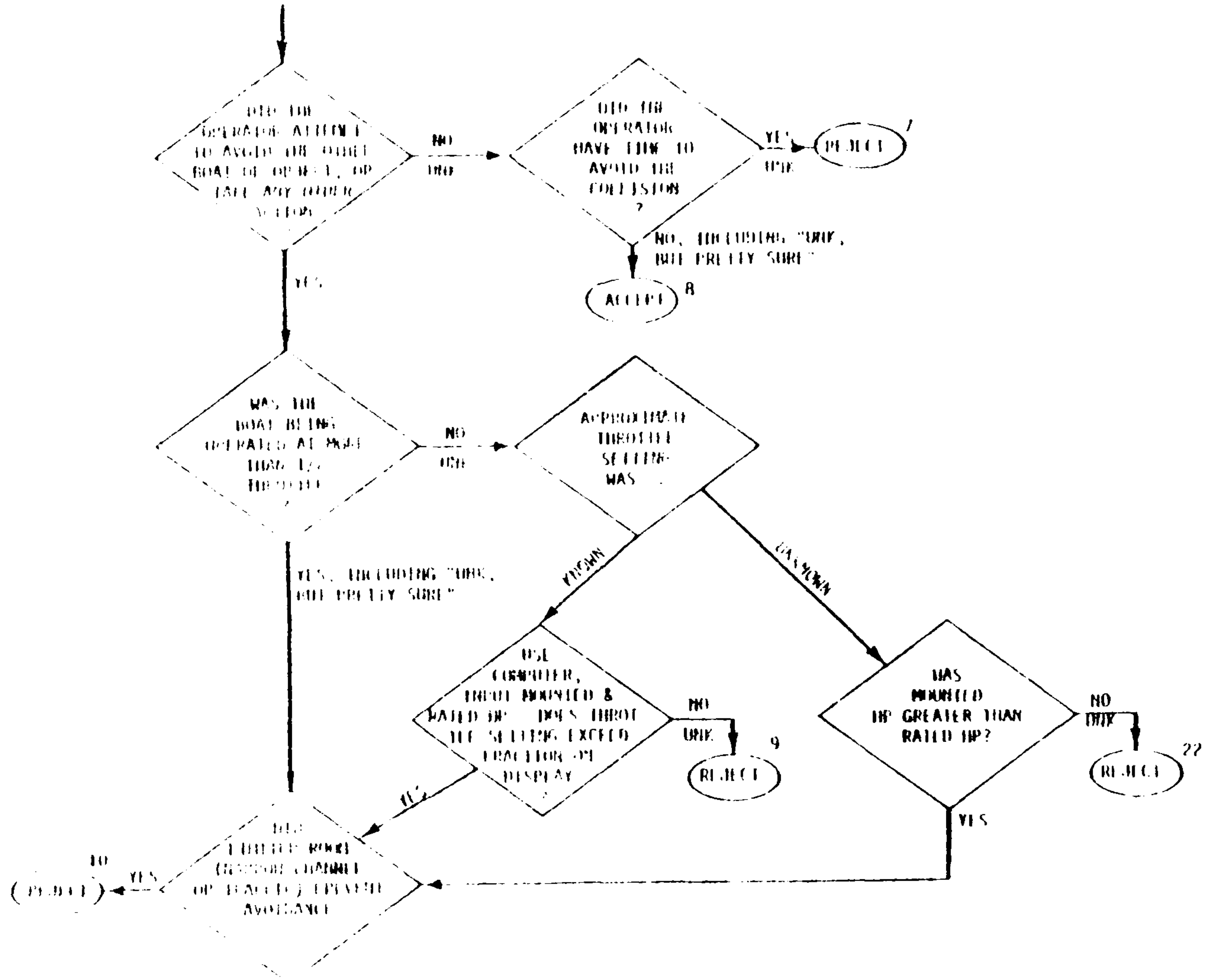


FIGURE 3. CHANGES AT NODE 9

not half of the rated horsepower was in use. For example, a boat that is rated for 30 horsepower may have a 100 horsepower motor mounted on it. The analyst would input these two numbers and the calculator would display a throttle setting (0.468 in this case). If the throttle setting in the accident was greater than or equal to that in the display, then the accident would be passed on to the next node. Otherwise, it would be rejected. The calculator is programmed to use a simple exponential relationship between rpm and horsepower in use to compute the throttle setting needed (with the mounted horsepower) to exceed one-half of the rated horsepower. A flow chart for this program is shown in Figure 4 (see also Appendix B. PRAM Throttle Setting Program).

The formula that was used was derived from the boating literature and telephone conversations with Mr. David Beach of BIA and Mr. Lysle Gray of the USCG. Typical horsepower and prop load curves are shown in Figure 5 (see Reference 1). These curves allow the calculation of the horsepower in use for a given engine and throttle setting.

The final powering-related decision tree, including the changes at nodes 9 and 13, is shown in Figure 6. Accidents which are accepted by this decision process are defined to be powering-related.

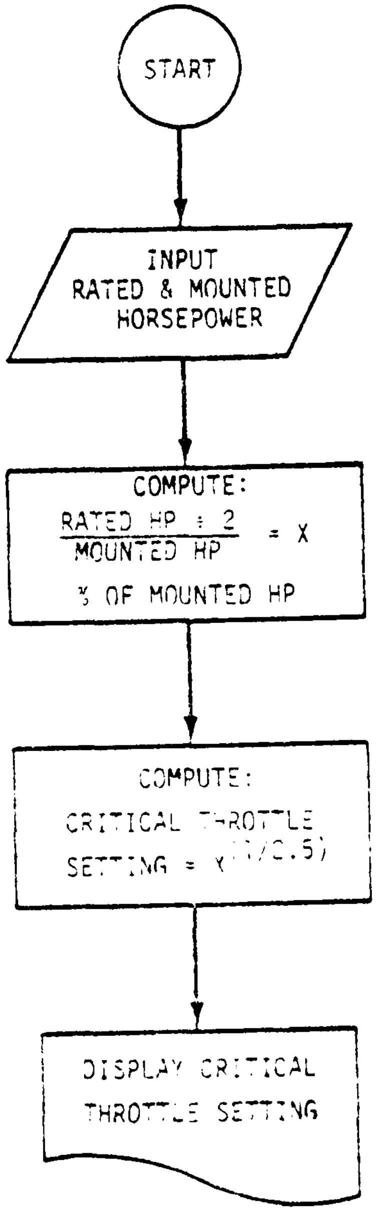


FIGURE 4. FLOW CHART FOR PRAM THROTTLE SETTING PROGRAM

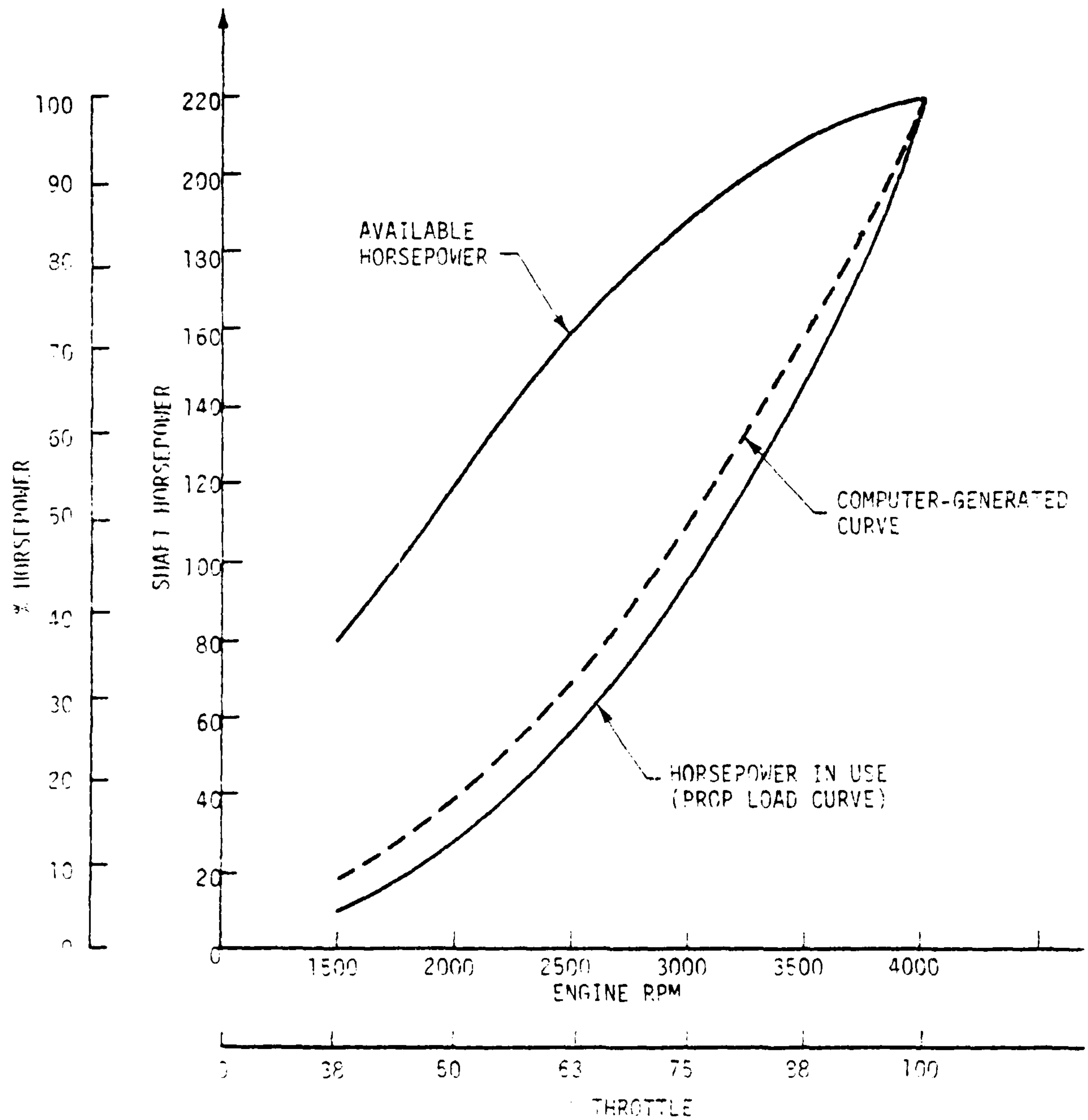


FIGURE 5. HORSEPOWER VS. THROTTLE SETTING (see Reference 1)

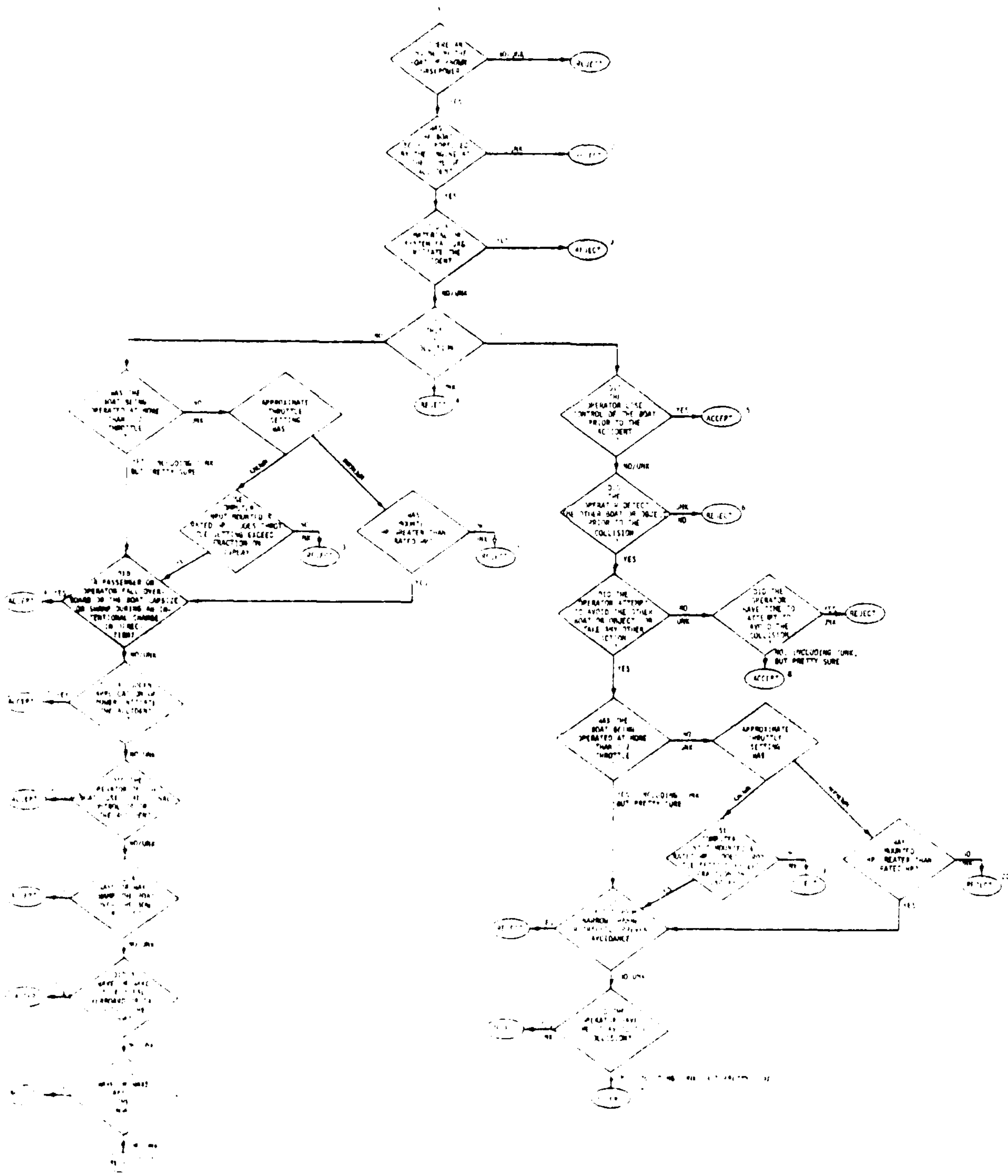


FIGURE 6. FINAL POWERING-RELATED ACCIDENT DECISION TREE

3.0 THE POWERING-RELATED ACCIDENT MODEL

PRAM has been modified since the completion of Volume I of this technical brief. Severity information has been added, so benefit estimates can be generated at a later date, and so that other variables can be correlated with severity. All of the accidents in the sample that were accepted at nodes 12, 14, 15, 16, 17, 18, and 19 will be processed through the revised powering-related accident decision tree (Figure 5) during coding. It is anticipated that a percentage (perhaps as much as 5%) of these accidents will now be rejected at nodes 9, 13, 21, and 22. Those accidents which were previously rejected at nodes 9 and 13 of Figure 1 will be rechecked to determine if they should remain rejected under the new decision tree. It is not anticipated that the overall sample size will change appreciably, but these accidents must be rechecked since the decision tree has been modified.

