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Bethesda, Maryland 20084

TECHNICAL EVALUATION OF THE RHS 200 FOR HIGH SPEED FERRY APPLICATION

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ADVANCED HYDROFOIL SYSTEMS OFFICE
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A performance and passenger ferry evaluation of a Rodriquez Cantiere Navale RHS 200 surface-piercing hydrofoil ship was conducted for the USCG and the UMTA. Calm and rough water powering characteristics of the 125 ton, 254 passenger, diesel-powered ship were determined. The tests included investigation of ship takeoff power, time, and distance requirements. A wide scope of hullborne and foilborne turning trials were performed. Bollard pull and underway towing capabilities were assessed. Emergency stopping distances were also determined. The bow wake of the ship was measured, interior and

exterior sound levels were recorded, and spectral definition of structural vibrations were obtained. The rough water trials primarily considered the effect of the flap-controlled Seakeeping Augmentation System on ship motions and accelerations in State 3 and State 5 seas. The ferry service evaluation included ship compliance with USCG applicable requirements and operational and arrangement information pertinent to ferry utilization. Independently developed curves of form are included.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

A performance and passenger ferry evaluation of a Rodriquez Cantiere Navale RHS 200 surface-piercing hydrofoil ship was conducted for the USCG and the UMTA. Calm and rough water powering characteristics of the 125 ton, 254 passenger, diesel-powered ship were determined. The tests included investigation of ship takeoff power, time and distance requirements. A wide scope of hullborne and foilborne turning trials were performed. Bollard pull and underway towing capabilities were assessed. Emergency stopping distances were also determined. The bow wake of the ship was measured, interior and exterior sound levels were recorded, and spectural definition of structural vibrations were obtained. The rough water trials primarily considered the effect of the flap-controlled Seakeeping Augmentation System on ship motions and accelerations in State 3 and State 5 seas. The ferry service evaluation included ship compliance with USCG applicable requirements and operational and arrangement information pertinent to ferry utilization.

ADMINISTRATIVE INFORMATION

The RHS 200 hydrofoil evaluation was sponsored by the United States Coast Guard under authorization USCG MIPR Z 70099-1-07080 of 26 August 1981. The work was conducted for the U.S. Coast Guard and the Urban Mass Transportation Administration (UMTA) by the David W. Taylor Naval Ship Research and Development Center's Advanced Hydrofoil Office, Code 1150. (Work Units 1-1155-300, 1-1155-400, and 1-1155-600).

The Rodriquez built RHS 200 surface-piercing hydrofoil, owned by Societa Aliscafi - SNAV S.P.A. of Messina, Italy was chartered under Charter Contract No.

N00033-82-C-30D6 negotiated by the Military Sealift Command. Installation of the equipment began on 5 April 1982. Actual underway trials commenced on 13 April 1982 and the agreement expired on 10 May 1982.

Ms. Patricia Cass of UMTA, Mr. Tom Milton, and Lt. Peter Boyd of the U.S. Coast Guard participated in the trials.

INTRODUCTION

The David Taylor Naval Ship Research and Development Center (DTNSRDC) was requested by the United States Coast Guard (USCG) and the Urban Mass Transportation Administration (UMTA) to evaluate a RHS 200 Hydrofoil Ship in terms of its overall calm and rough water performance and in terms of its suitability as a high speed passenger ferry.

The RHS 200 is a diesel-powered, surface-piercing, hydrofoil ship of 125 tons displacement which is being built by the Rodriquez Cantiere Navale S.P.A., Messina, Sicily. The ship is of interest because of its relatively large size and passenger capacity and the refinements which have been made to improve ride quality in a seaway. The RHS 200 is designed to carry up to 254 passengers over a range of 200 nautical miles at a cruising speed of 36 knots. The RHS 200 is fitted with a Seakeeping Augmentation System (SAS) which uses analog programmed control of hydraulic actuated flaps installed on the foil systems to reduce ship motions in rough water.

UMTA is interested in the RHS 200 because it is examining the use of high speed ferry services for cost-effective improvement of commuter access to inner city areas and for special interest routes. The USCG had identified the RHS 200 hydrofoil as one of several advanced marine vehicles which could be considered as potential replacements for the WPB class patrol craft.

The David Taylor Naval Ship Research and Development Center's Hydrofoil Special Trials Unit Detachment (DTNSRDC-HYSTUDET) developed a trials plan (Ref. 1) which responded to the technical trials needs of both the USCG and UMTA and assembled a data acquisition system to be used during the trials. DTNSRDC, through the auspices of the Military Sealift Command, arranged the lease of the prototype RHS 200, SUBERJUMBO, for the period of the trials. In April 1982, a trials team consisting of DTNSRDC, DTNSRDC-HYSTUDET, USCG, and Contractor personnel were deployed to Messina, Sicily to conduct the trials. The trials were completed via 12 separate daily voyages undertaken within the on-site period of 5 April through 12 May 1982.

This report contains the results of the RHS 200 ferry service evaluation and the related investigations. The content and the format of the report has been selected and arranged to satisfy UMTA performance assessment requirements.

The complete, comprehensive performance evaluation of the RHS 200 has been published as a separate report for the USCG entitled Technical Evaluation of the RHS 200 For High Speed Ferry Application and U.S. Coast Guard Missions (Ref. 2). The reader is referred to this publication for a technical treatment of the evaluation. At the request of UMTA, certain corresponding sections of this report have been deleted from this UMTA version.

UMTA-requested passenger and trials participant questionnaires are summarized in Appendix A.

A complete listing of references is given on page 87.

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UMTA-requested passenger and trials participant questionnaires are summarized in Appendix A.

A complete listing of references is given on page 87.

SHIP CONFIGURATION AND TEST BACKGROUND

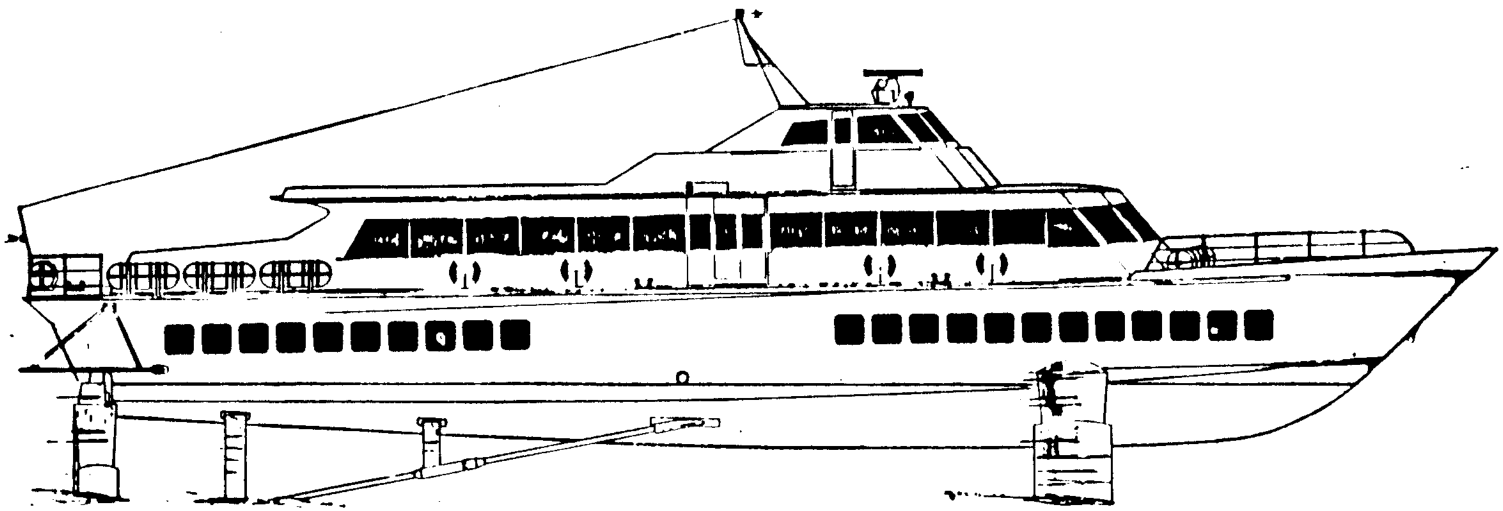
RHS 200 HYDROFOIL SHIP

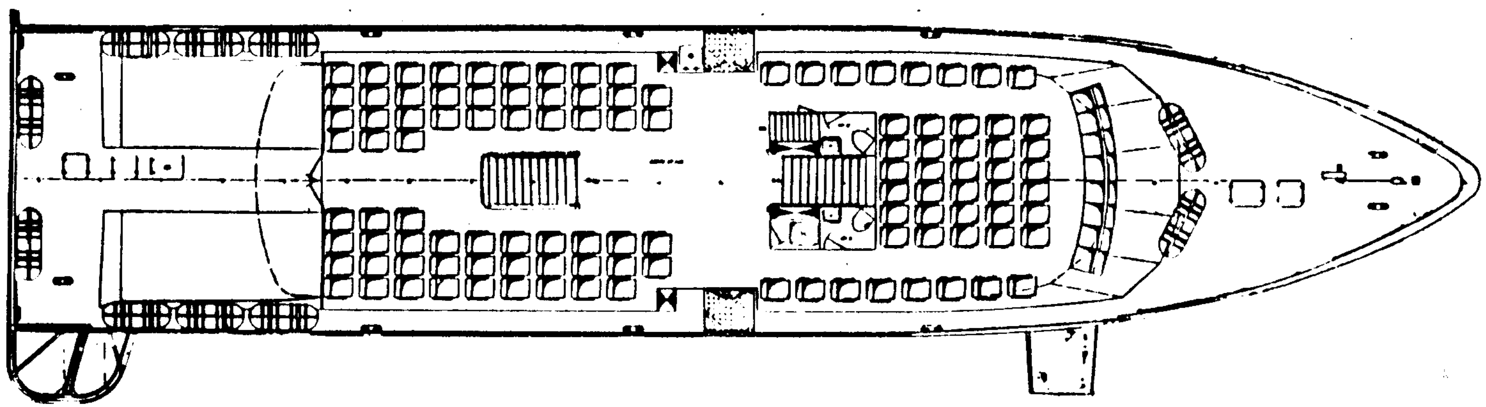
The RHS 200 SUPERJUMBO, shown in Figure 1, is designated Rodriquez hull number 192 and is the prototype of a new series of surface-piercing hydrofoil ships being developed by Rodriquez for use as high speed passenger ferries. Inboard and outboard profiles, deck plans, and other general information descriptive of the RHS 200 type hydrofoils are given in Figures 2 and 3. These figures have been developed from similar information presented in Reference (3). The overall length of the RHS 200 is 117.5 feet, and the beam of the hull is just under 23 feet. Because the surface-piercing foil systems are non-retractable, they are the controlling factors on overall beam and ship draft. Maximum width, or span, across the foils is 47.2 feet. Maximum draft is approximately 15 feet when the ship is pierside or is operating in the hullborne mode. In the foilborne mode, the ship operates with a draft of 6.8 feet. The ship was designed to a displacement of 125 tons. The displacement is 133.8 tons at the overload condition with full passenger, baggage, fuel and liquids, and crew load. A full load displacement of 123 tons is targeted for follow-on ships. The normal fuel capacity is 5.9 tons.

The hull of the RHS 200 is constructed of magnesium alloy aluminum. The framing, longitudinal, and other main hull structural components are weldments. Hull and deck platings and the interior and exterior cabin bulkheads have been assembled using aircraft style, riveted, manufacturing procedures. The ship is arranged to contain two passenger decks, a lower level machinery space, and a pilot house. The lower deck is divided into forward and after passenger salons by the amidships machinery space. The main deck, or belvedere, passenger cabin is effectively divided in forward and after sections by access arrangements. Each of the four passenger areas provides seating for approximately 60 individuals. Two restrooms are included on each deck. The RHS 200 used in the trials included a bar installed on the aft, starboard side of the forward salon. The after end of the belvedere cabin was extended to include a baggage storage area. All of the passenger areas are well appointed, carpeted, air-conditioned, and

Figure 1. RHS 200 Hydrofoil (SUPERJUMBO)

RHS 200 PERFORMANCE EVALUATION - APRIL 1982





Length overall	35.80m	Displacement	120 tonn
Molded breadth	7.00m	Power plant	2x2600 HPM
Width across foils	14.40m	Cruising speed	36 knots
Draught, waterborne	4.55m	Cruising range	200nm
Draught, foilborne	2.05m	Passengers	254

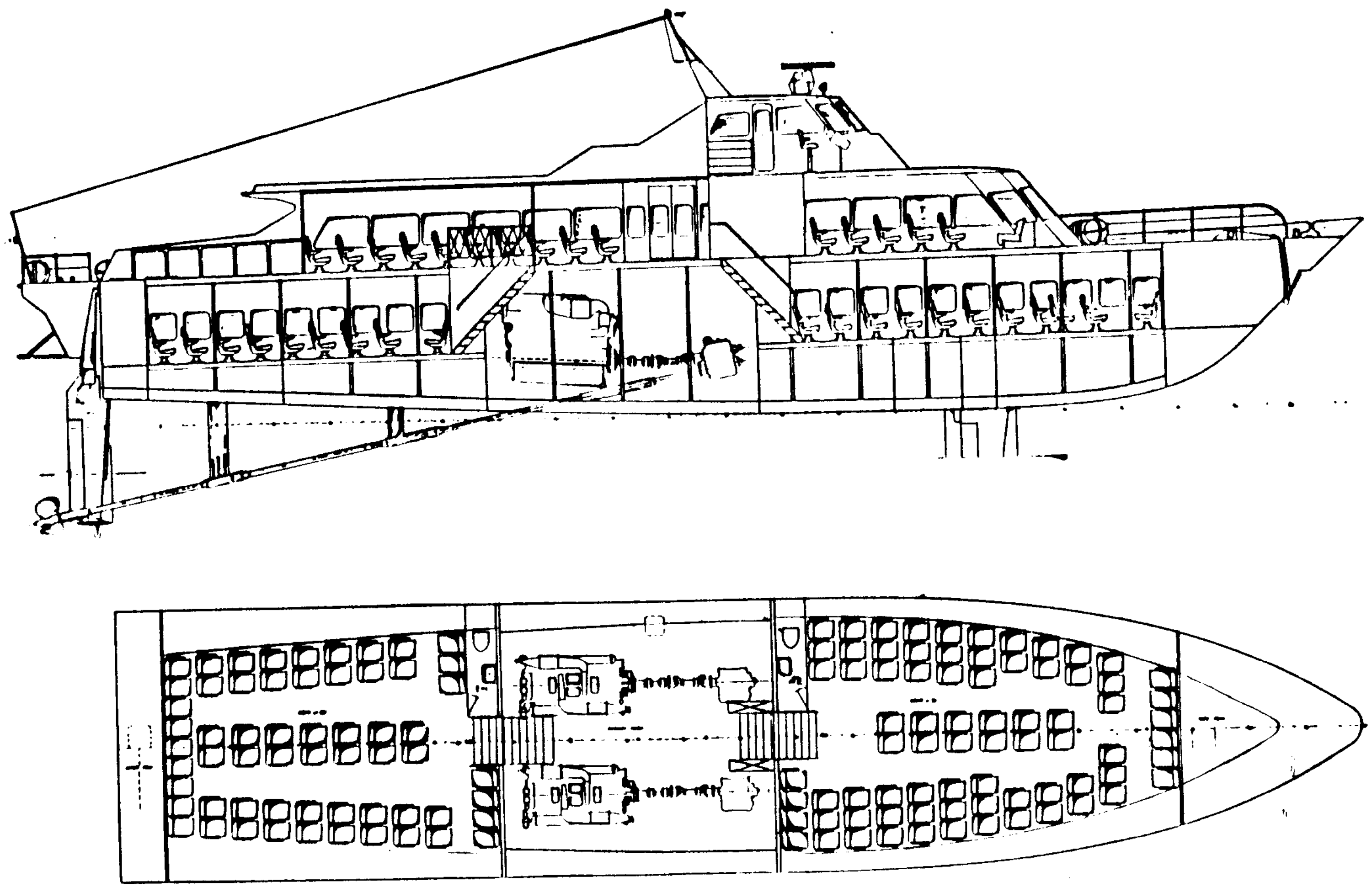


Figure 3 - RHS 200 Inboard Profile and Lower Deck Plan

they provide good exterior viewing. Aircraft style, non-reclining, seating is used throughout. Closed-circuit television and audio entertainment systems are also installed.

Weather deck areas are normally not for passenger use and are limited to fore and quarter decks and narrow weather passages down each side of the belvedere cabin. The foredeck is used for anchor equipment and as a ship mooring station. The quarter deck is also a ship handling station and is used for crew and passenger boarding when the ship is tied-up, stern-to, in Mediterranean style mooring. In the rapid turnaround, ferry service environment, passenger boarding can be through amidship accesses on either side of the belvedere cabin. In these instances the ship is brought alongside, pierside ramps are extended, and boarding commences.

During operation, all ship control is exercised from the pilothouse. The bridge console is arranged for three manned stations.* The Captain occupies the center position and has direct control of the helm and the SAS Control and Status Panel. The principal features of the SAS control panel are listed in Table 1. This information effectively highlights the extent to which the operator can exercise control of the SAS. The navigational radar is installed on the left-hand side of the bridge console. This station is manned by a crew member who operates the radar when required. The RHS 200 is equipped for open ocean navigation and communication. Loran C equipment is also installed.

The engineer's station, situated on the right side of the bridge console, is the third manned station included within the pilothouse. The engine room is designed as an unmanned space. Therefore, all propulsion and auxiliary system control, indication, and alarm functions are incorporated into the engineering section of the bridge console. Principal features of this installation are summarized in Table 2. The station includes panel assemblies which were made by the manufacturers of different systems used on the ship and by Rodriquez; therefore, there is some duplication of installed indicator and alarm functions. The duplications have been omitted from Table 2.

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*Refer to photographs at the end of the Ferry Evaluation Section on pages 45 through 78.

TABLE 1 - SAS CONTROL PANEL CONTROL AND DISPLAY CAPABILITY

- SAS Mode Selection: Self Test, Manual, Takeoff, Automatic
- Analog Display of Ship Pitch and Roll Angles - 2 Gages
- Analog Display of Flap Positions - 4 Gages
- Potentiometer Control of Pitch, Roll and Heave Trim
- Potentiometer Control of Pitch, Roll and Heave Channel Gains
- Selective Self Test of Pitch, Roll and Heave Channels
- Engage, Disengage, Forward Rudder Control
- Gyroscope Power and Status Indication
- Self-Test Voltage Readout
- System Power and Status Indication

The main equipment installed in the machinery space include the propulsion diesels, reduction gearboxes, diesel generator units, and a power distribution switchboard. Load capability of the generators is reviewed under the hotel loads discussion of the Ferry Service Evaluation Section. A single generator is used for normal operating loads. A second unit is brought on-line when the air-conditioning load is applied. The power distribution panel is located in the pilothouse for navigation light circuits. Fire-fighting equipment consists of fixed CO_2 self-contained automatic systems for power plant and fuel tank spaces, and portable extinguishers for cabins and holds.

RHS 200 propulsion is supplied by two MTU 16V652-TB81 diesel engines which are rated at 2600 horsepower each. The engines drive forward through reversing reduction gearboxes which provide 1:1.718 reduction between the engine and the propeller shafts. Maximum engine output speed is 1460 RPM which results in a maximum propeller shaft speed of 850 RPM. Angled shafts are used to connect the gearboxes with the propellers which are close-mounted immediately aft of the rear foil. Distance pieces, instrumented to measure propeller shaft torque, thrust, and RPM, were installed in both propeller shafts at the output side of the reduction gearboxes.

TABLE 2 - ENGINEER'S CONTROL STATION: PRINCIPAL CONTROL, ALARM, AND INDICATOR FEATURES

- Combined Ahead, Astern Propeller Pitch and Engine Throttle Control
- MTU Engine Cylinder Temperature Alarm and Selectable Digital Indication
- MTU Engine Status Alarm and Selectable Digital Indication for:

Charging Air Pressure	Sea Water Pressure
Starting Air Pressure	Cooling Water Temperature
Cooling Water Pressure	Piston Cooling Oil Pressure
Engine Oil Pressure	Engine Oil Pressure
Gear Oil Temperature	Gear Oil Pressure At Filter
Gear Control Oil Pressure	

- MTU Analog Indicators for:

Fuel Rack Position	Engine Percent Load
Engine Speed	Propeller Shaft Speed

- Engine Start, Stop and Emergency Stop Control
- Propulsion System Alarm and Indication for:

Clutch Position Ahead	Engine Speed Sensor Failure
Clutch Position Astern	Shaft Speed Sensor Failure
Disengaged Clutch	Fuel Oil Pressure Low
Overspeed	Starting Repetition

- Analog Display of Reduction Gear Temperatures
- Propeller Pitch Control and Status Including:

Analog Pitch Display	Fine Pitch Adjustment
Load Control On/Off	Constant RPM On/Off
Back Up Control On/Off	Normal/Takeoff Selection
Ahead Control	Astern Control

- Fire Alarm System Status and Control Panel
- Electrical Distribution System Control and Status Panel
- Cabin Environmental System Control Panel