Most of the information coded in PRAM in the version in Volume I of this technical brief was population and background information concerning the powering accidents. Few of the variables included detailed sequential information about the accident causes. One reason for this was that over 300 of the accidents in the PRAM sample were non-fatal accidents, and little sequential information was available. Event trees have been developed for [illegible] nodes which processed a significant number of accidents. In the [illegible] of nodes where few fatalities were accepted, detailed event trees [illegible] developed because the information needed was not available. The event trees that were developed are presented in section 3.2.

3.1 Severity Variables

[illegible] dealing with injuries, fatalities, and property damage suffered as a result of powering accidents have been incorporated into PRAM. These [illegible] will be used to perform cost/benefit analyses for the current [illegible] proposed powering regulations, and possibly for evaluations of effectiveness. It is possible that the current (or proposed) standard may reduce the severity of powering-related accidents instead of or in addition to preventing accidents.

For the boat that has been accepted through the powering-related accident decision tree, the damage to the vessel and the number and extent of the injuries to persons on that vessel are coded. The codes and coding instructions for these variables can be found in Appendix A (Revised PRAM Analyst's Guide). They are coded in columns 66 through 69 on the PRAM coding sheet (Figure 7).

Severity information is also coded for other vessels which may have been involved in the accident but are not included in the PRAM sample. The number of fatalities, damage to vessel(s), and injuries are coded. The codes and coding instructions for these variables are found in Appendix A, for columns 70 through 74. If the accident involved only one vessel, then these columns are coded all zeros. If the second (or other) vessel is also included in the PRAM sample, then severity information relevant to it is included in its coding, and a "9" in column 70 indicates that fact for this boat.

3.2 Event Trees

Sequential event trees have been developed for nodes 14, 15, 17, 18 and 19. Not enough data was available at other nodes of the powering-related accident decision tree (see Section 3.3 PRAM Sample). These event trees were developed in order to capture some of the detailed sequential information concerning powering-related accidents that is available primarily in fatal accident reports. The trees were developed to enable engineering solutions to powering problems by providing data of a detailed nature about the causes of these accidents and the relationships between events. Solutions (in the form of proposed standards) can be proposed and tested for breaking one or several accident sequences. The effectiveness of the current standard can be similarly analyzed. The five nodes indicated above were the nodes of acceptance for 12 or more fatal accidents each from the 1975 data, and therefore provided a significant amount of data for constructing event trees. More trees may be constructed, and these may be refined, when the fatal powering-related accidents from 1975 have been processed (see Section 3.3 The PRAM Sample). The trees will be included in PRAM and coded in a manner very similar to other variables.

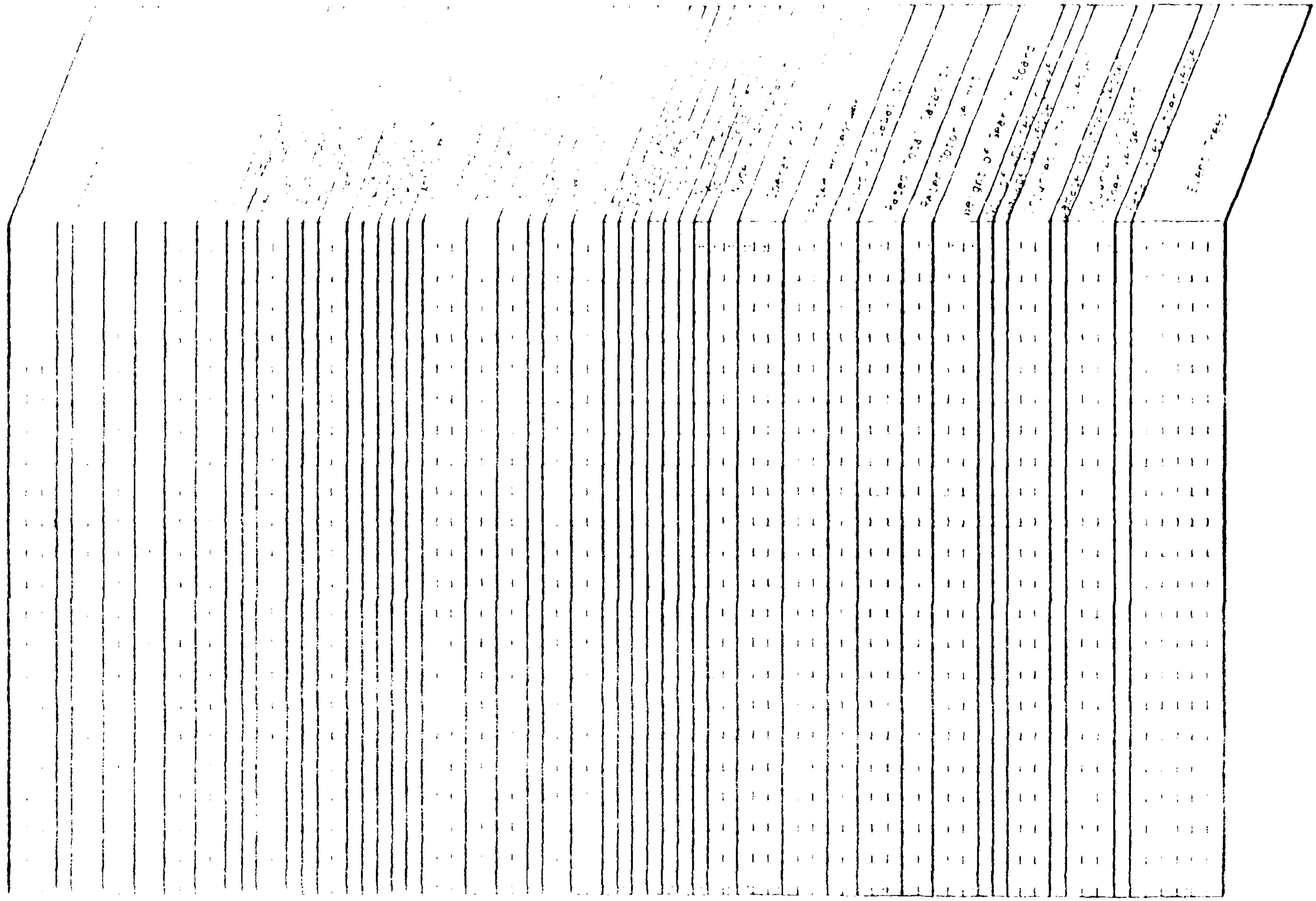


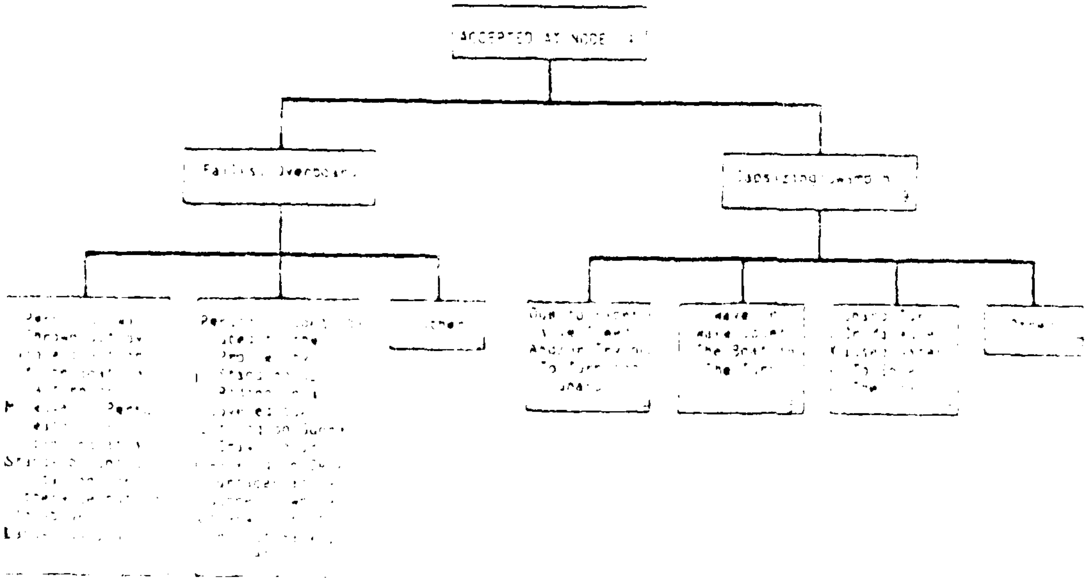
FIGURE 2. PRAM CODING SHEET

Node 14

Accidents accepted at this node involve capsizings, swampings, and falls overboard during intentional changes in direction (course changes). For these accidents, three additional types of information are coded: the type of turn, the type of event that caused boaters' lives to be at risk, and the significant contributing factors in the accident. The coding instructions are shown on the following pages and will be added to the PRAM Analyst's Guide.

FOR ACCIDENTS ACCEPTED AT NODE 14:

Column(s)	Variable	Description/Codes
75	Turn	Choose the best description. The turn was: 1) "Normal" - often less than 90°, not "sharp" for the boat's speed. 2) "Sharp" - often near 90°, sharp for the boat's speed. 3) "Turn around" - a turn of 180° to 360° 4) Unknown
76 77	Node 14 Tree	Process the accident as far down this tree as possible, and enter the appropriate code. If the accident involved multiple victims, code the two best descriptors side by side in columns 76 and 77. If the accident involved one fatality and one or more others, code the fatality as the code in column 76. If only one victim was involved, then code 0 in column 76. Consult project leader before using any "other" codes.



APPENDIX A. PRAM* ANALYST'S GUIDE

(Revised)

August 1977

USCG 61700

C. Christian Stiehl

(* an abbreviation for Powering-Related Accident Model)

The pages that follow contain much of the information you will need to analyze accidents for PRAM and fill out the code sheets.

The first page has a decision tree that you should use to decide whether an accident should be coded in PRAM or not. Whatever your decision may be, you should write "rejected at node ____" or "accepted at node ____" on the front of the BAR. If the accident was rejected, set it aside. If the accident was accepted, then continue coding the information for that accident until the coding has been completed.

Succeeding pages show you exactly how to code all of the information required by PRAM. A row on the coding sheet is to be filled out for each accident coded into PRAM. The first page of this section is a reduced sample coding sheet for PRAM.

The last couple of pages show the quality assurance procedures for PRAM. These should be read and understood before coding begins.

4.0 REFERENCES

1. Lord, Lindsay, "Cost-Effective Propeller Size." Motorboat, January, 1977. pp. 123-125.

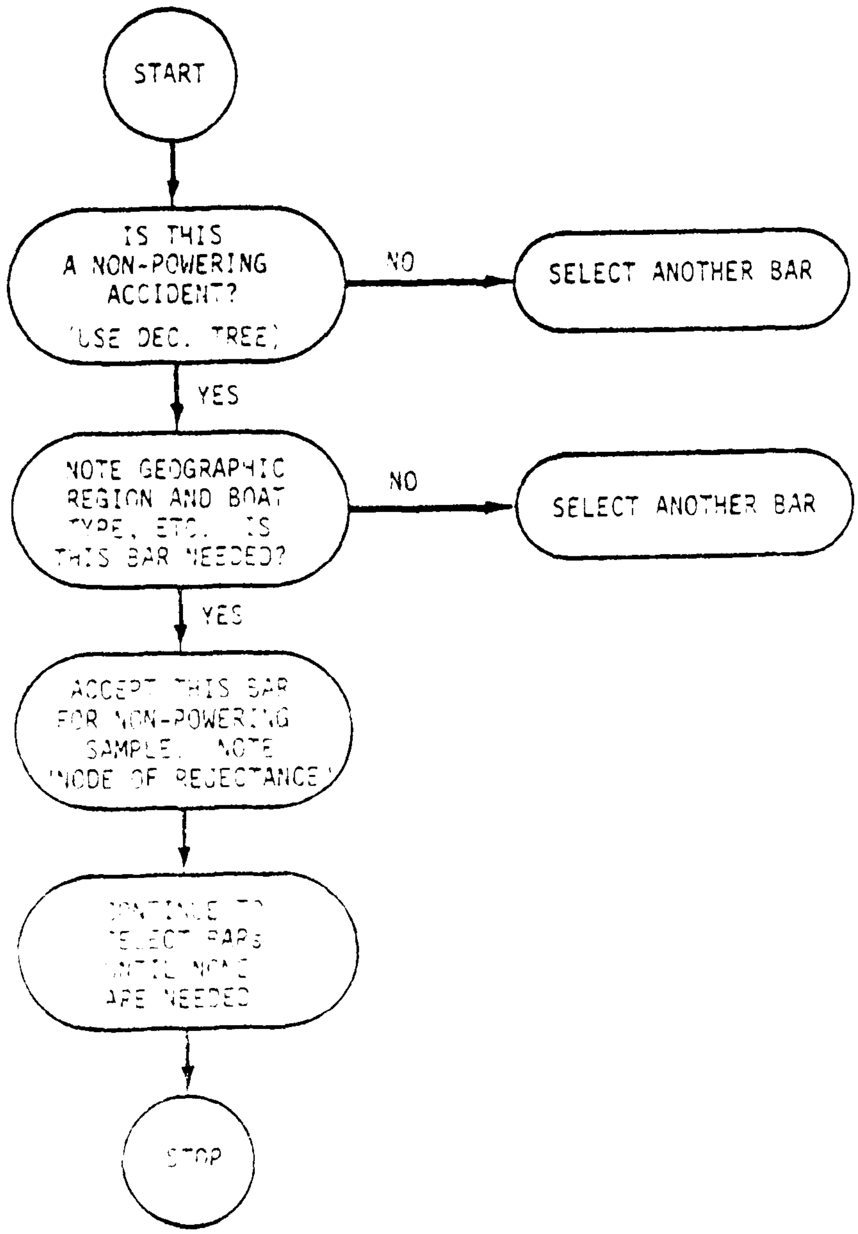


FIGURE 9. SAMPLING PLAN FOR NON-POWERING ACCIDENTS

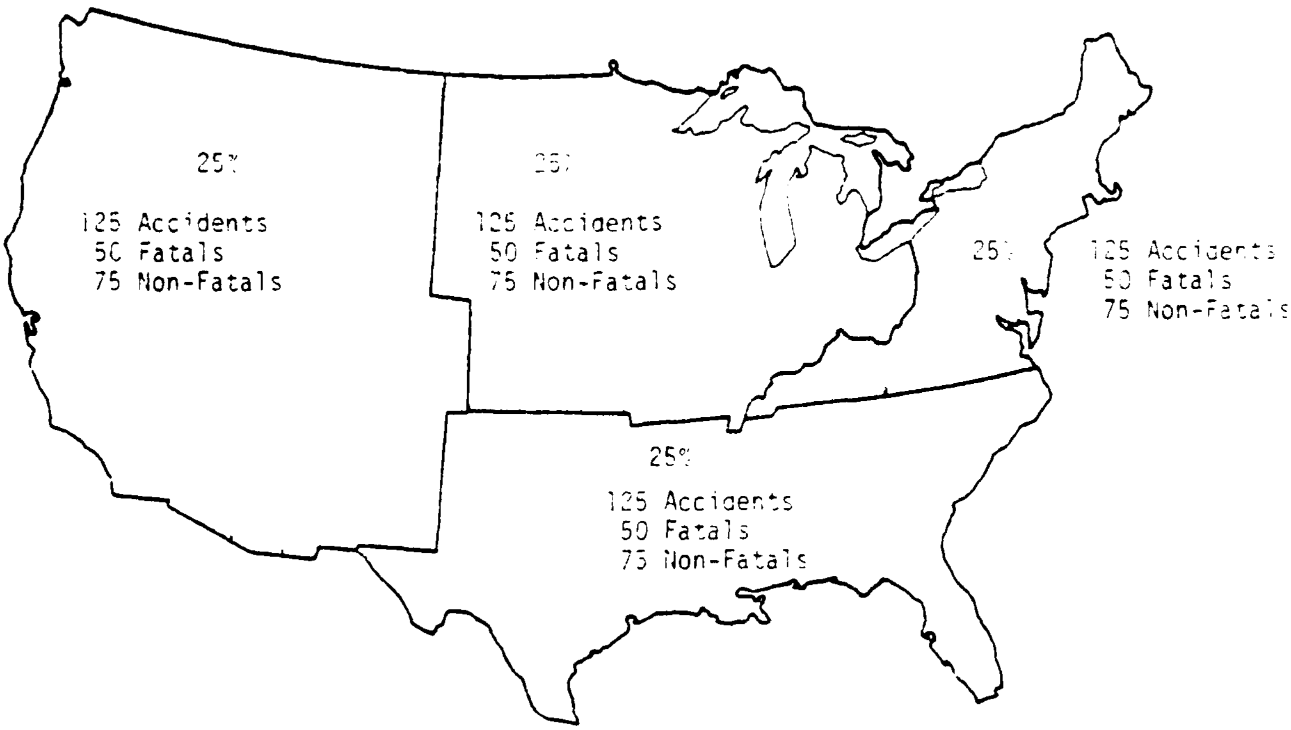


FIGURE 8. NON-POWERING ACCIDENTS BY GEOGRAPHIC REGION

process will continue until two complete duplicate decks of correctly coded data are obtained. The only way that a keypunching or coding error could survive such a verification process would be if the exact mistake were made twice independently on the same variable in the same accident. The probability of such an occurrence is remote. As before, a further check is provided against this possibility since the project leaders (R. White, C. Stiehl, and N. Whatley) will review a sample of 10% of each batch of accidents that is coded. When errors in coding or interpretation are discovered, there will be reviewed with the analysts by the project leaders.

The comparisons of the non-powering sample to the powering-related sample will be made only for those boat types which are currently covered by the standard. Provided enough detailed data is available from the accident reports, these comparisons may be made within individual boat types (or other sub-categories of variables) in order to evaluate the relative effectiveness of the standard in various domains.

Exposure data will be gained from several sources and estimated from others. The exposure data is critical for a detailed evaluation of risk and standard effectiveness. The non-powering accident sample will provide some data concerning exposure, and allow a comparison to the exposure data estimated from other sources. This comparison will indicate the tendency (or lack of it) for overpowered boats to be in non-powering accidents. After the completion of PRAM and the analyses of powering ratios for boats in powering-related and non-powering accidents, the collection, estimation, and analyses of exposure data represent the next significant step in the analysis of the effectiveness of the current powering standard.

A total of 500 non-powering accidents will be sampled, including 200 fatal accidents and 300 non-fatal accidents (these are the approximate total sample sizes for fatal and non-fatal powering-related accidents). Accidents will be selected in order to be representative in terms of geographic region and boat type. Figure 8 shows the sampling plan by geographic region.

The 500 accidents will be sampled such that 62.5% are outboards and 37.5% are other boat types. These percentages match the breakdown within the powering-related sample for those boats covered by the present standard and those that are not covered. Figure 9 depicts the sampling plan for the 500 non-powering accidents.

3.4 Quality Assurance Procedures

The PRAM quality assurance procedures outlined in Volume I of this technical brief have been amended to include further verification of the coded information. Each accident will be processed independently by two analysts. The independent codings will then be keypunched and compared by a computer program for discrepancies. The discrepancies will be checked for keypunching and coding errors, and recycled for keypunching the corrected codes. This probabilities of death, injury, and property damage when the accidents do occur. Such a standard may or may not demonstrably reduce accident frequency, but it may reduce accident severity significantly. The analyses of fatal and non-fatal accidents will allow results such as those described to surface when they are present.

Table 1 indicates that there are several fatalities at nodes 14, 15, 17, 18, and 19. Accident Event Trees have been developed to code important sequential information for accidents accepted at these nodes. The event trees were described earlier in this technical brief. The fatal accidents provide much of the information needed for processing data in the event trees, while the non-fatal accidents typically do not. For this reason, all powering related fatal accidents from 1976 will be sampled and coded. This will provide detailed input for the event trees and may provide a large enough sample size at other accept nodes to increase the number of event trees in PRAM.

The Non-Powering Accident Sample

A sample of non-powering-related accidents will be collected and analyzed for two reasons: 1) these data will be compared to the powering-related sample in terms of the ratio of mounted horsepower to rated horsepower, and 2) comparisions may be made involving other powering ratios or other variables.

If the current powering standard measures the risk of involvement in a powering-related accident to a significant degree, then the powering ratios for the boats in the powering-related sample should be higher (more "overpowered" boats) than in the non-powering-related sample (for boat types covered by the standard). If there is no significant difference in the powering ratios for the two samples, then either the standard does not effectively measure the risk of involvement in a powering-related accident, or boats that are overpowered are just as likely to be in a non-powering accident as a powering accident. The second explanation means that the standard may measure a general accident propensity, measures of exposure (hours of operation, number of overpowered boats, etc.) may be needed to normalize the comparisons.

3.3 The PRAM Sample

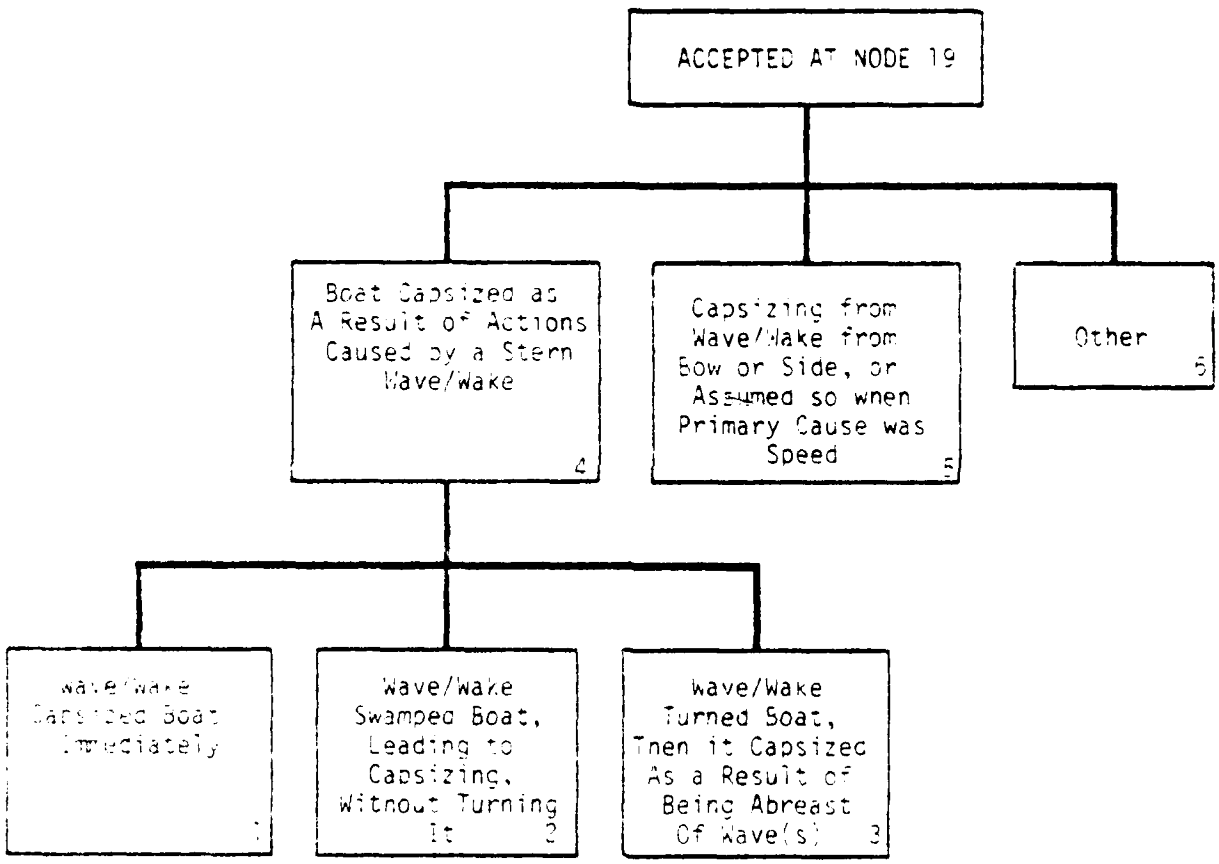
The sample of powering related accidents to be used in PRAM includes all 1975 accidents in the Coast Guard files that survive the decision tree (Figure 4), and all 1976 fatal accidents that are accepted by that decision tree. At the writing of this technical brief, only the 1975 data had been sampled. Table 1 shows that a total of 381 accidents were accepted from the 1975 data as powering related, including 96 fatal accidents (involving 117 fatalities) and 285 non-fatal accidents.

TABLE 1. 1975 PRAM SAMPLE BY NODE OF ACCEPTANCE

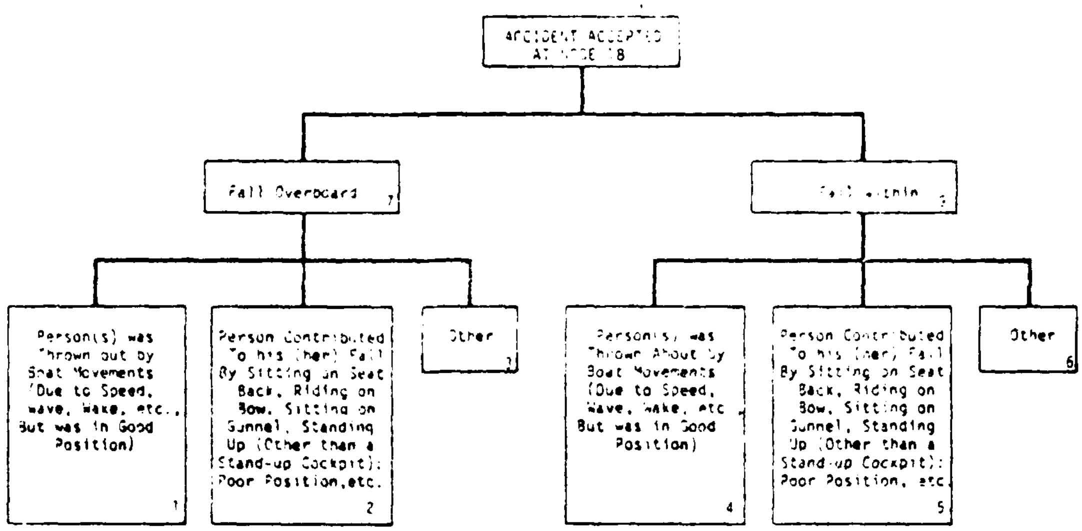
PRAM Node of Acceptance		Number of Fatal Accidents	Number Non-Fatal Accidents
5	(Lost control)	1	93
8	(No attempt to avoid collision)	1	19
12	(Attempted to avoid, not enough time)	7	33
14	(Fall overboard/capsizing during maneuver)	22	23
15	(Sudden application of power)	13	11
16	(Loss of directional control)	9	24
17	(Wave over bow)	18	25
18	(Fall overboard due to wave)	16	30
19	(Capsizing)	10	27
	TOTAL	96	285

From the table it is clear that the fatal accidents are not distributed in the same manner as the non-fatal accidents by node of acceptance. For example, nearly one-third of the non-fatal accidents were accepted at node 5, while only 1% of the fatal accidents were accepted at that node. Collisions account for approximately 50% of the non-fatal sample, but only 10% of the fatal sample. This necessitates the inclusion of both fatal and non-fatal accidents in the analyses of the powering problem, since the potential exists for different causes and countermeasures for each. While it is true that in terms of potential benefits one fatal accident may be weighted as equivalent to as many as 50 non-fatal accidents, the differences in accept nodes indicate different powering problems. What may be a solution to the cause of certain powering accidents may have no bearing on the causes of other powering accidents. One possible benefit from such analyses is the finding of a regulation or standard that minimizes the

Column(s)	Variable	Description/Codes
		8) Improper or excessive loading was a factor in this accident.
		9) Poor equipment (poor condition) was a factor in this accident.
79	Node 19 Tree	Process the accident as far down the tree as possible. Do not use the "other" code without consulting a project leader.