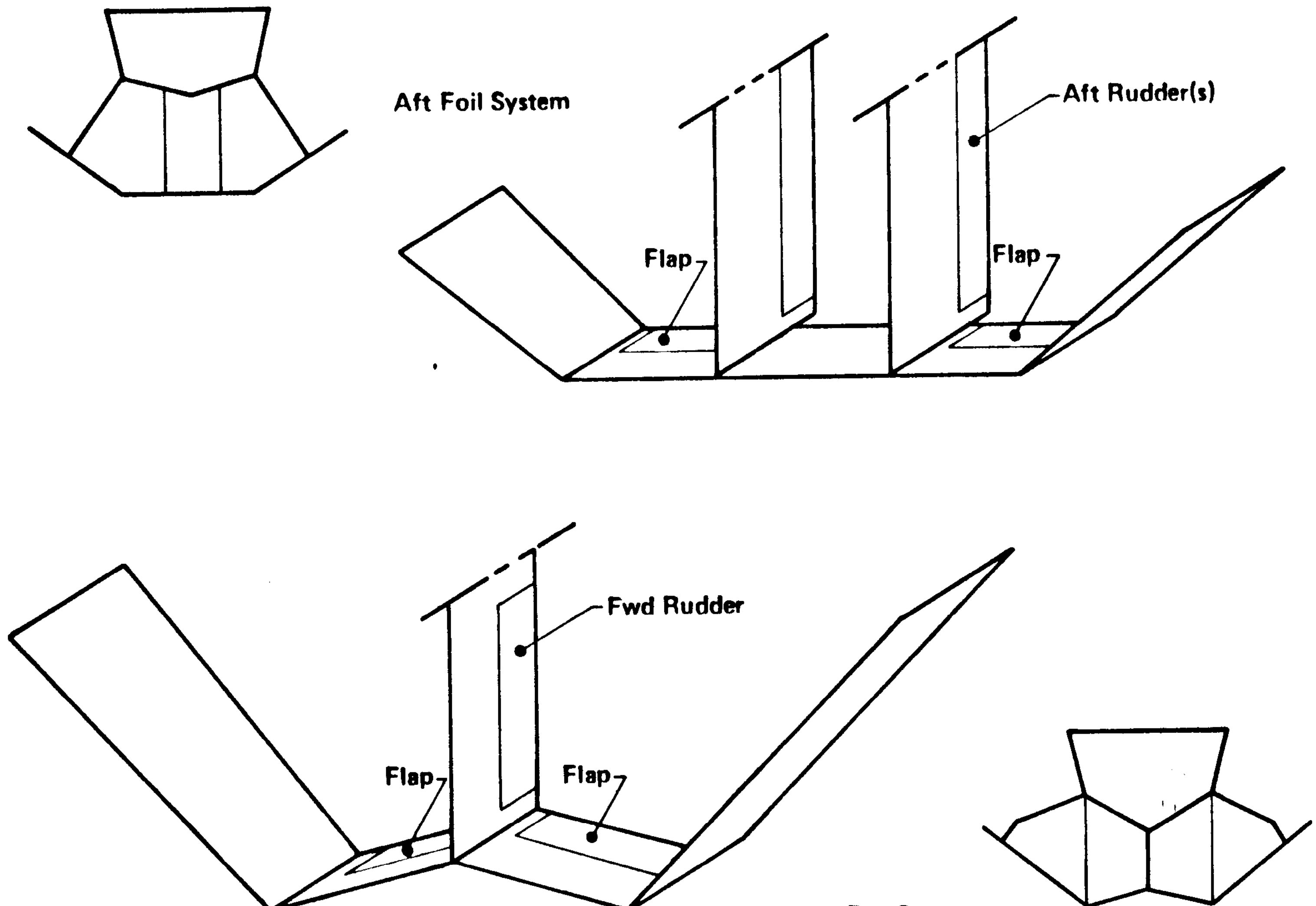
At the time of trials, three-bladed, supercavitating, controllable-pitch (CP) propellers were installed on the ship. They were manufactured by Karlstad Mechanical Werkstadt (KaMeWa) of Karlstad, Sweden. The CP installation also included load control units which provided programmed interfacing of propeller pitch control to the load characteristics of the engines.

Except for the selection of the MTU 16V652-TB81 engines and the use of CP propellers, this propulsion arrangement is typical of that used on all Rodriquez hydrofoil ships. At the time of the trials, Rodriquez representatives expressed concern with the power available from the MTU engines and the relatively high; 670°C, exhaust stack temperatures at which they operated. However, these problems have been corrected. The engines for the next RHS 200, the YBN 209, have undergone successful acceptance tests. The exhaust gas temperature was decreased from 670°C to an average of 550°C.

The foil system schematic included in Figure 4 has been adapted from Reference (1) for discussion purposes. Forward and aft foil systems shown in the central portion of the figure only include those system components which either generate lift or are used for directional control. Supplementary sketches in the figure, which include outlines of hull cross sections, are intended to provide typical definition of the entire foil systems, including those elements whose main function is structural support. Components of the foil system are largely hollow weldments which have been manufactured out of nickel-copper alloy steel. The welded assemblies are fixed to structural hard points at the hull using bolt-up attachments.

The trailing edge flaps shown in Figure 4, which are installed on the RHS 200 foil systems, are not required for normal operation of the ship. Basically, the lift forces developed by a conventional surface-piercing hydrofoil system are functions of the submerged area of the foils and the square of ship speed. As ship speed is increased in the hullborne mode, increasing values of lift are generated by the essentially fully submerged foil system. Takeoff occurs at a speed where the lift forces are sufficient to support the weight of the ship. As the hull clears the water surface, lift-producing elements of the foil system are also exposed and an inherent trade-off between ship speed and remaining submerged foil area is initiated. Flying height is maintained without the use of height

RHS 200 PERFORMANCE EVALUATION - APRIL 82



Foil System Schematic

sensors, automatic control systems, or similar equipment. A surface-piercing foil system is inherently stable in all modes of foilborne operation, including calm and rough water conditions and turning maneuvers.

Any hydrofoil system will react to surface disturbances of the sea. The reaction is typically more pronounced in the case of a surface-piercing system because of the interfacing of lifting surfaces with the surface of the sea. Rodriquez engineers, in conjunction with the Hamilton Standard Division of United Aircraft, have developed the SAS as a means for improving the rough water ride qualities of their larger series ships. The SAS uses a gyroscope and accelerometer sensor package, mounted in the machinery space near the center of gravity of the ship, to sense ship motions. The motion signals are input to an analog computer which is integral with the SAS control panel installed on the bridge. The computer uses this, and flap position feedback information, to exercise the electro-hydraulic flap control required to minimize ship motions in a seaway. Each flap is driven by a separate hydraulic actuator. Position transducers, mounted on the actuators are used to sense flap position. Hydraulic power is supplied by electrically driven pumps installed in the machinery space. The W-shaped transverse section of the forward foil system, shown in Figure 4, has been adopted to allow the forward flaps to exercise increased roll control authority.

As outlined in Table 1, several modes of SAS operation are available. In the Self Test mode, the analog computer executes a diagnostic evaluation that is intended to confirm full operational status of the system. In the Manual mode, the operator can use the flaps to trim the ship in roll, pitch, or heave. In the Takeoff mode, the forward flaps are deflected down to a position of approximately 12 degrees. This increase in forward foil lift causes the ship to increase trim, which results in increased lift from the working elements of both foil systems. The Takeoff mode is manually disengaged when the takeoff is completed. The SAS Automatic mode provides full computer-controlled dynamic positioning of the flaps in response to rough water ship motions. The operator can still exercise roll, pitch, and heave trim control with the SAS in the Automatic mode. The operator can also exercise limited control of the rate of response of the SAS system by the selection of low, medium, or high gain settings in the roll, pitch, and heave channels.

Directional control of the RHS 200 is provided by the dual aft and single forward trailing edge rudders shown in Figure 4. The aft rudders are controlled by a common actuator which is directly driven from the helm. These rudders can be deflected nominally 30 degrees in either direction. An aft rudder position signal is taken from a transducer installed on the actuator and is input to the SAS analog computer for control of the forward rudder. The forward rudder is not deflected until the aft rudders are deflected 10 degrees, and its deflection rate per unit of helm position is programmed to be one-half that of the aft rudders. These procedures have been adopted to provide a more physically comfortable turn during foilborne operation. The SAS control panel includes a switch which allows the operator to disengage the forward rudder if desired. There is no other SAS input or control of ship turning. Flap-induced rolling of the ship into a turn cannot be used to improve the turning characteristics of a surfacing-piercing foil system.

TEST DEVELOPMENT AND SCOPE

The evaluation of the RHS 200 was performed under the joint sponsorship of the USCG and UMTA. USCG interest in the RHS 200 was based on the ship's potential as a replacement for the WPB class patrol boat, while the UMTA interest rested in the design role of the ship as a high speed passenger ferry. Test requirements, which differed substantially in many areas but were largely common in the area of ship performance evaluation, were developed by each agency. Full definition of USCG test needs are defined in Reference 4 while UMTA data requirements are given in Reference 5. DTNSRDC-HYSTUDET was assigned responsibility for the design, conduct, and documentation of a test series which would explore the ship performance test requirements which were common to both sponsors. The resulting trials agenda, Reference 1, was prepared and used for the conduct of the tests. A summary of the test activities included in the trials agenda is given in Table 3. The open and closed symbols in the table provide broad indication of test completion.

TABLE 3 - RHS 200 PERFORMANCE EVALUATION TRIALS SCOPE

CALM WATER SPEED-POWER	
Speed Log Calibration	●
Hullborne Speed-Power	●
Calm Water Takeoff Trials	●
Foilborne Speed-Power & Trim	●
CALM WATER TURNING	
Spiral Turning	●
Debris Avoidance Maneuvers	●
Low Speed Maneuverability	●
Tactical Diameters	●
RESPONSE CHARACTERISTICS	
Stopping Characteristics	●
Tactical Response Time	●
Wake Evaluation	●
TOWING CHARACTERISTICS	
Bollard Pull Tests	●
Towing Capability	●
RHS 200 Characteristics Under Tow	●
ROUGH WATER TRIALS	
Hullborne Matrix Trials	●
R/W Takeoffs and Landings	●
Foilborne Matrix Trials	●
R/W Spiral Turning	o
R/W Debris Avoidance	o
Slamming	o
Seakindliness	o
Anchoring	o
PHOTOGRAPHIC COVERAGE	
ACOUSTIC & VIBRATION SURVEYS	

Legend: o not completed ● completed

FERRY SERVICE EVALUATION

PASSENGER AND BAGGAGE CAPACITY

Passengers are supplied with individual row seats similar to those found on commercial passenger aircraft. No differentiation in seating class is made. All seats are arranged with a 33.5 inch pitch. Seats are 27.6 inches long.

The number of seats between aisles varies significantly. Some seats are individual. Most seats are arranged so that the passenger is in a seat which is no further than three seats from the aisle (counting his seat). A set of seats in the aft, lower salon, are arranged so that passengers are four seats from the aisle. Some seats in each lower salon are arranged facing aft.

The seats tested on the SUPERJUMBO were special seats used for promotional purposes and long voyages. They were similar to those on aircraft with folding tables, reclining capability, and deluxe seat covers. Seats for production boats on short routes would be significantly simpler for a weight savings of 11.25 pounds per seat or 2610 pounds for the ship. These would not have the folding table. Their reclining capability would be restricted and their seat covers would be simpler.

The RHS 200 SUPERJUMBO capacity is as follows:

Passengers	
Upper Salon	108
Lower Forward Salon	66
Lower Aft Salon	58
	232
Baggage	803 $ft.^3$

Baggage is stowed in two areas aft in the upper salon. These areas are for the baggage of all passengers and are on either side of the after entryway.

Four heads are provided. Two are in the upper salon, port and starboard sides, and one is located in each of the lower salons.

A bar is located in the lower forward salon. It has a sink, refrigerator, storage, and hotplate. Together with its access, it occupies a space of 476.4 $ft.^3$ with a deck area of 65.6 $ft.^2$.

PASSENGER ACCESSIBILITY

The RHS 200 SUPERJUMBO has been reviewed with respect to ANSI A117.1-1980 "Specifications for Making Buildings and Facilities Accessible To and Usable by Physically Handicapped People" (Reference 6). The vessel is clearly not designed for people in wheelchairs. No particular uncorrectable difficulties for visually handicapped or hearing impaired people are apparent. Specific problem areas are described below. Section numbers refer to sections in the reference standard.

Wheelchairs

Entry. The aft and side entry doors provide about 47 inches clear opening. This is sufficient for entry by a wheelchair (S4.2.1). However, each door is fitted with a 6 1/4 inch high coaming. Several people would be required to lift the wheels over the coaming. Special ramps could be provided but these would be greater than 5 feet long (ANSI section 4.8). In the case of the side doors, each ramp would extend nearly to the ship center line. Portable coamings would probably not receive the approval of the regulatory bodies and would, in any event, result in increased loading and unloading times. The coamings must be included due to the potential for shipping water into the cabin and down to the lower salons.

Interior Movement. The movement of people in wheelchairs within the RHS 200 is severely restricted. The lower salons are essentially not accessible because of the stairways to those areas.

Any wheelchair user entering through the aft door can only pass to the railing aft of the aft stairway. The passage beyond this is only one-half as wide as necessary.

Passengers entering through the side entries are restricted to the area between the stairs to the lower salons. Stanchions are located approximately 1.8 feet off the centerline at frame 49. However, sufficient clearance is available to permit movement of wheelchairs around these obstacles. Access in this central location is from side to side.