The trees that have been constructed are intended to provide more detailed information about the accidents. The trees will undoubtedly be amended as more accidents are processed through PRAM. Whenever an analyst presents a case to a project leader that is potentially coded as "other" in one of the trees, the project leader will consider amending the tree to include a node for that particular type of scenario. The ordering of the contributing factors for each acceptance node (each tree) is different. These factors were ordered to reflect their importance and the availability of the information at each node, after reading a sample of accidents at each node.



Node 19

The accidents that are accepted at node 19 include capsizings caused by a wave or wake. Detailed related factors and accident scenario descriptions are coded. The coding instructions are shown on successive pages and will be included in the PRAM Analyst's Guide.

FOR ACCIDENTS ACCEPTED AT NODE 19:

Column(s)	Variable	Description/Codes
75 76 77 78	Contributing Factors	Choose the contributing factors in this accident. If less than four apply, right hand justify and insert 0's in left hand column(s). Read down the list in order and code the first four that apply, in order. Thus, the codes from 75-78 should be ascending. 1) Poor operator judgment: inexperience, misjudgment of his or boat's abilities, etc. 2) Lack of PFDs or lack of PFD use was a factor. 3) Operator was unable to outrun or escape stern wave/wake that he knew was coming 4) Excessive speed was a factor in the accident. 5) Rough water was a factor in the accident. 6) Alcohol was a factor in the accident. 7) More flotation (beyond basic, or any if there was none) would have helped.

Node 18

These accidents include falls within the boat and falls overboard that result from a wave or a wake. For these accidents, detailed codes have been developed for contributing factors in the accidents and for the nature of the fall. The coding instructions are on the pages that follow and will be incorporated into the PRAM Analyst's Guide.

FOR ACCIDENTS ACCEPTED AT NODE 18

Column(s)	Variable	Description/Codes
75 76 77 78	Contributing Factors	Choose the contributing factors in this accident. If less than four apply, right hand justify and insert 0's in left hand column(s). Read down the list in order and code the first four that apply, in order. Thus, the codes from 75-78 should be ascending. 1) Hit by the boat or prop after fall. 2) The fall led to a capsizing or swamping. 3) Improper loading or excessive loading was a a factor in this accident. 4) Excessive speed was a factor in this accident. 5) Poor equipment (poor condition) was a factor in this accident. 6) Lack of PFDs or lack of PFD use was a factor in this accident. 7) Lack of flotation for boat (or lack of level flotation) was a factor; i.e., more flotation would have definitely helped. 8) Collision with another vessel or object after the initial accident. 9) Alcohol involvement on the part of operator or others.
79	Node 18 Tree	Process the accident as far down this tree as possible. Note that no "8" is used. Do not code an "other" without discussing the accident with a project leader

2) Strong current and/or rough water was a factor.

3) Operator inexperience was a factor.

4) Lack of PFDs or failure to use them was a factor.

5) Alcohol was a factor.

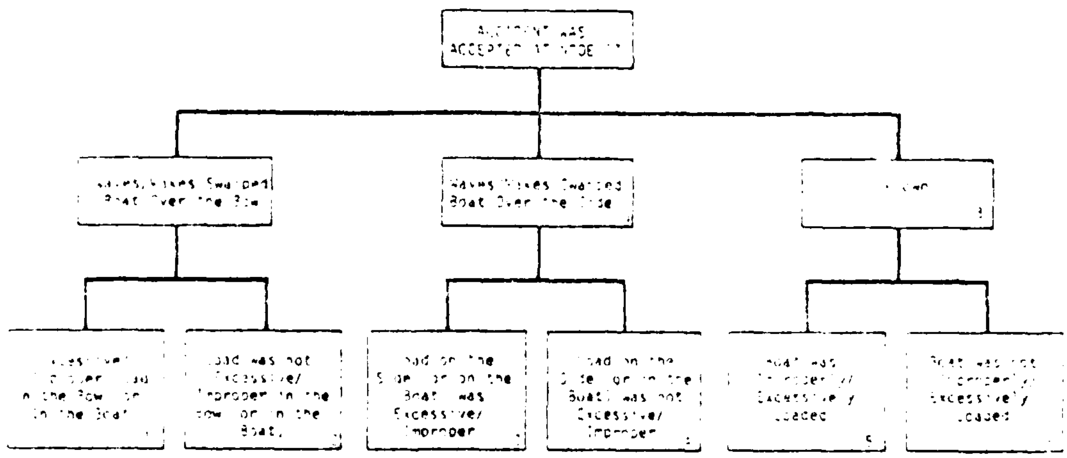
6) Poor operator judgment was a factor.

7) More flotation (beyond 0, or beyond basic) would have helped.

8) A capsizing followed the swamping.

9) Poor equipment (poor condition) was a factor in this accident.

79	Node 17 Tree	Process the accident as far down this tree as possible. The loading decisions involved primarily loads at the bow or gunwale, but these decisions may be based upon the overall load if the loading distribution within the boat isn't known.



Column(s)	Variable	Description/Codes
78 79 80	Contributing Factors	Choose the contributing factors in this accident. If less than three apply, right hand justify and insert 0's in left hand column(s). Read down the list in order and code the first three that apply, in order. Thus, the codes from 78-80 should be ascending.

1) Hit by boat or prop after initial accident.
2) Stood up, improperly seated, or otherwise not in a proper position.
3) Handling gear (engine, line, anchor, fishing, etc.).
4) Engine trouble/control trouble, poor conditions.
5) Lack of PFDs, or not using PFDs.
6) Lack of flotation, more flotation in boat would have helped.
7) Collision occurred after initial accident.
8) Boat was out of control after the accident (underway, not drifting).
9) Alcohol was involved.

Node 17

These accidents involve boats which were swamped by a wave or wake over the bow or side. For these accidents, the contributing factors and some details concerning the reasons for the swampings are coded. The coding instructions are on the pages that follow and these will be included in the PRAM Analyst's Guide.

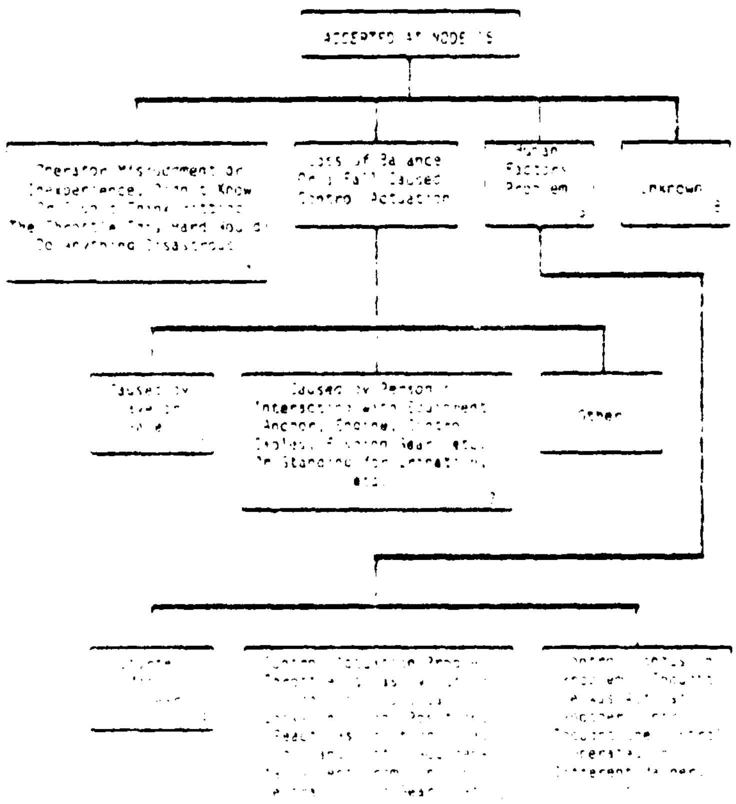
FOR ACCIDENTS ACCEPTED AT NODE 17:

Column(s)	Variable	Description/Codes
75 76 77 78	Contributing Factors	Choose the contributing factors in this accident. If less than four apply, right hand justify and insert 0's in left hand column(s). Read down the list in order and code the first four that apply, in order. Thus the codes from 75-78 should be ascending.

1) Speed was a factor, it was excessive considering the circumstances.

FOR ACCIDENTS ACCEPTED AT NODE 15:

Column(s)	Variable	Description/Codes
75	Circumstances	Was the vessel: 1) Just getting underway from a stopped or slow speed situation (intentional or otherwise) 2) Increasing speed, but already underway 3) Unknown
76	Operator Intentions	Was the change in speed: 1) Intentional 2) Unintentional 3) Unknown
77	Node 15 Tree	Process the accident as far down this tree as possible. Do not use an "other" code without consulting a project leader.



Column(s)	Variable	Description/Codes
78 79 80	Contributing Factors	Choose the contributing factors in this accident. If less than three apply, right hand justify and insert 0's in left hand column(s). Read down the list in order and code the first three that apply, <u>in order</u>. Thus, the codes from 78-80 should be ascending. 1) Hit by boat or prop after initial incident. 2) Lack of PFDs or lack of PFD use. 3) Excessive speed was a factor in the accident. 4) Boat's own wake contributed to the accident. 5) A wave contributed to the accident. 6) Unfamiliarity with controls or human factors problem with controls. 7) Collision with another vessel or object(s) after initial incident. 8) Lack of flotation for boat (or lack of level flotation for boat); i.e., more boat flotation would definitely have helped. 9) Alcohol involvement on the part of operator or others.

[illegible]

A[illegible] [illegible] at this node are initiated by a sudden application of power. In these accidents, the circumstances under which the power was applied ([illegible] getting underway, etc.), whether the sudden application of power was intentional, detailed scenario information about the circumstances causing [illegible] to be at risk, and significant contributing factors are all coded. [illegible] instructions are presented on the following pages and will be [illegible] to the PRIM Analyst's Guide.

PRAM Coding Instructions

Once you have decided that an accident is acceptable for PRAM, then fill out one row on the coding sheet completely for that accident using the following instructions.

CARD 1

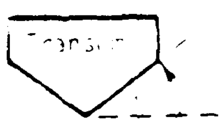
Column(s)	Variable Name	Description and Coding Instructions
01 02 03	Boat Number	This is the number of the boat in our sample. It is used to identify the accident in case we should ever need to refer to it again. The first boat coded into PRAM will be "001;" and the next will be "002," etc., until all of the appropriate accidents have been coded. Each time an acceptable accident is found, it should have the next sequential boat number written on it in bold black printing. All accidents involving more than one boat, wherein more than one boat will be processed through PRAM, will be numbered starting from 900. For each accident of this type, skip to the next multiple of 5 for the starting number. Thus, for the second accident having more than one boat in PRAM, the boat numbers would be 905, 906, etc. For the third accident, 910, 911, etc. Therefore, for boat numbers under 900, there was one boat per accident with a powering-related problem, and for numbers over 899, there were multiple boats per accident with powering-related problems.
04	Coded By	The analyst who codes each particular accident should enter his personal one digit code here. Codes are: 0 = Mark Perry 4 = Bob White 1 = Stuart Burnell 5 = Jack Bowman 2 = Benny Smith 6 = Olivia Corder 3 = Chris Stiehl 7 = Nona Whatley 9 = John Askins
05 06	State	Enter the appropriate two digit code for the state where the accident occurred, according to the list below.

Column(s)	Variable Name	Description and Coding Instructions

Alabama	01	Alaska	02	Arizona	04
Arkansas	05	California	06	Colorado	08
Colorado	08	Connecticut	09	Delaware	10
Dist. of Columbia	11	Florida	12	Georgia	13
Hawaii	15	Idaho	16	Illinois	17
Indiana	18	Iowa	19	Kansas	20
Kentucky	21	Louisiana	22	Maine	23
Maryland	24	Massachusetts	25	Michigan	26
Minnesota	27	Mississippi	28	Missouri	29
Montana	30	Nebraska	31	Nevada	32
New Hampshire	33	New Jersey	34	New Mexico	35
New York	36	North Carolina	37	North Dakota	38
Ohio	39	Oklahoma	40	Oregon	41
Pennsylvania	42	Rhode Island	44	South Carolina	45
South Dakota	46	Tennessee	47	Texas	48
Utah	49	Vermont	50	Virginia	51
Washington	53	West Virginia	54	Wisconsin	55
Wyoming	56			Unknown	88

[illegible]	Month	Enter the appropriate two digit code for the month when the accident occurred (01 = January, etc.... 12 = December). NOTE: FOR ALL THE TIME ORIENTED VARIABLES, CODE THE TIME THAT THE ACCIDENT BEGAN. Unknown = 88
[illegible]	Day	Enter the appropriate two digit code for the day of the accident (01 = 1st of the month, etc.). Don't forget the 0. Unknown = 88
[illegible]	Year	Enter the last two digits of the year in which the accident occurred. Unknown = 88
[illegible]	Time	Code the two digits (in military time, i.e., 0 - 24 hours) corresponding to the time, to the nearest hour, that the accident began. Code the time of the capsizing, for example, when a boat capsizes and the people are not recovered for 10 hours. Round up from the half hour, i.e., 22:30 is coded as "23." Unknown = 88
[illegible]	Accident Type	Code the primary (first) accident type. For example, if there is a collision causing someone to fall out of the boat, all people on board are coded as victims of a collision, not a falls overboard. Similarly, if a person falls out of a johnboat causing it to capsize, throwing a second person into the water, both victims are coded as falls overboard, since that was the primary cause of the accident. Occasionally more than one accident happens consecutively in time. A person might fall overboard, and a second person (coming to his aid) might be struck by the boat or prop. Code the first event.

Column(s)	Variable Name	Description and Coding Instructions
15	Accident Type (continued)	1 = collision/grounding 2 = swamping/capsizing/flooding/sinking 3 = fires and explosions 4 = falls overboard/falls within the boat 5 = struck by boat or propeller 6 = other 8 = unknown
16	Boat Type	Code the single digit that corresponds to the best description of the boat involved. 1 = high performance boat 2 = open powerboat 3 = cabin motorboat 4 = auxiliary sail 5 = canoe/kayak (powered) 6 = houseboat 7 = inflatable (powered) 8 = unknown 9 = other
17 18	Boat Length	Code the length of the boat as a two digit number, ignoring inches. For example, a 15' 11-1/2" boat would be coded "15." For all accidents, code "boat data" for the appropriate boat. For falls overboard, this would be the boat that the victim left. For hit by the boat or prop, this would be the boat that did the hitting. Unknown = 88.
19	Boat Width	Code the one digit number that corresponds to the boat's maximum width (measured to the nearest foot, rounding up from 6"). 0 = 0-3 ft 1 = 4 ft 2 = 5 ft 3 = 6 ft 4 = 7 ft 5 = 8 ft 6 = 9 ft 7 = 10 ft 8 = unknown 9 = greater than 10 ft
20	Hull Shape	Code the one digit that best corresponds with the shape of the boat's hull, using the figure below. 0 = Deep-V (θ greater than 18°) 1 = Semi-V (θ less than 18°) 2 = Cathedral or tri-hull 3 = Flatbottom 4 = Roundbottom 5 = Other 8 = unknown



Column(s)	Variable Name	Description and Coding Instructions
21 22	Year of Manufacture of Boat	Code the last two digits of the year that the boat was manufactured (model year). Unknown = 99
23	Type of Power	Code one digit corresponding to the type of power in use. 0 = Other; 1 = Outboard; 2 = I/O; 3 = Inboard; 9 = Unknown
24	Speed	Code one digit which best corresponds to what is known about the boat's speed. 0 = 0-10 mph 5 = 51-60 mph 1 = 11-20 mph 6 = Unknown, but greater than 61 mph 2 = 21-30 mph 7 = Unknown, but increasing speed 3 = 31-40 mph 8 = Unknown 4 = 41-50 mph 9 = Unknown, but decreasing speed
	Did the boat have a motorwell	0 = No; 1 = Yes; 9 = Unknown
[illegible]	Steering Controls	Code the appropriate one digit code 1 = Controlled from engine, including those where it is not certain but the analyst is pretty sure. 2 = Remote steering, of any type, including those where it is not certain but the analyst is pretty sure. 3 = Tiller 4 = Other 9 = Unknown Use code [illegible] if the engine in use is [illegible] type of steering isn't specified [illegible] boat type (johnboat) suggests tiller [illegible] engine [illegible] under 20 hp
	Motor Manufacturer	Code the one digit that corresponds to the [illegible] manufacturer. 1 = Mercury Marine (Mercruiser) 2 = Johnson 3 = Evinrude 4 = Chrysler 5 = OMC 6 = Clinton or McCulloch 7 = Eska [illegible]

Column(s)	Variable Name	Description and Coding Instructions
28 29 30	Horsepower	Code the horsepower of the engine(s) in use. If more than one engine was in use, then code the combined horsepower. Round down to the nearest whole number. Unknown = 888
31 32	Motor Weight	Code the weight of the motor (in pounds). Remember that "88" means unknown. For this variable, if the motor weight is known, then code the motor weight divided by 10. If the weight is not known, but the manufacturer is known, then use the outboard blue book to determine the motor weight. If the manufacturer is not known, use the chart below. For decimals, round to the nearest whole number, rounding up for 0.5. NOTE: CODE THE COMBINED WEIGHT IF MORE THAN ONE ENGINE WAS USED.

Motor HP	Motor Weight (lb)
2.0- 4.5	30
5.0- 9.0	50
9.1- 15.0	60
15.1- 29.9	100
30.0- 39.9	135
40.0- 49.9	150
50.0- 59.9	180
60.0- 69.9	200
70.0- 79.9	220
80.0- 99.9	250
100.0-135.0	260

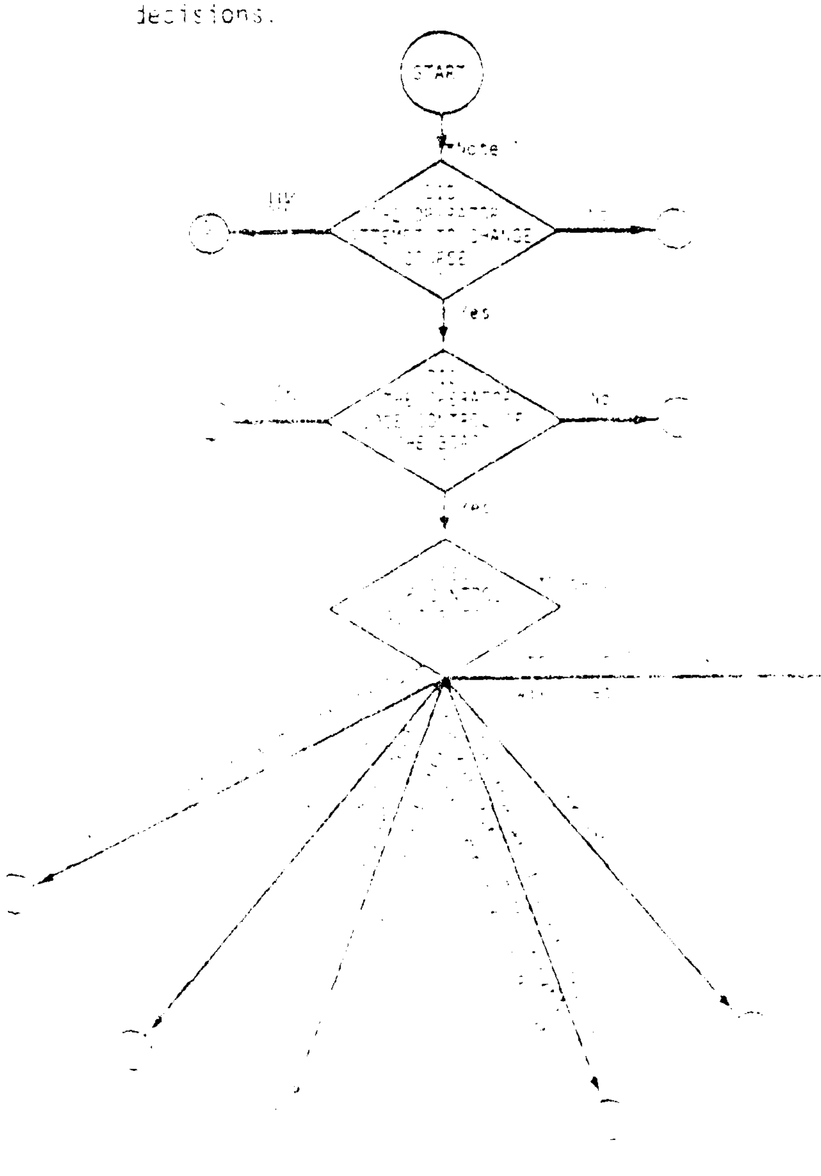
Column(s)	Variable Name	Description and Coding Instructions
33 34	Maximum Engine RPM	Code the maximum engine rpm as a two digit number by determining the maximum engine rpm and dividing it by 100. Round to the nearest 500 rpm, rounding up if at 250 or 750. If the engine make is unknown, then use the guide below. Unknown = 88. For any rpm over 8700, use 89. If the motor manufacturer is known, use the outboard blue book. If the manufacturer is unknown, but the horsepower is known, use the following table.

Engine HP	Maximum RPM
0-4.0	4000
4.1-7.[illegible]	4800
[illegible]-10.[illegible]	5500
10.[illegible] or over	5800

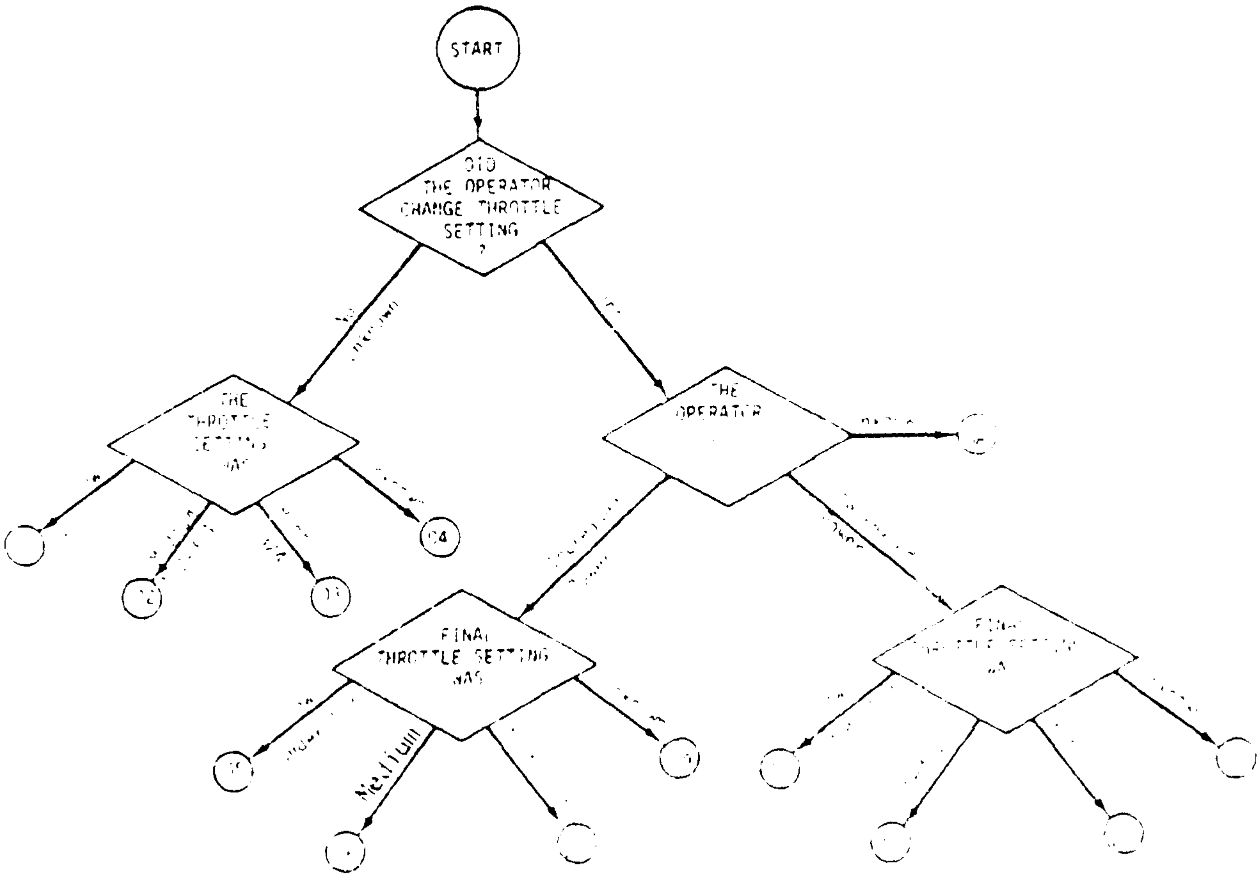
Column(s)	Variable Name	Description and Coding Instructions
36	Course	Choose the appropriate one digit code from the decision tree.

*Note 1: Code "No" if the accident happened very quickly and there is no evidence to the contrary. Code "Yes" if there is any intentional movement of the steering wheel. An operator who must turn the wheel to stay on a heading (because of waves, etc.), is intentionally "changing course" with respect to the steering wheel.

*Note 2. For codes 4 through 9 the analyst must decide the best fitting code when more than one may apply. For example, dynamic instability might be caused by a large wave, and might be best coded as "9" in that particular case. Great care should be taken in these decisions.



Column(s)	Variable Name	Description and Coding Instructions
36 37	Powering Behavior	Choose the appropriate two digit code from the decision tree shown below. Starting the engine in gear is not a change in throttle setting. "Cruising" does not imply that the throttle setting was over 3/4. The questions in the tree refer to the period of time immediately prior to the accident, not several minutes before. The word "gunned" is interpreted as a high throttle setting. An operator who is attempting to get a water skier up is assumed to be at full throttle. If the analyst knows the speed in mph and the total weight of the boat + people + gear (approximately), then the throttle setting can be obtained by using a computer/calculator program which can be obtained from a project leader (C. Stiehl, R. White, or N. Whatley - see Appendix B).