The positioning of wheelchairs in these areas is severely restricted. Wheelchairs in these locations could restrict the movement of passengers through the ship, particularly in an emergency situation.

Location of one row of wheelchairs in the aisle associated with the aft entry would be in a space only 51 inches wide. 64 inches is required for comfortable flow, 60 inches for restricted flow, and 48 inches is the minimum allowable (see section A4.2 of the ANSI standard). In addition, access to rows on the side would be blocked. This makes this area unacceptable for wheelchairs, given emergency use of this exit.

Using similar criteria for acceptable passage, an estimated five (5) wheel chairs could be located in the central area of the upper salon. This is the maximum number of spaces which could be safely devoted to wheelchairs (ignoring the coaming difficulty mentioned above). Use of entry ramps mentioned above, if permanently installed, would eliminate two of these spaces. Additional wheelchair locations could be provided by removing other seats.

Securing of Wheelchairs. At present, no provision is made for securing wheelchairs and their passengers. Securing wheelchair passengers is absolutely necessary because of the motions exhibited by this vessel in normal and emergency operations. The securing devices used for this purpose could be adapted from similar devices used on subway rail cars.

Use of Heads. Heads in the lower salons are not accessible because of the reasons described above. The single head located in the upper salon is not accessible (Section 4.22.1 of ANSI standard). Its door is only 18 1/8 inches wide. The space is only 47 inches by 29 3/4 inches large (see Section 4.22.3 of ANSI standard). The toilet and lavatory do not meet the standards of Sections 4.16 and 4.19 of the ANSI standard. The ANSI standard cannot be met given the existing arrangement of the ship.

Other Considerations

This ship is adaptable to other requirements of the ANSI standard. Handrails and other obstacles are of the correct size, height, and distance from the bulkhead (Sections 4.4, 4.5, 4.9.4 of ANSI standard).

The requirements for stair tread width (ANSI Section 4.9.2) are not met because these are only 8.5 inches wide. This could be accepted either through a restriction, waiver, or modification.

Adaptations would be required to comply with the alarm, tactile warning, and signals requirement of ANSI standard Sections 4.28, 4.29, and 4.30, respectively.

PASSENGER COMPARTMENT MOTION

The pitch and roll motions and the vertical, lateral, and surge accelerations of the RHS 200 were measured at various locations throughout the ship during rough water trials conducted in State 3 and State 5 seas. It was found that the foil systems, even with the SAS disengaged, were very effective in limiting the motions of the ship while either hullborne or foilborne in a seaway. The accelerations which occurred were considered to be more severe than the motions. Although it was possible to move about the ship even in the heavier sea condition, it would be suggested that passengers remain seated during operations in State 4 seas or higher. Seat restraints were not installed nor were they required in any of the seas experienced during the trials. Roll and pitch motions were reduced with the SAS active. The SAS did not have appreciable effect on the measured accelerations.

CRAFT AVAILABILITY

The RHS 200 was operated underway on 12 separate voyages during the trials period. Although this figure is small in relation to the high number of voyages to be expected in a ferry service application, the important feature in the trials operation is that the tests were never postponed or delayed because of any equipment failure or maintenance activity. All normal maintenance needs were accomplished during warm-up periods or upon completion of a day's trials. Two of the noted voyages were made over a single weekend for the purposes of rough water trials. The first day's effort was mounted without any advance warning within a 2-hour period. The ship had been in stand-down status with the engines secured the previous day. The information which Rodriquez has provided regarding the use of the RHS 200 during the June through September 1982 operating period, presented in the subsequent section on Operations and Maintenance, cites a schedule achievement of 94.4 percent. It is noted that this high level of availability was established over an open-ocean, Naples to Palermo, transit which required over 12 hours for round trip completion. The experience of the DTNSRDC trials team was in agreement with the Rodriquez information; from reliability and maintenance points-of-view, RHS 200 availability must be assigned a very high value.

RELIABILITY AND MAINTAINABILITY

Reliability

As tested, the RHS 200 exhibited extremely high reliability. Not one corrective maintenance action was required during the trials period. The reliability of these hydrofoils is achieved by careful attention to design and selection of components and conduct of planned maintenance. The observation of a corrective action on a failure that had occurred before the trials period, the ease of trials equipment installation, and the conduct of planned maintenance indicate that this boat is easy to maintain.

Observed Operational Reliability, Maintainability and Availability

As indicated above, the operational availability of the RHS 200 was 100% during the trials period. Operational and maintenance cost data are presented in Table 4, as supplied by Rodriquez, for typical passenger operation. In addition, Rodriquez has provided operational critiques from several companies employing Rodriquez hydrofoils in passenger service, Table 5. All of the reports indicate successful operations with Rodriquez hydrofoils.

ACCEPTABILITY UNDER USCG REQUIREMENTS

The acceptability of a vessel under United States laws is determined by the United States Coast Guard (USCG). If an owner wishes to register a vessel in the United States, he must apply to the USCG, who will make a determination of suitability and the necessary modifications.

TABLE 4. OPERATING AND MAINTENANCE COST ESTIMATE

FUEL USE	795 kg/hr @ cruise speed of 35 knots OR 299 gal/hr @ cruise speed of 35 knots 67 gal/hr @ cruise speed of 10 knots Useable fuel in tonnes - 5.16 (approx. $1.00/gal)	
OIL USE	5 kg/hr	(Approx. $1.00/qt)
MAINTENANCE	$75-$125 per Hour of Operation (low estimate)	
CREW COST	Subject to great variations from area to area Italian crew requirements and cost	
	1 Master	$ 30K/year
	1 Chief Engineer	30K/year
	1 Engineer	25K/year
	3 Deck Hands	20K/year each
	1 Deck Boy	15K/year
	3 Attendants	15K/year each
		$205K/year

The following discussion can only be taken as an indication of the likelihood of approval and of those things which must be modified to receive approval. It is not an actual determination; that only being possible, on a case basis, by the USCG.

The rules applied to shipping are found in Title 46 of the U.S. Code of Federal Regulations (CFR) (Reference 7). The examination of this case will be in reference to the CFR. One of two subchapters is applicable to this vessel: either Subchapter H, Passenger Vessels, or Subchapter T, Small Passenger Vessels.

TABLE 5. HIGHLIGHTS OF PASSENGER SERVICE RELIABILITY MAINTAINABILITY AND AVAILABILITY PER RESPONDING COMPANY

1. Red Funnel Group; Southampton, England
   - RHS 70 Hydrofoil
   - 1,290,262 passengers since 1974
   - 51,617 trips totaling 557,500 miles
   - 1,026 trips list in six years. Two-thirds due to heavy weather, one-third due to mechanical difficulties.
2. Condar, Ltd; Guernsey, England
   - PT 50, RHS 140, RHS 160 Hydrofoil
   - 142,000 miles in 1979
   - 18 days lost to weather (2.2%); 2 days lost to mechanical failures (.24%)
3. A/S Dampskebsselskabetresund; Scandinavia
   - 5 Rodriquez Hydrofoils
   - 700,000 passengers per year
   - 10,000 trips per year
   - 97-98% technical regularity; 99% weather regularity
   - 8000-9000 hours between major overhaul on engines
4. Hong Kong Macao Hydrofoil Company; Hong Kong
   - RHS 140 Hydrofoils
   - 17,000,000 passengers in 16.5 years of operation
   - 18,940 trips and 719,720 miles
   - 97-98% operational reliability
5. Han Ryeo Development Co., Ltd; Seoul, South Korea
   - Rodriquez Hydrofoils
   - 9 years of service
   - 1,000,000 passengers and 70,999 miles
   - 13% downtime due to weather or breakdowns
6. Urban Transit Authority; New South Wales, Australia
   - 5 Rodriquez Hydrofoils
   - 18,900,000 passengers in 15 years of service
   - 15,600 round trips
   - 2% breakdown

Those vessels with less than 100 gross tons are considered "small". In order to determine which rule applies, the gross tonnage (a measure of the enclosed volume) must be found.

The estimate of tonnage is based upon the following assumptions:

1. The entire upper salon would be exempted as a sheltered space for protection of passengers on short voyages 46 CFR 69.03-63(a) .
2. The entire wheelhouse would be exempted 46 CFR 69.03-63(i) .
3. Neither the forepeak nor afterpeak could be adapted for the carriage of ballast because they are used for other purposes.
4. Neither doublebottom is counted.

The estimated tonnage of the vessel is 149.0 gross tons. This would require that the ship be registered as a Passenger Vessel under Subchapter H. Furthermore, 46 CFR 175.05-1(b) states that any vessel under 100 gross tons carrying more than 150 passengers shall comply with certain requirements of Subchapters F, H, J, and P as determined by the Officer in Charge, Marine Inspection. For these reasons, the ship will be considered under Subchapter H.

The following paragraphs are an estimate of the likelihood of the vessel satisfying the requirements and in some cases the steps which might be taken to meet them. Paragraph numbers refer to the corresponding paragraph in the Code of Federal Regulations, Subchapter H.

This evaluation assumes that the RHS 200 will only be used for domestic voyages in open waters; this includes the ocean as well as rivers, lakes, bays, and sounds.

General Provisions (CFR 70)

This section describes general provisions and definitions and applies because the RHS 200 carries more than 150 passengers. These provisions shall all be assumed to be met except for:

70.20 - General Marine Engineering Requirements which refers to Subchapter F.

70.25 - General Electrical Engineering Requirements which refers to Subchapter J.

which will be discussed later.

Inspection and Certification (CFR 71)

This section describes the activites to be performed during design, construction, and operation. They are not relevent to this study.

Construction and Arrangement (CFR 72)

Hull Structure (72.01). The SUPERJUMBO RHS 200 was built to the requirements of the Registro Italiano Navale (RINA). The RINA requirements cover the areas of concern to the U.S. Coast Guard and those of the American Bureau of Shipping, (ABS). Most likely, the ship could be built to ABS standards, thus satisfying the structural standards requirements of 46 CFR.

The watertight subdivision requirements can be met. The above paragraph on watertight integrity describes the inspection of watertight bulkheads. Although no testing could be performed during the trials period, the standard could certainly be achieved.

General Fire Protection (72.03). General fire protection is discussed under part 72.05, "Structural Fire Protection."

Fire Control Bulkheads and Decks (72.05-10). The code requires that the hull, structural bulkheads, decks, and deckhouses be constructed of steel or other equivalent metal. This ship is constructed of aluminum alloy. Aluminum does not have fire protection qualities equivalent to steel: That is, the insulating material necessary to ensure that protection has not been provided. Therefore, the aluminum cannot be considered to be equivalent to steel.

The code also requires that vessels be subdivided into main vertical zones not exceeding 131 feet in length. This ship, only 117 feet long, is not subdivided into vertical zones.

The hull, bulkheads, and decks are not constructed in such a manner that would appear to permit them to meet any of the standard fire tests (A or B). The code had established requirements for fire resistance based upon the type of spaces separated by the bulkhead.

Ceilings, Linings, Trim, Etc. (72.05-15). The plastic materials used for interior finishings, the carpet materials, and the passenger seat materials have been approved by Italian agencies. Some were approved by RINA, and others were approved by the Italian aviation agency. However, the nature of the testing required by those agencies is not known. As a minimum, these materials would require testing under U.S. regulations and would most likely require substitution of approved materials.

Stairways, Ladders and Elevators (72.05-20). Stairways are required to be constructed of steel. Those of the RHS 200 are not. The stairs to the lower salons of the RHS 200 have the following parameters:

Angle-	47° aft and 45° forward
Depth-	10 inches
Width-	46.25 inches
Height-	7.5 inches

All of these meet the requirements of the Code except those for the stairway angle, which must be limited to 40°. Handrails are approximately the correct height, but are constructed of aluminum. The stairways between passenger areas are not enclosed; therefore, they are not protected from fire. The location of these main stairways adjacent to the main machinery present a fire safety hazard which is also of serious concern.

Doors, Other Than Watertight (72.05-25). Some modification to the doors will be required. Most particularly, wire-inserted glass, a minimum of 1/4-inch thick, must be used for doors opening onto safety areas from accommodation areas.

Windows and Airports (72.05-30). Wire-inserted glass is required for windows on lifeboat embarkation areas.

Insulation, Other Than Fire Protection (72.05-40). USCG-approved materials must be used.

Paint (72.05-45). This requirement is probably satisfied and certainly can be complied with.

Ventilation (72.05-50). Because there is no fire subdivision, most of these requirements are not applicable. The duct to the main machinery space which passes through the passenger space will require an automatic fire damper.

Means of Escape (72.10). Escape from the lower salons is inadequate for the following reasons. The main stairways from the lower salons exit into another accommodation area, not to the weather. Ready and direct access to lifeboat embarkation areas is required. Two independent means of escape are required. The RHS 200 has vertical escape ladders with deck hatches and escape windows as secondary means of escape. Subpart 72.10-15 specifically prohibits use of vertical ladders as a secondary means of escape. Where it is demonstrated that a stairway is impractical, a vertical ladder may be used. No use of escape windows is considered. The means of escape, especially from the lower salon, must definitely be upgraded.

Ventilation (72.15). These requirements are satisfied.

Accommodations for Officers and Crew (72.20). This requirement is adequately satisfied because the ship is not intended for overnight voyages.

Passenger Accommodation (72.25). Separate male and female toilet facilities are required but are not provided.

Rails and Guards (72.40). This requirement is satisfied.

Watertight Subdivision (CFR 73)

The design of watertight subdivision is dependent on several particulars of the ship's design and operation that are yet to be determined. The judgments regarding this ship are only indications of its expected performance. As a ship design is developed, the calculations to verify adequate subdivision will be performed.

The calculations supplied by Rodriquez were not in a format compatible with the requirements of the code. To the extent that was cost-effective, these calculations were checked and compared with the code. All indications are that the RHS 200, as tested, may not satisfy the one compartment flooding criterion established under CFR 73.

Margin Line (73.05-6). The requirements for shear are defined in Section 73-05.6. This ship has a discontinuous bulkhead deck as described below. The margin line was assumed to be 3 inches below the bulkhead deck for each compartment.

Rules for Subdivision (73.15). This vessel is required to comply with Subpart 73.15 because it is under 150 gross tons and is intended for ocean or coastwise service, not for international voyages. One compartment subdivision is required.

The RHS 200 is unusual because the bulkhead deck is discontinuous. The main deck is the bulkhead deck for the engine room while the second deck serves that purpose for the remainder of the ship. The code makes no provision for vessels of this type construction at this size. However, Subpart 73.10-25, for vessels over 150 gross tons, does make such provision. For the purpose of this study, it will be assumed that the provisions of Support 73.10-25 do apply. This assumption requires confirmation by the Coast Guard.

To satisfy the requirement for the stepped bulkhead deck, two criteria must be met. First, the sides of the vessel must extend to the deck corresponding to the upper margin line throughout the vessel's length, and all openings below this deck throughout the vessel's length must meet the requirements for side openings below the margin line. Second, the two compartments adjacent to the "step" in the bulkhead deck must be within the permissible length corresponding to their own margin lines, and their combined length must not exceed twice the permissible length based on the lower margin line.

The vessel sides do extend to the upper bulkhead deck throughout the ship's length. The requirements for openings are addressed in subpart 73.40.

A check on floodable length was made for compartment IIC, from frames 58 to 70 and compartment III, the engine room compartment. This was done with a conservative permeability of 0.95. The estimates of floodable length over these combined compartments is 17.3 feet. The combined length of the compartments is 35.4 feet which is 0.79 feet greater than twice the floodable length. This calculation is somewhat imprecise so further detailed calculation would be required. Some adjustment of bulkhead location could be made to correct a small deficiency, if present.

Collision Bulkhead (73.20-1). This requirement for both provision and location is satisfied.

Machinery Space Bulkheads (73.20-5). This requirement is met.

After Peak Bulkheads (73.20-10). This requirement for vessels over 150 gross tons is met.

Shaft Tunnels (73.20-15). This requirement does not apply.

Double Bottoms (73.25). No doublebottom is required on this vessel.

Penetrations and Openings in Watertight Bulkheads (73.30). To the extent that is possible to check, this requirement is met.

Watertight Bulkhead Doors (73.35). This requirement does not apply. There are no such doors.

Openings in Vessel's Sides Below Bulkhead Decks (73.40). This subpart does not permit openings in the side on vessels below 150 gross tons. This would eliminate the windows in the lower salons of this ship. If the vessel was over 150 gross tons, non-opening port lights could be installed. These would require dead covers. The escape windows would certainly not be permitted. The windows are required to be of a substantial type approved by the Commandant. The windows used on the RHS 200 are unlikely to receive such approval; standard round windows would be required.

Watertight Integrity Above the Margin Line (73.45). No provision is made to limit the spread the water above the bulkhead deck. Although it would interfere with arrangement of the lower salons, coamings around the manholes to the spaces below the bulkhead should be considered.

Stability (CFR 74)

Stability Test (74.05). A stability test would be required.

Stability Standards (74.10). The minimum required intact stability is:

Weather criteria: GM=2.75 feet (req'd); where GM is defined as the distance between ship center of gravity and its metacenter.

Passenger criteria: GM=1.69 feet (req'd)

In the full load condition, with passengers standing on the main deck, the worst case GM is 5.87 feet. The requirement is met.

Damaged stability: One-compartment flooding is required with damage extending to one-fifth of the beam and from the baseline upward without limit. The basic damaged stability requirement is met because of the very large intact GM. However, as mentioned above, the margin line may be submerged along part of the length, thus violating this part of the damaged stability criterion. No cross-flooding or permanent or liquid ballast is required. Damaged stability must be carefully examined.

Lifesaving Equipment (CFR 75)

General Provisions (75.05). The lifesaving equipment provided must be of USCG approved type and made of approved materials.

Lifeboats, Life Rafts, Lifefloats, and Buoyant Apparatus (75.10). Subpart 75.10-25 states that inflatable life rafts may be substituted for lifeboats but that a rescue boat must be provided. This rescue boat must be seaworthy, rigid, with built-in buoyancy, readily launched, and easily maneuvered. It must be capable of being used to recover an unconscious person who has fallen overboard.

Hydraulic releases are required on all life rafts. Those on the SUPER-JUMBO were being so fitted during the trials period.

The total capacity of the inflatable life rafts on each side of the ship must be equal to one-half of the number of persons on board. The RHS 200 is fitted with ten 25 person life rafts plus one 15 person life raft. This is adequate for the 232 passenger version and may be acceptable on the 254 passenger version.

Buoyant apparatus are required sufficient for 25% of the persons on board (76 persons). Alternatively, inflatable life raft capacity may be increased by that amount.

Storage and Marking of Lifeboats, Life Rafts, Lifefloats, and Buoyant Apparatus (75.15). The life raft storage on the bow is unacceptable. Life rafts are to be capable of being launched while loaded with a full complement. This is not feasible on the RHS 200.

Equipment for Lifeboats, Life Rafts, etc. (75.20). The inflatable life rafts and buoyant apparatus must be equipped as specified in this subpart of the Code.

Davits for Lifeboats (75.25). Not applicable.

Inflatable Life Raft Launching Devices (75.27). The RHS 200 is deficient in not permitting boarding of life rafts before launching. Launching devices must be added.

Lifeboat Winches (75.30). Not applicable.

Blocks and Falls for Lifeboats (75.33). Not applicable.

Installation of Lifeboats, Davits, and Winches (75.35). Not applicable.

Installation of Inflatable Life Raft Launching Devices (75.37). This equipments are not required on domestic voyages.

Life Preservers (75.40). USCG approved life preservers must be provided as follows:

One per person aboard

\+ 10% of number of persons, for children

\+ one for each person on watch in engine room, pilothouse, and bow lookout station.

Life preservers, including those for children, are to be distributed throughout the spaces. If they are stowed in boxes, lockers, or closets, the boxes, lockers, or closets must not be capable of being locked (unlike those on the SUPERJUMBO). Each life preserver must have an approved, attached light.

Exposure Suits (75.41). Not applicable unless operated on the Great Lakes. If operating on the Great Lakes during the winter season, exposure suits equal to the number of life preservers must be provided. The stowage rules are the same as those applied to life preservers.

Ring Life Buoys and Water Lights (75.43). Eight life buoys are required. Six of these must have lights. This is currently exceeded on the RHS 200.

Line-Throwing Appliances (75.45). An impulse-projected rocket type or shoulder gun type line-throwing appliance must be provided with the associated equipment listed in the Code. This was not provided on the prototype.

Embarkation Aids (75.50). Provision shall be made for embarking persons into floating life rafts. This includes adequate illumination of the entire process of launch from the stowed position until the life raft is waterborne.

Portable Radio Apparatus (75.55). Not required on domestic voyages.

Emergency Position Indicating Radiobeacon (EPIRB) (75.60). This is required unless the ship has an approved VHF radiotelephone and it will not be more than 20 miles from a harbor of safe refuge.

Ship's Distress Signals (75.90). Twelve approved hand-held, rocket propelled, parachute, red-flare distress signals must be provided.

Fire Protection Equipment (CFR 76)

Fire Detecting and Extinguishing System, Where Required (76.05). A fire main system, fixed fire entinguishing system (CO_2 and sprinklers), and hand portable fire extinguishers are required.

Fire Main System, Details (76.10). Only one fire pump is required. Water shall be delivered from the two highest outlets, simultaneously, at 50 psi. The pump shall be fitted with a pressure gauge and relief valve.

The hydrant and hose size are to be standard 1 1/2 inch. The hydrant nozzle is to be 1/2 inch. Fifty foot hose lengths are to be used.

Hydrants are to be located so that any place accessible to passengers and crew, except the machinery space, can be reached by two streams (at least one from a single length of hose) from separate outlets with doors closed. Currently, the RHS 200 has one hydrant on the stern, and one each port and starboard near the passenger doors. An additional two hydrants must be located in the upper salon. At least one hydrant must be located in each lower salon.

The machinery space also requires two independent streams but both with single lengths of hose. This requires two hydrants in the machinery space. Each fire hose must have combination solid stream and water spray nozzles. Two fire hoses must have applicators. Each hose in the machinery space shall have an applicator.

All hoses must be lined and Underwriters Laboratory approved. National Standard hose coupling threats must be used. These requirements can be met.

Steam Smothering System (76.13). This system must not be used.

Carbon Dioxide Extinguishing Systems (76.15). Carbon dioxide systems are required for the machinery space, forward paint locker, and aft paint locker. CO_2 is not required for the tanks. The following parameters apply:

Space	Capacity	Pipe Size	Nom. Cyl. Outlet Area
Machinery	242 lb	1 in.	0.5 in.
Fwd Paint Locker	42 lb.	1/2 in.	0.1 in.
Aft Paint Locker	31 lb.	1/2 in.	0.1 in.

The machinery space lines are approximately correct, however the system capacity is very small. The paint locker systems must be added.

A delayed discharge system is required. An alarm must sound for twenty seconds in any space before CO_2 is discharged into the space. Provision shall be made for automatically shutting down ventilation to the machinery space when CO_2

is being used. Detailed specifications on system control and operation are described in the code and must be followed.