Column(s)	Variable Name	Description and Coding Instructions
38 39	People on Board	Code two digits for the number of people on board the boat (be sure to right-hand justify; i.e., code 1 as "01"). For falls overboard, the falls overboard victim(s) is counted as one of the people on board. Water skiers are not counted as POB, nor are any other people who are not from this boat. 88 = unknown.
40	Activity	Code the appropoiate digit for the activity at the time of the accident. Water skiing includes the boat, the skier, manuevering to pick up the skier, etc. Trying to take off and get a water skier up = 7. Project leader approval must be obtained in order to use a "0". 0 = Something other than those on the list (but underway) 1 = Pleasure cruising, going from one place to another, etc. 2 = Fishing 3 = Hunting 4 = Water skiing 5 = Skin [illegible] or swimming (principal activity, [illegible] the moment, the boat was underway) 6 = [illegible] 7 = Leaving a dock, or otherwise just getting underway
41	Body of water	Code the appropriate digit. 0 = [illegible] creek, channel, etc. (often fresh water) 1 = [illegible] than a Great Lake), swamp, etc. 2 = Great [illegible] 3 = Coastal [illegible] inlet, sound, harbor, [illegible], etc. [illegible] salt water 4 = Ocean 8 = Unknown
42	Water Conditions	Code the appropriate digit [illegible] [illegible] [illegible] [illegible] [illegible]
[illegible]	[illegible]	[illegible] If no visibility information [illegible] the BAR [illegible] visibility [illegible] other information contradicts what [illegible], then consider fog and rain [illegible] as "fair" at best

Column(s)	Variable Name	Description and Coding Instructions
		0 = Good 1 = Fair 2 = Poor 8 = Unknown
44	Wind	Code the appropriate digit. 0 = None 1 = Light (less than or eq. 6 mph) 2 = Moderate (7 thru 14 mph) 3 = Strong (15 thru 24 mph) 4 = Storm (25 mph or more) 8 = Unknown
45	Number of Recoveries	Code with one digit the number of people on the boat who survived the accident, where "8" means unknown, and "9" stands for more than 7. Water skiers and others involved in the accident, whether from this boat or not, <u>are</u> included here.
46	Number of Fatalities	Code with one digit the number of people on the boat who died in the accident, where "8" stands for unknown, and "9" means more than 7. Water skiers and others involved in the accident, whether from this boat or not <u>are</u> included here. NOTE: Columns 45 and 46 should sum to at least the number of POB, and probably more.
47 48	Node of Acceptance	Code as a two digit number the node on the PPAM accident decision tree where this accident was accepted.
49 50 51	Operator Skill/ Experience	Code three digits for this variable. The first digit corresponds to the operator's experience in this particular boat, or boats of this type. The second digit corresponds to the operator's total experience in boats. The third digit corresponds to what is known about the formal boating safety education of the operator. For example, if the operator had 50 hours of experience on boats of this type, 150 hours of total experience on boats, and had had no formal boating safety courses, then he would be coded "1[illegible]."

Column(s)	Variable Number	Description and Coding Instructions
		For Experience (This Boat): 0 = Under 20 hours 1 - 20-100 hours 2 = 100-500 hours 3 = Over 500 hours 8 = Unknown For Experience (Total): 0 = Under 20 hours 1 = 20-100 hours 2 = 100-500 hours 3 = Over 500 hours 4 = Exact number unknown, but operator is known to have considerable experience 8 = Unknown For Education: 0 = None 1 = USCG Auxiliary Course 2 = Power Squadron Course 3 = Red Cross Course 4 = State Course 5 = Other Course (including professional licenses) 6 = More than one course 7 = Yes, but particular course unknown 8 = Unknown
52 53 54	Rated Horsepower	Code three digits corresponding to the rated horsepower. 888 = Unknown
55 56	Rated Weight Capacity of POB	Code two digits corresponding to the rated weight of the people on board (persons capacity) divided by 10, up to a code of 88. "88" is used for unknown. "89" for this variable means a persons capacity of from 1001 to 1500 pounds. "99" stands for not applicable (boats which are not rated).
57 58 59	Rated Total Weight Capacity	Code three digits corresponding to the rated total weight capacity of the boat, divided by 10. "888" stands for unknown, and "999 means not applicable (boats which are not rated). "889" is used for boats whose total weight capacity exceeds 8870 pounds.

Column(s)	Variable Name	Description and Coding Instructions
60 61	Rated Weight Capacity of The Motor	Code two digits corresponding to the rated weight of the motor divided by 10. "88" stands for unknown, and "99" stands for not applicable (I/O, inboards). If the motor weight capacity is unknown, but the horsepower capacity (outboard) is known, then the following codes will be used:

Rated Horsepower Capacity	Motor Weight Capacity	Code
0.1 to 2	25	03
2.1 to 3.9	35	04
4.0 to 7.0	55	06
7.1 to 15.0	75	08
15.1 to 25	100	10
25.1 to 45	155	16
45.1 to 80	240	24
80.1 to 150	315	32
150.1 to 250	420	42

Column(s)	Variable Name	Description and Coding Instructions
62 63 64	Weight of Gear on Board	Code the weight of the gear on board divided by 10 as a three digit number. Include the weights of all items on board other than the people and the motor. 888 = unknown. As examples: (ESTIMATE)

Full gas tank (approx. 40 lbs.)
Small ice chest-full (@ [illegible] lbs.)
Large ice chest-full (@ [illegible] lbs.)
Anchor (@ 20 lbs.)
Battery (@ 45 lbs.)
Anchor line and other line (@ [illegible] lbs.)
Ski equipment (@ 10 lbs. per pair)
Fishing equipment/hunting equipment [illegible] (@ 25 lbs.)
PFDs and Navigational Aids (compass, flashlight, charts, etc. (@ 15 lbs.)

If the items on board are unknown, then calculate the weight of gear on board as follows:

For jonboats or [illegible] less than [illegible] use:
25 x POB = wt. in lbs. of gear on board.

For boats [illegible] feet or longer use:
(25 x POB) + [illegible] = wt. in lbs. of gear on board.

For boats with more than [illegible] POB use:
[illegible] x POB = wt. of gear on board.

Column(s)	Variable Name	[illegible] on and Co[illegible] [illegible]ctions
65	No. of Engines in Use	1 = 1 [illegible] in use 2 = 2 [illegible] in use 3 = 3 [illegible] more engines in use 8 = Unknown
66	Damage to This Vessel	[illegible] damage to the vessel, use the code [illegible] corresponds to the cost of repairing the [illegible], [illegible] known; otherwise, use the code which [illegible] corresponds to the known damage. The [illegible] to the cost at the time of the [illegible] not what the cost would be today. For [illegible] the BAR states that the damage was [illegible] accident, DO NOT figure the inflati[illegible] number, but code it as is. The [illegible] any significantly valued pe[illegible] as well as damage to the boat. [illegible] loss is reported (including the [illegible] valuable gear that may have been [illegible]. The code "[illegible]" should be used [illegible] damage is specifically stated, and [illegible] in a BAR [illegible]. [illegible] the accident is a fall overboard, [illegible] mishaps (capsizing, etc.), then [illegible] damage unless there is evidence [illegible]. For collisions, [illegible] assume a [illegible] if [illegible] information is given. [illegible] THIS VARIABLE. Consult [illegible] project leaders if you feel [illegible]
		[illegible] specifically stated [illegible]
		[illegible] damage [illegible]

Columns	Variable Name	Description and Coding Instructions
		injured. For the third digit code the most severe injury among those who were injured. If only one person was injured, then the least and most severe codes should be the same. If no one was injured, then use 0 for the least severe injury and for the most severe injury. Injuries include burns, broken limbs, effects of exposure/hypothermia, etc.

No. of People Injured (Column 67)

0 = 0
1 = 1
2 = 2
3 = 3
4 = 4
5 = 5
6 = 6
7 = 7 or more
8 = Unknown
9 = Unknown, but some were injured

Severity (Column 68 - "least" - and 69 - "most")

0 = Minor cuts and bruises, no [illegible] treatment
1 = Cuts, abrasions, bruises requiring treatment
2 = Injuries resulting in 24 hours or less of incapacitation (missing work, etc.)
3 = Injuries resulting in more than 24 hours incapacitation, and up to one week
4 = Injuries resulting in one week to one month [illegible]
5 = Injuries resulting in one to six months of incapacitation
6 = More than six months, but [illegible]
7 = Permanent disability, but not [illegible]
8 = Unknown
9 = Permanent disability, [illegible] blindness plus

Damage to Other Vehicle(s) — [illegible] that best describes the damage to the other vessel(s) in this accident. NOTE: If the other vessel(s) in this accident are [illegible], then [illegible] in columns [illegible] [illegible] other vessel(s) [illegible] the one [illegible] [illegible]

[illegible] of personal property [illegible] damage, [illegible] resulting from a collision

Variable Name	Description and Coding Instructions
Number of Recoveries	Code with one digit the number of people on the boat who survived the accident, where "8" means unknown, and "9" stands for more than 7. Water skiers and others involved in the accident, whether from this boat or not, <u>are</u> included here.
Number of Fatalities	Code with one digit the number of people on the boat who died in the accident, where "8" stands for unknown, and "9" means more than 7. Water skiers and others involved in the accident, whether from this boat or not <u>are</u> included here.

NOTE: Columns 45 and 46 should sum to at least the number of POB, and probably more.

Variable Name	Description and Coding Instructions
Node of Acceptance	Code as a two digit number the node on the PRAM accident decision tree where this accident was accepted.
Operator Skill/ Experience	Code three digits for this variable. The first digit corresponds to the operator's experience in this particular boat, or boats of this type. The second digit corresponds to the operator's total experience in boats. The third digit corresponds to what is known about the formal boating safety education of the operator. For example, if the operator had 50 hours of experience on boats of this type, 150 hours of total experience on boats, and had had no formal boating safety courses, then he would be coded "120."

NOTE: For operator total experience find median of each range checked in the experience columns on the BAR and add the two. If only one experience block is shown on BAR, use that figure for total experience and 8 for experience this boat.

For Experience (This Boat):

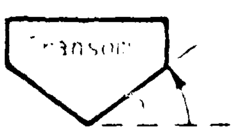
0 = Under 20 hours
1 = 20-100 hours
2 = 100-500 hours
3 = Over 500 hours
8 = Unknown

umn(s)	Variable Name	Description and Coding Instr...
33 34 35 36 37		Leave these columns blank
38 39	People on Board	Code two digits for the number of people on board the boat (be sure to right-hand justify; i.e., code 1 as "01"). For falls overboard, the falls overboard victim(s) is counted as one of the people on board. Water skiers are not counted as POB, nor are any other people who are not from this boat. 98 = unknown.
40	Activity	Code the appropoiate digit for the activity at the time of the accident. Water skiing includes the boat, the skier, manuevering to pick up the skier, etc. Trying to take off and get a water skier up = 7. Project leader approval must be obtained in order to use a "0". 0 = Something other than those on the list (but underway) 1 = Pleasure cruising, going from one place to another, etc. 2 = Fishing 3 = Hunting 4 = Water skiing 5 = Skin diving or swimming (principal activity, but at the moment, the boat was underway 6 = Docking 7 = Leaving a dock, or otherwise just getting underway 9 = Not underway, docked, at anchor, drifting, etc.
41		Leave this column blank.
42	Water Conditions	Code the appropriate digit 0 = Calm 2 = Choppy/rough 3 = Swift current 4 = Very rough 8 = Unknown
43		Leave this column blank.
44		Leave this column blank.

Column(s)	Variable Name	Description and Coding Instructions
21 22	Year of Manufacture of Boat	Code the last two digits of the year that the boat was manufactured (model year). Unknown = 88
23	Type of Power	Code one digit corresponding to the type of power in use. "Other" includes jet boats, air boats. 0 = Other; 1 = Outboard; 2 = I/O; 3 = Inboard; 8 = Unknown
24	Speed	Code one digit which best corresponds to what is known about the boat's speed. 0 = 0-10 mph 5 = 51-60 mph 1 = 11-20 mph 6 = Unknown, but greater than 60 mph 2 = 21-30 mph 7 = Unknown, but increasing speed 3 = 31-40 mph 8 = Unknown 4 = 41-50 mph 9 = Unknown, but decreasing speed
25		Leave this column blank
26		Leave this column blank
27		Leave this column blank
28 29 30	Horsepower	Code the horsepower of the engine(s) in use. If more than one engine was in use, then code the combined horsepower. Round down to the nearest whole number. Unknown = 888
31 32	Motor Weight	Code the weight of the motor (in pounds). Remember that "88" means unknown. For this variable, if the motor weight is known, then code the motor weight divided by 10. If the weight is not known, but the manufacturer is known, then use the outboard blue book to determine the motor weight. If the manufacturer is not known, use the chart below. For decimals, round to the nearest whole number, rounding up for 0.5. NOTE: CODE THE COMBINED WEIGHT IF MORE THAN ONE ENGINE WAS USED.