Foam Extinguishing System (76.17). Not applicable.

Manual Sprinkling System (76.23). Not required.

Automatic Sprinkling System (76.25). Not required.

Fire Detection and Smoke Detection Systems (76.26, 76.30, 76.33). Not required.

Manual Alarm System (76.36). Not required.

Hand Portable and Semi-Portable Fire Extinguishers (76.50). Some changes in the portable fire extinguishers are necessary. The following is the requirement for this ship:

Location	Number	Type
Stairway to Wheelhouse	1	AII
Each Salon	1	AII
Galley	1	BII or CII
Baggage Area	1	AII
Paint and Lamp Locker (each)	1	BII
Machinery Room	5	BII

Specifications for these are given in the Code.

Fire Axes (76.60). Two fire axes are to be provided.

Vessel Control and Miscellaneous Equipments. The requirements of this section are satisfied.

Marine Engineering - Subchapter F

Major redesign of marine engineering systems will be necessary. Some of the important areas are:

Pressure Vessels (54)

Diesel Fuel Piping, Tank Vents, Tank Sounding (56.50-60, 56.50-75, 56.50-85, 56.50-90)

Lubrication Oil System Piping (56.50-80)

Main Propulsion Machinery (58.05)

Internal Combustion Engine Installation (58.10)

Electrical Engineering - Subchapter J

Electrical systems drawings are not available. However, based upon the different standards for voltage and frequency, major changes can be expected. This is compounded by the much more stringent standards imposed by the U.S. as compared to those in Italy. As a practical matter, a complete electrical system redesign would probably be required.

OPERATIONAL FACTORS

Pilothouse Visibility

Visibility from the pilothouse is excellent. Windows are placed so that 360 degree visibility is available. Thin mullions separate window panes; a slight movement of one's head permits visibility around any of these. The only exception is in the stern quarter direction. Fashion plates extending from each side of the deckhouse aft reduce visibility in those directions. Refer to visibility drawing in Figure 5. Good views of the forward foil tips for docking, however, require observers on the bridge wings.

Instrumentation and Control Layout

Instrumentation and controls are positioned well. The captain is on the centerline when at the wheel. The engineer is to his right and an observer is to his left. The captain has a speed log, a compass and Stability Augmentation System (SAS) controls. The engineer has machinery and electrical system controls. The observer as a radar and radio. Electronic navigation equipment is located on the overhead, aft. Refer to the photographs at the end of this section.

Instrument visibility was generally good. However, ability to read the digital exhaust temperature unit suffered in bright light. The engine and shaft speed indicators could not be easily viewed from any position other than the engineer's location.

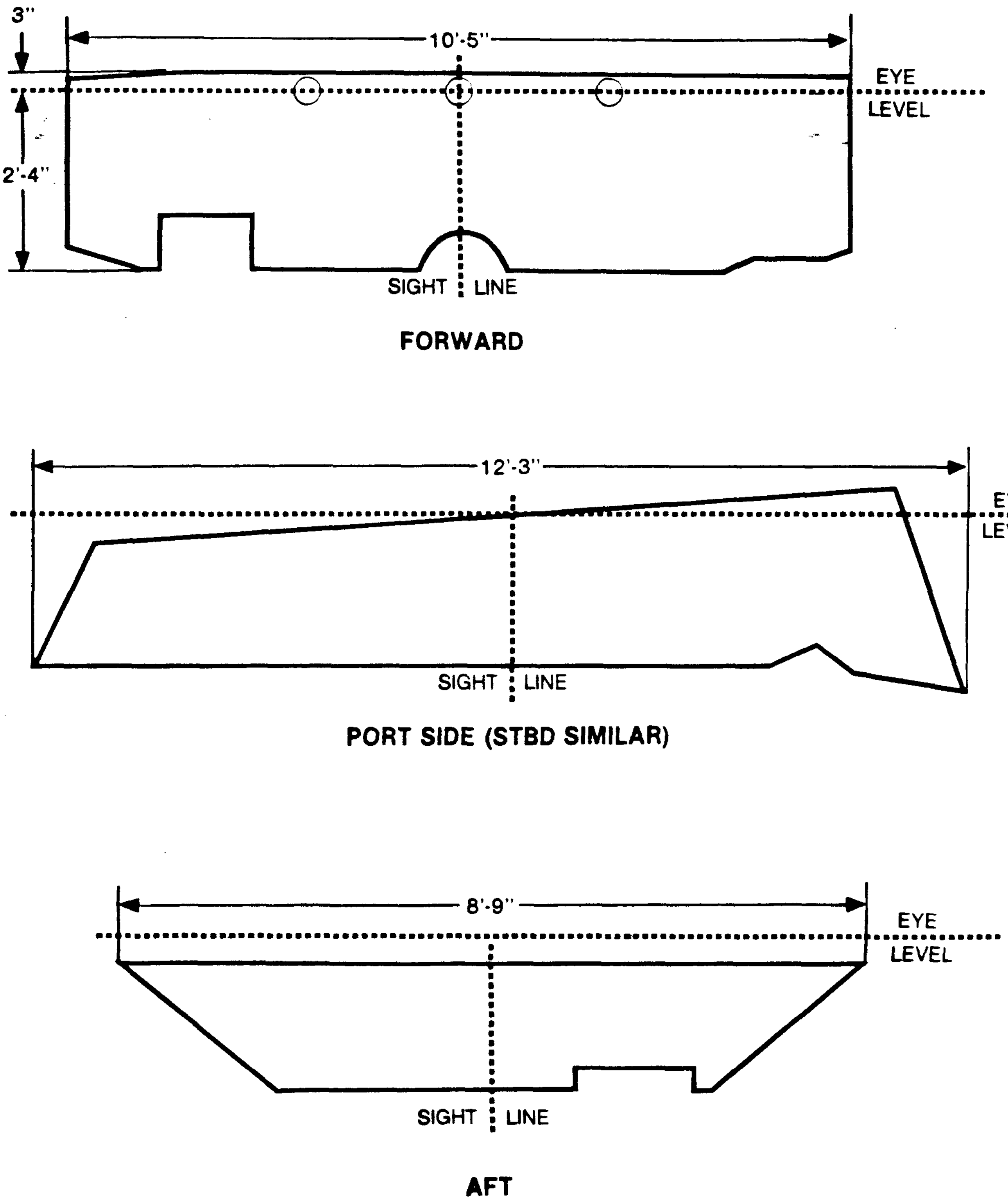


Figure 5 - Pilot House Visibility From Captain's Chair

Night Operations Capability

Although the craft is equipped with radar, a night vision capability would most likely be required for its operation in congested waters. This is due to its much greater speed than other vessels likely to be present. The ship was not operated at night during the test period.

PIER FACILITIES SUPPORT

Minimum Water Depth

At full load weight, the RHS 200 draws 15.3 feet of water. To ensure adequate clearance, the water depth should be 3 feet greater at low tide (dependent upon local tidal ranges). This will accommodate the ship in a trimmed condition or at a very low tide.

Fenders and Camels

The overall width of the RHS 200 forward surface-piercing foil is 47.6 feet. The hull width is only 23 feet, leaving a 12.3 feet overhang on each side. Camels 14.8 feet wide should be used to prevent damage to the foils. Fenders should be used due to the minor potential for damage to the ship's aluminum hull. Consequently, boarding and loading operations are more difficult because of the increased distance from pier to ship.

Ramps

The RHS 200 terminal should include ramps to reach the entry/exit points. These must extend beyond the fenders to the deck. In general, these ramps would be similar to those used for conventional small passenger ferries. Other mooring requirements are similar to those for a conventional ferry of the same size.

Shore Connection

Electrical. A 220V, 50 kW electrical panel must be provided for shore power.

Water. No special water facilities are needed. A small garden hose is needed for washing down the ship after operation.

Sewer. No sewer facilities are used on the ship in Italy. For American operations, a holding tank or other processing system would be required.

MANNING REQUIREMENTS

The manning requirements for a vessel vary greatly based upon location, regulations, union rules, maintenance program and type of service. Therefore only an example manning roster can be provided.

The RHS 200 SUPERJUMBO has operated on a run between Palermo and Naples. It required about six hours in each direction and makes one round trip daily. The ship's crew is as follows:

Category	Number
Captain	1
Chief Engineer	1
Mechanic	1
Sailors	2
Hostess	1
Barman	1

Other hydrofoils operate from each of these terminals. Therefore, the shoreside personnel are not devoted to this ship. Typically, a manager, two assistants, and two laborers are stationed at each terminal. The manager and assistants are responsible for selling and taking tickets and administration while the laborers assist in mooring the hydrofoils and perform terminal maintenance.

Planned maintenance and most corrective maintenance is performed by the ship's crew. Specialists are used for jobs requiring unusual skills. Extra personnel are used for large jobs. On the average, one mechanic per day is required. This ship must also be docked once per year. This depot level labor is not considered here.

When a vessel operated in the United States, the crew complement is subject to the judgement of the Officer in Charge, Marine Inspection (46 CFR 157) and of the union. Because this is covered on a case basis, no determination of crew size for U.S. operations is made here.

Manning will also depend upon the labor contract agreed to by the operator and the union. These, in turn, depend upon the particular service. However, it is most likely that these manning levels will be greater than those required by the Coast Guard.

CRAFT OPERATING PARAMETERS

The calm water speed and powering operational parameters of the RHS 200 were evaluated under light and heavy ship test configuration. The results of these tests which considered normal hullborne and foilborne operation and limited single engine hullborne tests are presented in detail in the Calm Water Speed and Power section of this report. Similar data were obtained at single speeds hullborne and foilborne in State 3 seas and foilborne in State 5 seas. These results are presented and compared with calm water results at the same speeds in the Rough Water Ship Performance section of this report. These sections also include respectively, discussions of the wide scope of calm water, and the more limited rough water, takeoff tests that were performed. Ship performance was largely as advertised. A typical maximum foilborne speed of 36 knots was achieved at full power conditions. State 3 sea operation did not have noticeable effect on speed and power requirements. In State 5 seas typical power increases of 11 percent were required to achieve the same speed if the SAS were active. Required power increased to between 17 and 31 percent and speed was reduced with the SAS secured. The ship has a 50 percent calm water takeoff power margin. Rough water takeoff powering requirements, which included five different headings is State 3 seas and only head sea cases in State 5, were not largely different from the calm water requirements.

Deck Equipment Arrangement

The deck equipment arrangement on the RHS 200 offered no particular difficulties in operation or maintenance. While the hull was considered easy to maintain and the deck equipment maintenance normal, it was judged that the deck and bitts were more difficult to maintain. None of the equipment jeopardized the safety of operation. Anchoring equipment layout contributed to improved safety. Lack of hand rails posed a safety problem for some deck work but this problem can be rectified on future vessels.

Motion, vibration and noise did not cause any difficulties to deck operations. However, high winds speeds over the deck while foilborne did make deck operations more difficult.

Anchoring

Anchoring was conducted in calm water. It was routine and very efficient. There were no safety problems. There is no risk of damage to the ship, including the foils. The RHS 200 rides well at anchor. The chief reason for ease of operation is that the anchor rides in a bullnose at the bow ready for "letting go". The RHS 200 is frequently "Med Moored", requiring ease in anchoring. The capstan and anchor windlass were adequate.

Boat Launching Capability

The RHS 200 is not equipped with a true ship's boat. Life saving equipment consists of ten (10) twenty-five (25) passenger life rafts and one (1) fifteen (15) person life raft. During the time of the trials, these life rafts were being fitted with hydraulic releases. A small boat powered by a 2 HP engine was installed during the trials. No davit is provided and therefore boat launching and recovery were not observed.

ENGINEERING EQUIPMENT ARRANGEMENT

The RHS 200 has an unmanned engine room. Engineers enter the engine room only for starting and stopping the engines and for periodic inspection. Constant manning of the machinery is not required due to the excellent reliability of the propulsion plant.

The CP propellers could be converted to fixed pitch depending on the mission requirements. This would result in lower cost, less weight, and better efficiency at some speeds.

The machinery and their arrangement caused no problems with ship safety or maintenance. Engines and other machinery are easy to maintain. Equipment outside the engine room was easy to maintain. Motions and vibration caused no special problems for the engineers. The engine room was noisy and good hearing protection is required.

Temperature caused no special problems. The MTU 16V652 engines have an exhaust temperature limit of 650 degrees C (1202 degrees F). This is quite high and was carefully monitored. It was sometimes necessary to reduce speed in a turn or seaway to maintain the exhaust temperature below this limit. The trials were conducted only in moderate ambient temperatures. Operations in extreme temperatures could result in difficulties.

EMERGENCY OPERATING PROCEDURES

Emergency operating procedures for the RHS 200 were not considered in the trials beyond the evaluation of both single engine hullborne speed and powering characteristics, and hullborne and foilborne emergency stopping characteristics. The ship, in the event of damage to or the failure of a single propulsion plant, could readily make an extended hullborne transit at speeds up to 12 knots. Details of the single engine tests and their results are included in the Calm Water Speed and Power section of this report. The stopping characteristics of the ship are summarized and the tests are cited in a following section. Emergency procedures relative to life boats, fire fighting and similar aspects are reviewed in the subsequent section titled "Acceptability Under USCG Requirements."

HOUSEKEEPING CHARACTERISTICS

The RHS 200 is generally well-suited to maintenance. The only difficulties are cleaning the carpet around the seats and the potential for stains on the carpet or seat covers. The floor is carpeted throughout the passenger areas which requires vacuuming. The seat covers are a synthetic material. The susceptibility of shipboard materials to fire has been discussed previously.

MANEUVERABILITY

RHS 200 maneuverability was evaluated in calm water spiral turning tests designed to explore rudder effectiveness and ship directional stability limits, in tactical diameter trials, in low speed maneuverability tests, in zig-zag maneuvers, and in special tests designed to demonstrate differential thrust turning capability at zero speed of advance. The specifics of all of the tests and discussion of their results are given in the Calm Water Turning section of the U.S. Coast Guard version of this (Ref. 2) report. Hullborne turn rates to 3 degrees per second were achieved. Maximum foilborne rates were slightly less. Due to a combination of high speeds and low turn rates, foilborne tactical diameters were 555 yards at 28 knots and 920 yards at 35 knots. Hullborne minimum tactical diameters of 270 yards and 360 yards at speeds of 8 and 16 knots respectively, were determined. The rudders were found to still be effective at speeds below 2 knots. The ability to measure speed expired before rudder effectiveness. No directional instabilities were found. Zero speed of advance turn rates of 2 degrees per second were demonstrated. The zig-zag tests showed that the ship responded very quickly and accurately to the helm. The limited rough water turning tests are discussed in the Rough Water Turning section. The rudders were effective at 2 degrees of deflection in head and following State 5 seas. Calm water turning capability was not reduced in State 3 seas. With the SAS active there was also little or no reduction in turn capability in State 5 seas. In these sea conditions the Captain of the RHS 200 elected to use reduced rudder command when turning with the SAS secured.

STOPPING CHARACTERISTICS

The crash stop and crash reverse characteristics of the RHS 200 are discussed in the Crash Stop Response section of the calm water performance evaluation of Reference 2. It was possible to stop the ship in 30 yards, or less than one ship length, from an initial hullborne speed of 16 knots. It was possible to stop the ship in 96 yards, or 2.50 ship lengths, from an initial foilborne speed of 35 knots under crash reverse conditions. The distances required to stop the ship under crash stop conditions were only slighter longer. The CP propellers were believed to be of added benefit in the emergency stops.

STRUT FAILURE CONDITION

The welded foil system assemblies of the RHS 200 are attached to primary hull structure at bolt-on attachment points. The attachment fasteners are designed to shear under foil impact loads. In such a scenario the damaged foil would fall away from the ship and a crash landing would occur. The low flying height of the RHS 200 and the shape of its hull would permit a gentle crash landing. The most severe factors to be expected would be the negative surge accelerations which would occur with the impact loads on the foil. The load levels at which the attachment bolts would fail were not defined.

WAKE EVALUATION

The bow-generated wave train of the RHS 200 was recorded during ship transits past a near-shore instrumentation station. Typical height versus time traces of the wave series are presented and discussed under the Wake Evaluation section of the performance evaluation (Reference 2). In either the hullborne or the foilborne mode of operation the RHS 200 bow wake was nearly 2.0 feet peak-to-peak and each wave had a period of approximately 2.5 seconds. The wave series typically contained 5 well-defined waves.

OPERATION AND MAINTENANCE

The following operation and maintenance information was obtained from Rodriquez Cantiere Navale based on the 1982 operating season; 30 May 1982 through 1 October 1982.

Personnel Complement and Skills

During the 1982 season the vessel operated with two crews made up as follows:

Master

Chief Engineer

Engineer

2 Seamen

3 Apprentice Seamen

No shoreside maintenance support was expected. Maintenance was carried out by the ship's personnel with the help, whenever necessary, of a local companies personnel or personnel from the Rodriquez shipyard.

Operation Hours and Cost

1050 Hours at a cost of $712,962 US, broken down as follows:

Crew	$199,629
Fuel	$363,611
Lube Oil & Other Consumables	$14,259
Agency Charges & Harbor Dues	$28,519
Annual Maintenance (Inc. O/H & Storage)	$106,944

Maintenance Manhours and Cost (During Operations)

910.5 Manhours at a cost of $14,020 US

Load Factor

An average of 25.5%

Utilization of the RHS 200

80.8%

Planned Schedule and Frequency of Operation

From 1 May to 30 September; six days per week (with one day held in standby).

Percentage of Time Schedule Met

94.39%

Scheduled Trips Missed and Why

3rd and 4th of June; Replacement of a bent propeller blade.

13th of June, 26th and 28th of July; Adverse sea conditions.

1st of September; Damage to fresh water pump.

Average Time to Load and Unload

150 passengers in 10 minutes

5000 kilograms of luggage in 15 minutes (simultaneously with the passengers)

Weather Experience

Meteorological conditions during the last operation period were generally good. In rough sea conditions, the most frequent situation was a WNW wind and sea with an accompanying State 3 or 4 sea. State 7 seas were experienced on some days. When this occurred, the trips were cancelled. However, when the sea state increased to 7 during a trip already started, it was necessary to reduce the speed to about 29 knots in head and quartering seas. A few times, during the State 7 Sea voyages, the vessel came off foils to avoid unnecessary damage risks by anomalous waves. In both sea directions, the take-off was easily accomplished after an occasional landing by placing the ship in a beam sea.

PHOTOGRAPHS

Photographs on the following pages show a series of selected external and pilothouse views of the RHS 200 hydrofoil.

RHS-200 During Landing

RHS-200 During Takeoff

RHS-200 Foilborne

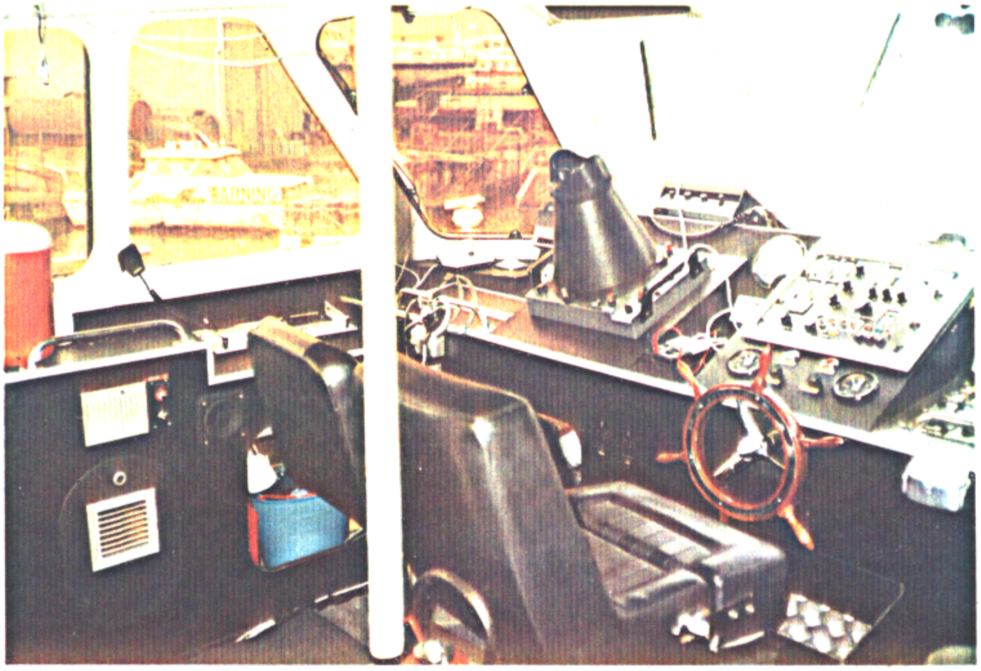
RHS-200 Foilborne

RHS-200 Foilborne

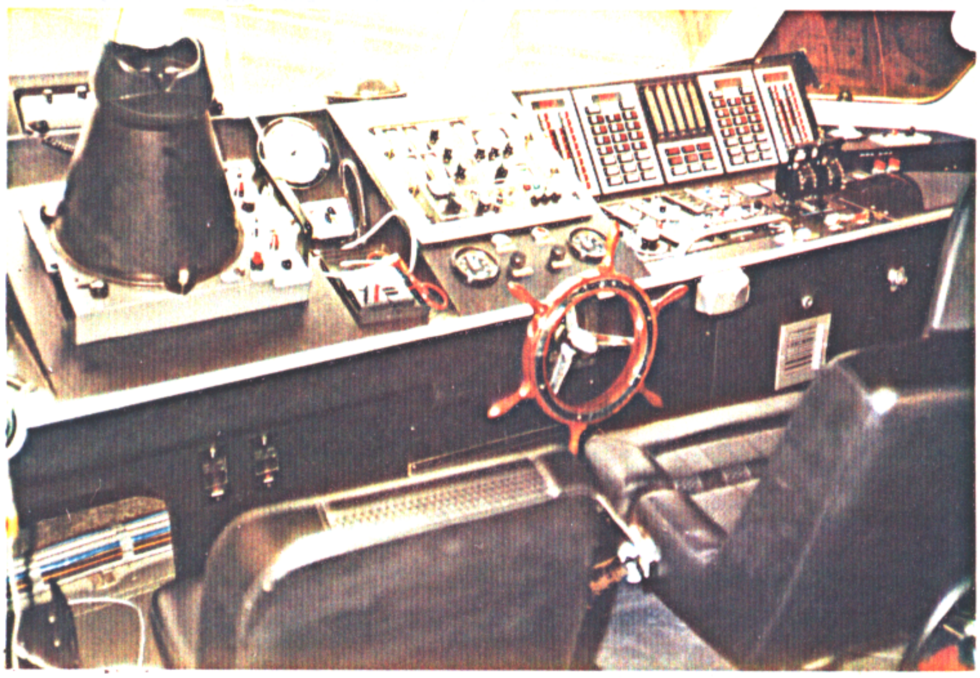
RHS-200 Foilborne

RHS-200 Hullborne - DIW

RHS-200 Hullborne - Backing Down



Pilot House Overview - Port Side



Captain's/Helmsman's Position

SUMMARY AND CONCLUSIONS

SUMMARY

The RHS 200 is a surface-piercing hydrofoil ship of 123 tons displacement design and built by the Rodriguez Cantiere Navale S.p.A., Messina, Italy as a 254 person capacity passenger ferry. The 117.5 foot ship is powered by two, 2600 horsepower, MTU 16V652-TB81 diesel engines which drive CP propellers installed on angled shafts. The aluminum hulled RHS 200 has an advertised cruising speed of 36 knots and a foilborne range of 200 nautical miles. The ship is fitted with a Seakeeping Augmentation System which uses electro-hydraulic control of flaps installed on submerged elements of the foil systems to minimize ship motions in rough water. The foil systems of the RHS 200 are of alloy steel.