Motor HP	Motor Weight (lb)
2.0- 4.5	30
5.0- 9.0	50
9.1- 15.0	60
15.1- 29.9	100
30.0- 39.9	135
40.0- 49.9	150
50.0- 59.9	180
60.0- 69.9	200
70.0- 79.9	220
80.0- 99.9	250
100.0-1[illegible]	260

Column(s)	Variable Name	Description and Coding Instructions
15	Accident Type (continued)	1 = collision/grounding 2 = swamping/capsizing/flooding/sinking 3 = fires and explosions 4 = falls overboard/falls within the boat 5 = struck by boat or propeller 6 = other 8 = unknown
16	Boat Type	Code the single digit that corresponds to the best description of the boat involved. 1 = high performance boat 2 = open powerboat 3 = cabin motorboat 4 = auxiliary sail 5 = canoe/kayak (powered) 6 = houseboat 7 = inflatable (powered) 8 = unknown 9 = other
17 18	Boat Length	Code the length of the boat as a two digit number, ignoring inches. For example, a 15' 11-1/2" boat would be coded "15." For all accidents, code "boat data" for the appropriate boat. For falls overboard, this would be the boat that the victim left. For hit by the boat or prop, this would be the boat that did the hitting. Unknown = 88.
19	Boat Width	Code the one digit number that corresponds to the boat's maximum width (measured to the nearest foot, rounding up from 6". 0 = 0-3 ft 5 = 8 ft 1 = 4 ft 6 = 9 ft 2 = 5 ft 7 = 10 ft 3 = 6 ft 8 = unknown 4 = 7 ft 9 = greater than 10 ft
20	Hull Shape	Code the one digit that best corresponds with the shape of the boat's hull, using the figure below. 0 = Deep-V (θ greater than 18°) 1 = Semi-V (θ less than 18°) 2 = Cathedral or tri-hull 3 = Flatbottom 4 = Roundbottom 5 = Other 8 = Unknown



Column(s)	Variable Name	Description and Coding Instructions

Alabama	01	Alaska	02	Arizona	04
Arkansas	05	California	06	Colorado	08
Colorado	08	Connecticut	09	Delaware	10
Dist. of Columbia	11	Florida	12	Georgia	13
Hawaii	15	Idaho	16	Illinois	17
Indiana	18	Iowa	19	Kansas	20
Kentucky	21	Louisiana	22	Maine	23
Maryland	24	Massachusetts	25	Michigan	26
Minnesota	27	Mississippi	28	Missouri	29
Montana	30	Nebraska	31	Nevada	32
New Hampshire	33	New Jersey	34	New Mexico	35
New York	36	North Carolina	37	North Dakota	38
Ohio	39	Oklahoma	40	Oregon	41
Pennsylvania	42	Rhode Island	44	South Carolina	45
South Dakota	46	Tennessee	47	Texas	48
Utah	49	Vermont	50	Virginia	51
Washington	53	West Virginia	54	Wisconsin	55
Wyoming	56			Unknown	88
				Coast Guard Controlled Water But Not a State	63

Leave these columns blank

Leave these columns blank

Year — Enter the last two digits of the year in which the accident occurred. Unknown = 88

Leave these columns blank

Accident Type — Code the primary (first) accident type. For example, if there is a collision causing someone to fall out of the boat, all people on board are coded as victims of a collision, not a falls overboard. Similarly, if a person falls out of a johnboat causing it to capsize, throwing a second person into the water both victims are coded as falls overboard, since that was the primary cause of the accident. Occasionally more than one accident happens consecutively in time. A person might fall overboard, and a second person (coming to his aid) might be struck by the boat or prop. Code the first event.

APPENDIX B. POWERING RELATED ACCIDENT MODEL (PRAM) CODING INSTRUCTIONS FOR NON-POWERING RELATED ACCIDENTS

PRAM Coding Instructions

Once you have decided that an accident is acceptable for PRAM, then fill out one row on the coding sheet completely for that accident using the following instructions.

CARD 1

Column(s)	Variable Name	Description and Coding Instructions
01 02 03	Boat Number	This is the number of the boat in our sample. It is used to identify the accident in case we should ever need to refer to it again. The first boat coded into PRAM will be "001;" and the next will be "002," etc., until all of the appropriate accidents have been coded. Each time an acceptable accident is found, it should have the next sequential boat number written on it in bold black printing. All accidents involving more than one boat, wherein more than one boat will be processed through PRAM, will be numbered starting from 900. For each accident of this type, skip to the next multiple of 5 for the starting number. Thus, for the second accident having more than one boat in PRAM, the boat numbers would be 905, 906, etc. For the third accident, 910, 911, etc. Therefore, for boat numbers under 900, there was one boat per accident with a powering-related problem, and for numbers over 899, there were multiple boats per accident with powering-related problems. For two boat collisions in non-powering, use sequential numbers in normal order, i.e., do not use 9XX.
04	Coded By	The analyst who codes each particular accident should enter his personal one digit code here. Codes are: 0 = Mark Perry 4 = Bob White 1 = Fran Orr 5 = Paula White 2 = Benny Smith 6 = Gay Parrott 3 = Chris Stiehl 7 = Nona Whatley 9 = Bob Douglas
05 06		Leave these columns blank.

PRAM PROGRAM LISTING (HP-97)

STEP	KEY ENTRY	KEY CODE	COMMENTS
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	-14	
[illegible]	[illegible]	02	
[illegible]	[illegible]	-24	
[illegible]	[illegible]	51	
[illegible]	[illegible]	21 11	
[illegible]	[illegible]	-14	
[illegible]	[illegible]	-24	
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	-62	
[illegible]	[illegible]	05	
[illegible]	[illegible]	52	
[illegible]	[illegible]	51	
[illegible]	[illegible]	-63 03	
[illegible]	[illegible]	-14	
[illegible]	[illegible]	16-11	
[illegible]	[illegible]	21 1[illegible]	
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	-14	
[illegible]	[illegible]	[illegible] 01	
[illegible]	[illegible]	-35	
[illegible]	[illegible]	01	
[illegible]	[illegible]	06	
[illegible]	[illegible]	03	
[illegible]	[illegible]	51	

STEP	KEY ENTRY	KEY CODE
060		
070		
080		
090		
100		

REGISTERS

User Instructions

PRAM
For Decision Tree: (For "Powering Behavior"):
Rated Hp | Mounted Hp/ Speed

STEP	INSTRUCTIONS	INPUT DATA UNITS	KEYS	OUTPUT DATA UNITS
1	Load the program			0.00
2	For use in conjunction with the PRAM decision tree, input the rated horsepower and press "A." The calculator will display the rated Hp on the printer and 1/2 the rated Hp on the display.	Rated Hp	A	Rated Hp (on printer) 1/2 Rated Hp (on display)
3	Input mounted horsepower and press "B."	Mounted Hp	B	Mounted Hp (on printer) Critical Throttle Setting (on printer & display)
[illegible]	FOR "POWERING BEHAVIOR", START HERE: Input the speed (in mph) and press "C." The calculator will stop for the next input within a second or two.	Speed	C	Speed (on printer) Speed² (on display)
[illegible]	Input total boat weight and press "R/S." The calculator will stop for the next input within a second or two.	T. Boat Wt.	R/S	T. Boat Wt. (on printer) Hp in use (on display)
[illegible]	Input mounted engine horsepower and press "R/S."	Mounted Hp	R/S	Mounted Hp (on printer) Throttle Setting (on printer & display)
[illegible]	To use the program for the decision tree again, return to step 2; for the "Powering Behavior" Tree, return to step 4.			

Program Description

Program Title PRAM

Name C. Christian Stiehl

Date 9/2/77

Address Wyle Laboratories

City State Zip Code

Program Description, Equations, Variables, etc.

This program serves two purposes. First, it allows the analyst to input the rated and mounted horsepowers for a boat, and calculate the critical throttle setting (in terms of % throttle) which must be exceeded for more than 1/2 of the rated horsepower to be in use. The calculator outputs this critical throttle setting with the first part of this program. If the analyst knows that the throttle setting for this boat in the accident in question was less than the calculator's output, then the accident (boat) is rejected from the PRAM sample. If the throttle setting execeeds that shown on the calculator, then the case is processed further in the PRAM decision tree. Example:

Input	Action	Output: Display	Printer
25 (rated Hp)	press "A"	12.5	25.0
75 (mounted Hp)	press "B"	-	75.0
		0.488	0.488

The second part of the program allows the analyst to compute the throttle setting for a boat (planing hull) when the speed, total boat weight, and mounted horsepower are known. This information is used to determine the coding for the "Powering Behavior" tree in PRAM. The analyst inputs the three variables listed above, and the calculator computes the throttle setting. Example:

Input	Action	Output: Display	Printer
40 (speed in mph)	press "C"	1600	40.0
[illegible] (total weight)	press "R/S"	112.5	[illegible]
[illegible] (mounted Hp)	press "R/S"	-	[illegible]
		[illegible]	[illegible]

This means that the boat in question must have been at nearly full throttle to have been travelling at the stated speed with the stated engine size and total boat weight.

Operating Limits and Warnings

The first part of the program uses the relationship: (% Hp) = (% Throttle)$^{2.5}$

The second part of the program uses: Speed = 160 SQRT(Wt./Hp) to get the horsepower in use, and then uses the relationship stated above to obtain the approximate throttle setting.

APPENDIX B. PRAM THROTTLE SETTING PROGRAM

This program was designed to be used by analysts in deciding whether certain accidents should be rejected or processed further in the powering-related accident decision tree, and in the coding of some accidents. In accidents there are cases where the throttle setting was known and was less than 1/2 throttle. In these cases, the program will help with the decision tree. The program requires knowledge of the mounted and rated horsepower for the boat. The analyst must, upon supplying this information to the calculator, decide if the boat's throttle setting exceeded that shown on the calculator's display. If so, it is processed further in the decision tree; otherwise, it is rejected.

The first part of the program uses the relationship that the percentage of horsepower in use is approximately equal to the percentage of full throttle setting raised to the 2.5 power. This relationship can be expressed as shown in Equation (1), where throttle setting is replaced by rpm (up to maximum recommended rpm) and percentage of horsepower in use is replaced by the horsepower in use (prop. load curve), and K is a constant.

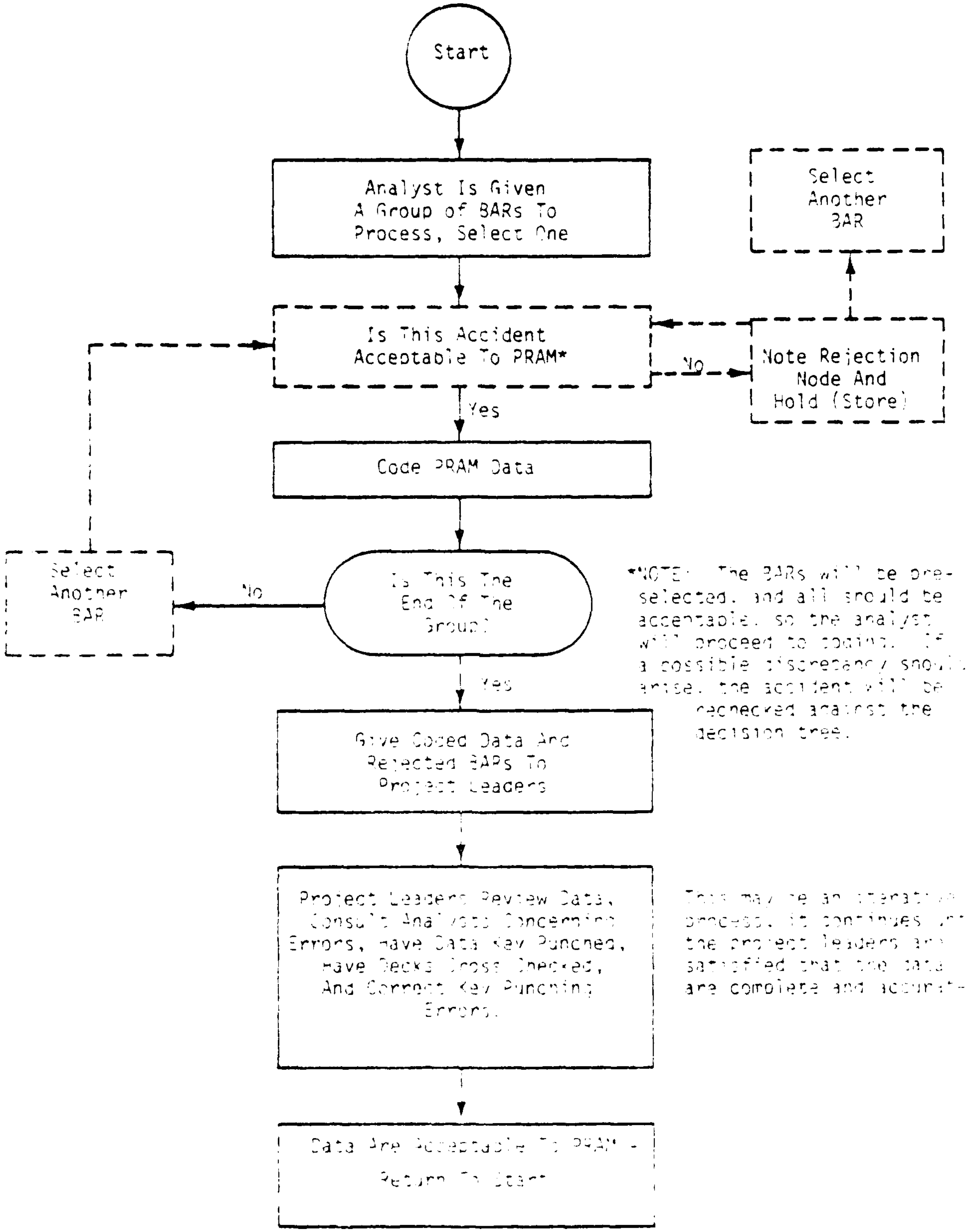
$$HP = K \cdot (rpm)^{2.5} \qquad (1)$$

This relationship has been shown to be close to empirical data (see Figure 5). It will allow borderline cases to be processed further in the powering-related accident decision tree since it credits the operator with using slightly more horsepower (particularly at low throttle settings) than the empirical data indicate.

The second part of this program allows the analyst to code the final throttle setting for the variable "Powering Behavior" (columns 36 and 37) when the mounted horsepower, speed, and total weight of the boat are known. This part of the program uses the approximate relationship shown in Equation (2) to calculate the horsepower in use, and uses the relationship shown in Equation (3) to compute the throttle setting.

$$\text{Speed} = \frac{160}{\sqrt{\text{weight/horsepower in use}}} \qquad (2)$$

$$HP = C \cdot (\text{Throttle})^{2.5} \qquad (3)$$


Start
Analyst Is Given A Group of BARs To Process, Select One
Is This Accident Acceptable To PRAM*
No
Note Rejection Node And Hold (Store)
Select Another BAR
Yes
Code PRAM Data
Is This The End Of The Group?
No
Select Another BAR
Yes
Give Coded Data And Rejected BARs To Project Leaders
Project Leaders Review Data, Consult Analysts Concerning Errors, Have Data Key Punched, Have Decks Cross Checked, And Correct Key Punching Errors.
Data Are Acceptable To PRAM - Return To Start
*NOTE: The BARs will be pre-selected, and all should be acceptable, so the analyst will proceed to coding. If a possible discrepancy should arise, the accident will be rechecked against the decision tree.
This may be an iterative process. It continues until the project leaders are satisfied that the data are complete and accurate.

PRAM Quality Assurance Procedures

The accidents that are coded into PRAM will be processed to two analysts. That is, each individual accident report will be coded by only two people. At the early phases of coding (for approximately the first 50 accidents) the analysts' work will be thoroughly reviewed by the project leaders (R. White, N. Whatley, C. Stiehl) for quality and adherence to the intent and instructions of the model. Thereafter, a sample of five from each group of 50 accidents that are coded will be reviewed by the project leaders.

When all of the accidents have been coded, two decks will be independently keypunched, one for each analyst. These two decks will be compared using Wyle's "Check Decks" program to find keypunching and coding discrepancies. The discrepancies will be reviewed by the project leaders and analysts to arrive at a consensus coding. Then both decks will be corrected. The final product of this procedure will be two complete sets of coded data, relatively free of keypunching errors. The only way that a keypunching error could survive this procedure would be if the exact mistake were made twice independently. The diagram on the next page depicts the entire process.

Coding Steps for PRAM

If you are the analyst, about to code data for PRAM, you should:

1) Check with the project leaders to make sure you have the correct sample of accidents to code.

2) Code all of the required information on the data sheet for the accident, according to the instructions on previous pages, and consulting with the project leader if any questions arise.

3) When you have completed a group of accidents to be coded, take the completed data sheets and the BARs that were accepted to the project leaders for review. Then proceed with the next group of accidents to be processed.

4) When errors are made (either in coding or keypunching) the project leaders will review these with the analyst in order to make sure that the correct information is coded on the computer cards. This may require some rereading of the BARs on your part, and perhaps some recoding.

Column(s)	Variable Name	Description and Coding Instructions
		3 = Injuries resulting in more than 24 hours incapacitation, and up to one week 4 = Injuries resulting in one week to one month of incapacitation 5 = Injuries resulting in one to six months of incapacitation 6 = More than six months, but not permanent 7 = Permanent disability, but not blindness 8 = Unknown 9 = Permanent disability, blindness or blindness plus
74	No. of Fatalities (Other Vessel(s))	Code the total number of fatalities on the other vessel(s) using the codes below: 0 = 0 1 = 1 2 = 2 3 = 3 4 = 4 5 = 5 6 = 6 7 = 7 8 = Unknown 9 = More than 7

CARD 2

Column(s)	Variable Name	Description and Coding Instructions
01 02 03	Boat Number	This is the PRAM case number
04	Johnboat	Code as follows: 0 = Not a johnboat 1 = Is a johnboat 2 = Is a bass boat 8 = Unknown
05 06 07	Boat Weight	Code the weight of the boat (only) divided by 10 888 Means Unknown 999 Means greater than 10,000 lb

Column(s)	Variable Name	Description and Coding Instructions
		may be zero damage. The code "0" should not be used unless the analyst is certain that there were no damages. If no information is given, and the accident was a collision, then the code "7" is assumed. THERE IS NO "UNKNOWN" CODE FOR THIS VARIABLE. Consult with a project leader if you feel that "unknown" is the proper code.

0 = No damage
1 = Slight damage, scratched gelcoat, etc., $200 or less
2 = Moderate damage, little or no structural damage. Perhaps several scratches and a bent prop, some fiberglass work, etc., up to $500
3 = Considerable damage, some structural damage, fiberglass and/or interior work, up to $2000
4 = Severe damage, boat may be a total loss, up to $4000
5 = Severe damage, up to $6000
6 = Severe damage, over $6000
7 = Some damage, but extent unknown

Note that a total loss of a jonnboat, for example, might be classified as "3", or even "2," if it only cost a few hundred dollars.

71 72 73	Injuries (Other Vessel(s))	Code the injury data for the other vessel(s) in this accident, remembering the guidelines established for the previous coding of injuries. If no one was injured, code "0" in columns 71 through 73.

0 = 0
1 = 1
2 = 2
3 = 3
4 = 4
5 = 5
6 = 6
7 = 7 or more
8 = unknown
9 = unknown, but some were injured

Severity: Columns 72 - "least" -, and 73 - "most"

0 = Minor cuts and bruises, or less, no treatment
1 = Cuts, abrasions, bruises requiring treatment
2 = Injuries resulting in 24 hours or less of incapacitation (missing work, etc.)

Column(s)	Variable Name	Description and Coding Instructions
		For experience (Total): 0 = Under 20 hours 1 = 20-100 hours 2 = 100-500 hours 3 = Over 500 hours 4 = Exact number unknown, but operator is known to have considerable experience 8 = Unknown For Education: 0 = None 1 = USCG Auxiliary Course 2 = Power Squadron Course 3 = Red Cross Course 4 = State Course 5 = Other Course (including professional licenses) 6 = More than one course 7 = Yes, but particular course unknown 8 = Unknown
52 53 54	Rated Horsepower	Code three digits corresponding to the rated horsepower. 888 = Unknown
55 56	Rated Weight Capacity of POB	Code two digits corresponding to the rated weight of the people on board (persons capacity) divided by 10. "88" is used for unknown. "89" for this variable means a persons capacity of from 1001 to 1500 pounds. "99" stands for not applicable (boats which are not rated). Use code "87" for 880 to 899 lbs. and use code "98" for 980 to 1000 lbs. If given in number of persons, multiply by 160 lbs.
57 58 59	Rated Total Weight Capacity	Code three digits corresponding to the rated total weight capacity of the boat, divided by 10. "888" stands for unknown, and "999" means not applicable (boats which are not rated). "889" is used for boats whose total weight capacity exceeds 8870 pounds.

Column(s)	Variable Name	Description and Coding Instructions
60 61	Rated Weight Capacity of The Motor	Code two digits corresponding to the rated weight of the motor divided by 10. "88" stands for unknown, and "99" stands for not applicable (I/O, inboards). If the motor weight capacity is unknown, but the horsepower capacity (outboard) is known, then the following codes will be used:

Rated Horsepower Capacity	Motor Weight Capacity	Code
0.1 to 2	25	03
2.1 to 3.9	35	04
4.0 to 7.0	55	06
7.1 to 15.0	75	08
15.1 to 25	100	10
25.1 to 45	155	16
45.1 to 80	240	24
80.1 to 150	315	32
150.1 to 250	420	42

Column(s)	Variable Name	Description and Coding Instructions
62 63 64	Weight of Gear on Board	Code the weight of the gear on board divided by 10 as a three digit number. Include the weights of all items on board other than the people and the motor. 888 = Unknown. As examples: (ESTIMATE)

Full gas tank (approx. 40 lbs.)
Small ice chest-full (@ 10-25 lbs.)
Large ice chest-full (@ 30-50 lbs.)
Anchor (@ 20 lbs.)
Battery (@ 45 lbs.)
Anchor line and other line (@ 5 lbs.)
Ski equipment (@ 10 lbs. per pair)
Fishing equipment/hunting equipment and catch (@ 25 lbs.)
PFDs and Navigational Aids (compass, flashlight, charts, etc. (@ 15 lbs.)

If the items on board are unknown, then calculate the weight of gear on board as follows:

For johnboats or O/B's less than 16' use:
25 x POB = Wt. (in lbs.) of gear on board.

For boats 16 feet or longer use:
(25 x POB) + 100 = Wt. (in lbs.) of gear on board.

For boats with more than 4 POB use:
(10 x POB) = Wt. of gear on board.

Column(s)	Variable Name	Description and Coding Instructions
65	No. of Engines in Use	1 = 1 Engine in use 2 = 2 Engines in use 3 = 3 or more engines in use 8 = Unknown
66	Damage to This Vessel	In coding the damage to the vessel, use the code that corresponds to the cost of repairing the vessel, if known; otherwise, use the code which best corresponds to the known damage. The "cost" refers to the cost at the time of the accident, not what the cost would be today. For example, if the BAR states that the damage was $100 in a 1970 accident, DO NOT figure the inflation in that number, but code it as is. The cost includes any significantly valued personal property as well as damage to the boat, if any such loss is reported (including the loss of any valuable gear that may have been on board). The code "0" should be used only when "no damage" is specifically stated, and not when such boxes in a BAR are left blank. If the accident is a fall overboard, with no subsequent mishaps (capsizing, etc.), then assume zero damages unless there is evidence to the contrary. For collisions, fires, and capsizings, assume a code of 7 if no damage information is given. THERE IS NO UNKNOWN CODE FOR THIS VARIABLE. Consult with one of the project leaders if you feel that "unknown" is the proper code for a particular case. 0 = No damage (specifically stated) 1 = Slight damage, scratched gelcoat, etc., $200 or less 2 = Moderate damage, little or no structural damage perhaps several scratches and a bent prop, some fiberglass work, etc., 500 or less 3 = Considerable damage, some structural damage, fiberglass and/or interior work, $2000 or less 4 = Severe damage, boat may be a total loss, $4000 or less 5 = Severe damage, $6000 or less 6 = Severe damage, over $6000 7 = Some damage, but extent unknown
67 68 69	Injuries This Vessel	For the first digit, code the number of people who were injured (do NOT include those who died). For the second digit, use the code corresponding to the least severe injury among those who were

Column(s)	Variable Name	Description and Coding Instructions

injured. For the third digit code the most severe injury among those who were injured. If only one person was injured, then the least and most severe codes should be the same. If no one was injured, then use 0 for the least severe injury and for the most severe injury. Injuries include burns, broken limbs, effects of exposure/hypothermia, etc.

No. of People Injured (Column 67)

0 = 0
1 = 1
2 = 2
3 = 3
4 = 4
5 = 5
6 = 6
7 = 7 or more
8 = Unknown
9 = Unknown, but some were injured

Severity (Column 68 - "least" - and 69 - "most")

0 = Minor cuts and bruises, or less, no treatment
1 = Cuts, abrasions, bruises requiring treatment
2 = Injuries resulting in 24 hours or less of incapacitation (missing work, etc.)
3 = Injuries resulting in more than 24 hours incapacitation, and up to one week
4 = Injuries resulting in one week to one month or incapacitation
5 = Injuries resulting in one to six months of incapacitation
6 = More than six months, but not permanent
7 = Permanent disability, but not blindness
8 = Unknown
9 = Permanent disability, blindness or blindness plus

70 — Damage to Other Vessel(s) — Use the code that best describes the damage to the other vessel(s) in this accident. NOTE: If the other vessel(s) in this accident are also in PRAM, then code "90000" in columns 70 through 74. If there is no other vessel(s) in this accident, other than the one being coded, then use "00000" in columns 70 through 74.

As before, the loss of personal property or gear is included as damage. Uncomplicated falls overboard resulting from a collision

Column(s)	Variable Name	Description and Coding Instructions
		may be zero damage. The code "0" should not be used unless the analyst is certain that there were no damages. If no information is given, and the accident was a collision, then the code "7" is assumed. THERE IS NO "UNKNOWN" CODE FOR THIS VARIABLE. Consult with a project leader if you feel that "unknown" is the proper code. 0 = No damage 1 = Slight damage, scratched gelcoat, etc., $200 or less 2 = Moderate damage, little or no structural damage. Perhaps several scratches and a bent prop, some fiberglass work, etc., up to $500 3 = Considerable damage, some structural damage, fiberglass and/or interior work, up to $2000 4 = Severe damage, boat may be a total loss, up to $4000 5 = Severe damage, up to $6000 6 = Severe damage, over $6000 7 = Some damage, but extent unknown Note that a total loss of a johnboat, for example, might be classified as "3", or even "2," if it only cost a few hundred dollars.
71 72 73	Injuries (Other Vessel(s))	Code the injury data for the other vessel(s) in this accident, remembering the guidelines established for the previous coding of injuries. If no one was injured, code "0" in columns 71 through 73. 0 = 0 1 = 1 2 = 2 3 = 3 4 = 4 5 = 5 6 = 6 7 = 7 or more 8 = Unknown 9 = Unknown, but some were injuried Severity (Columns 72 - "least" -, and 73 - "most") 0 = Minor cuts and bruises, or less, no treatment 1 = Cuts, abrasions, bruises requiring treatment 2 = Injuries resulting in 24 hours or less of incapacitation (missing work, etc.)

Column(s)	Variable Name	Description and Coding Instructions
		3 = Injuries resulting in more than 24 hours incapacitation, and up to one week 4 = Injuries resulting in one week to one month of incapacitation 5 = Injuries resulting in one to six months of incapacitation 6 = More than six months, but not permanent 7 = Permanent disability, but not blindness 8 = Unknown 9 = Permanent disability, blindness or blindness plus
74	No. of Fatalities (Other Vessel(s))	Code the total number of fatalities on the other vessel(s) using the codes below: 0 = 0 1 = 1 2 = 2 3 = 3 4 = 4 5 = 5 6 = 6 7 = 7 8 = Unknown 9 = More than 7
75 76 77 78 79 80		Leave these columns blank.

CARD 2

01 02 03	Boat Number	This is the PRAM case Number
04	Johnboat	Code as follows: 0 = Not a johnboat 1 = Is a johnboat 2 = Is a bass boat 3 = Unknown
05 06 07	Boat weight	Code the weight of the boat (only) divided by 10 888 means unknown 999 means greater than 10,000 lbs

END

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