DTNSRDC, at the request of the USCG and the UMTA, agreed to conduct calm and rough water performance and ferry service evaluations of the RHS 200. A trials agenda was written and a portable instrumentation and data acquisition system was assembled by DTNSRDC-HYSTUDET. The instrumentation system was to measure and record data for 36 separate parameters which were either developed within the system, taken from ship's instrumentation, or specially installed by Rodriquez in support of the trials effort. The most important parameters included ship motions and accelerations, control surface positioning, and speed and power measurements.

A trials team was deployed to Messina and the trials were conducted within a six week period beginning 5 April 1982. The calm water trials included definition of ship speed and powering characteristics and takeoff performance at displacements of 110 and 132 ton; spiral, tactical diameter, and zig-zag turning maneuvers; towing performance; and the evaluation of attendant characteristics such as wake profiles, airborne noise surveys, and structural vibration surveys. The rough water trials were largely limited to the conduct of matrix trials where ship powering requirements and responses to five different relative sea headings were measured in State 3 and 5 seas.

The reduction of the calm water trials data was primarily based on computer definition of average values taken over specific time intervals. Additional computer based procedures were used to correct some of the data for instrumentation discrepancies and to integrate data for elapsed time and distance presentations. The rough water speed and power data were reduced parallel to the calm water data. Power spectral density analysis, normal frequency spectural analysis, and manually derived histograms were all used at various stages during the reduction of the rough water motion and acceleration data.

During the calm water characteristic trials it was determined that the ship could achieve foilborne speeds slightly in excess of 36 and 35 knots for the 110 and 132 ton displacements respectively. The ship was power limited at 4400 horsepower in the case of the heavy ship trials and rpm limited at 1460 engine shaft speed in the light ship tests. During foilborne operation the ship is normally trimmed to near optimum attitudes. Hullborne speeds of 15 to 16 knots can be reached at power levels of 2300 to 2500 horsepower. Stable hullborne speeds approaching 19 knots were achieved at 3000 horsepower levels. Single engine hullborne capability to 12 knots was demonstrated.

A heavy ship foilborne range of 275 nautical miles was determined under optimistic procedures which considered 100 percent use of on-board fuel and no allowance for auxiliary consumption. The foilborne best range speed is 30 to 31 knots. A best specific fuel consumption of 0.38 pounds fuel per horsepower-hour was determined using starboard engine measured supply and return fuel flows. The maximum propulsive efficiency defined from the test data was 58 percent. This relatively low value was considered to result from inaccuracies in measured thrust data.

The RHS 200 has a takeoff power margin of over 50 percent. During takeoff the ship is typically clear of the water when a speed of 21 to 22 knots is reached in 15 seconds, and less than 100 yards, from the time and point of throttle advancement. Foilborne operation at 30 knots can be achieved in less than 30 seconds and within a distance of 185 yards. A distance of 30 yards is required to stop the ship using crash reverse procedures from an initial speed of 16 knots. The distance increases to 120 yards with initial operation foilborne at 35 knots.

Compared to a typical hydrofoil, the ship is relatively slow to turn. The maximum turn rate achieved in either the hullborne or the foilborne mode was 3 degrees per second. Directional stability is excellent while in the hullborne mode. Directional stability is reduced, but is always positive, at near zero rudder positions while foilborne. The low turn rates resulted in relatively large tactical diameters. Minimum values were 270 yards while hullborne at 8 knots and 555 yards while foilborne at 28 knots. The application of rudder usually resulted in significant losses in speed. Thirty-five knot foilborne operations could not be maintained during tactical diameter and zig-zag maneuvering tests if rudder commands over 20 degrees were applied at 35 knots. The RHS 200 always responded rapidly to the rudder and steady-state turning conditions were readily achieved. Yaw angle overshoots were very small during the conduct of zig-zag maneuvers. The rudders are completely ineffective while backing down. Differential power provides adequate steering control under these and zero speed of advance conditions.

Tactical response tests could not be performed due to a potential for damaging the engines. As is normal for all diesel power craft the ship should be maintained in a warmed-up status if it is to respond to an emergency condition. Five minute foilborne reaction times could be achieved with advance engine warm-up.

The bow wake of the ship is typically 2 feet in height and has a period of approximately 2.25 seconds in either the hullborne or foilborne mode of operation. The exterior broadside noise levels of the ship are at 85 dB A at 55 yards away. These levels are produced by the unsilenced engine exhausts. The extreme values of broadband interior noise are near the same levels. The interior sound data were obtained under conditions where the sound absorption status of the ship was severely compromised by removal of seats, etc. This situation would not exist in a normal ship configuration. The propulsion systems are the prime generators of onboard structural vibrations. The most severe vibration levels were recorded on the main deck directly above the propulsion machinery space. The 118 to 114 acceleration dB levels present at frequencies of 40 to 50 Hz could result in some passenger discomfort if exposure was continued beyond 2.5 hours of hullborne operation or 8 hours of foilborne operation.

Rough water matrix trials were conducted in high State 3 seas and low State 5 seas. The matrix test pattern used in the tests allowed evaluation of the response of the ship to head, bow, beam, quartering and following sea conditions. Hullborne trials were only performed in State 3 seas with the SAS secured. The foilborne trials were conducted in both sea conditions with the SAS active and were repeated with the SAS secured. State 3 sea takeoff trials were conducted at each of the given relative sea headings. State 5 sea takeoffs were performed into head seas. The rough water trials data were reviewed on the basis of speed and power characteristics, pitch and roll motions, and the acceleration levels which occurred or were present during the matrix trials.

No significant differences were found in the RHS 200 hullborne speed and power characteristics while operating in either calm water or State 3 seas. There is also little difference in the takeoff capability of the ship operating in calm water, State 3 seas and in State 5 head seas. Foilborne speed and power characteristics in State 3 seas are identical with those found in calm water. The use of the SAS did not have noticeable influence on these results. The effects of the sea and the SAS were both more pronounced in State 5 seas. With SAS control an average increase in power of 11 percent over that required for calm water operation occurred. With the SAS secured the average speed maintained in the tests was reduced and the power required averaged at least 22 percent higher than the calm water requirement. The range reductions which occurred in rough water operation were consistent with the power and speed changes.

Ship motions while on the hull in State 3 seas are very well damped by the foil system. Significant pitch angle excursions averaged 1 degree. Roll data from these tests were adversely effected by the presence of a large low frequency swell. Disregarding the swell, it was estimated that significant roll angle excursions would also have averaged 1 degree. The SAS was not activated in the hullborne tests because of an expected lack of low speed flap control authority.

While foilborne in State 3 seas the significant pitch angle excursions varied from 0.5 to 1.0 degrees without the SAS and 0.5 to 0.75 degrees with the SAS. In State 5 seas the angle varied from 1.0 to 2.25 degrees with the SAS secured and 0.5 to 1.5 degrees with the SAS active. The sea induced significant roll angles were also of relatively low values. Roll excursions of 1 to 3 degrees occurred in State 3 seas with the SAS secured. These values were reduced to 0.7 to 2 degrees through the use of the SAS. The ship continued to be well behaved in roll even in the higher sea condition. Significant roll excursions of 2 to 3.5 degrees occurred in State 5 seas without the SAS. These values were in the range of 1 to 2 degrees with an active SAS. The most significant fact to be found in these results are the very low pitch and roll excursions which occurred even with the SAS inactive.

The dampening of RHS 200 motions in a seaway may have been at the expense of increased accelerations. In most of the data obtained, the effect of the SAS on accelerations could not be clearly identified as either beneficial or detrimental. The acceleration data are presented and discussed in terms of standard deviations about the mean. A factor of 2.0 should be applied to the given data if estimates of the significant acceleration values are desired.

During the trials period, a large number of dimensional measurements were taken and observations were made. These permitted evaluation of the RHS 200 in a passenger ferry role for American operation and of the RHS 200 in a United States Coast Guard role.

The RHS 200 engineering plant and deck equipment were found to be well arranged for a small ship. In particular, visibility from the pilothouse was excellent.

The struts and foils extend beyond the sides of the ship. This requires special consideration at the pier and when coming alongside. Camels or fenders would be required at the pier.

The reliability and availability of the RHS 200 were found to be excellent. No failures occurred during the test period. The correction of one failure prior to the test period, the installation of test equipment, and planned maintenance were observed. These observations showed that maintainability was clearly considered in the design of the ship and the selection of its components.

The RHS 200 was not designed with wheel-chair bound users in mind. A number of deficiencies in the area should be corrected.

The RHS 200 falls short of the regulations for passenger vessels of this size. A number of areas would require redesign or waivers from the Coast Guard. Some of these areas include fire protection, firefighting, passenger access and escape, subdivision, lifesaving equipment and electrical engineering.

CONCLUSIONS

The trials conducted in the RHS 200 performance evaluation investigated the operational limits of the ship. The trials were successful and it was determined that the ship performed well in all areas of its design envelope. The following comments are relative to the performance of the ship but may not be necessarily based on numerical data.

The ship was operated on twelve separate voyages during the trials. None of the trials were disrupted or postponed due to any mechanical problem. Once warm-up was completed, departures were quickly accomplished. The voyages varied in length from 2 to 8 hours. At the end of a typical day, the crew would complete normal machinery maintenance and be ready to secure before the trials crew could complete normal end-of-day activities. All individuals involved in the trials were impressed with the physical appearance of the ship; its lines, appointments and arrangements. It was felt that normal housekeeping activity could be easily accomplished.

As a result of the 50 percent takeoff power margin, ship takeoff accelerations were impressive. The speed-power and lift-drag characteristics of the ship are difficult to judge without reference to comparable surface-piercing hydrofoil design information. Except during emergency stopping the benefits of the CP propeller were not distinctly evident. Adequate low and reverse speed control with fixed-pitch propellers and reversing gearboxes was demonstrated during a RHS 160 docking exercise. Rodriquez indicated that the relatively low ship turn rates could be improved with increased rudder area. The use of "spade" rudders below the foils may offer a more direct method of improvement.

The rough water ride qualities of the ship were well damped with and without the SAS. Occasional State 5 head sea slams which doused the pilothouse windshield with spray, resulted in motions judged hardly noticeable in the main deck aft cabin. Two members of the trials team were aboard during rough water. Both individuals were comfortable during the State 5 sea tests. The SAS was more effective in improving ride quality than the data indicated. Neither individual was concerned in regard to the capability of the ship to operate safely in any of the seas encountered.

ACKNOWLEDGEMENTS

The opinion is held that the surface-piercing hydrofoil ship performance data and other information included in this report is unique within the hydrofoil ship community. This information would not be available without the assistance of many individuals from a number of different agencies. The authors take this opportunity to thank all individuals who participated in this effort, most especially the Management and Personnel of Rodriquez Cantiere Navale, and most particularly the Captain(s) and Crew of the SUPERJUMBO. Special thanks are also extended to Engr. D. Mazzeo of the Rodriquez organization who provided valued technical assistance in all phases of the on-site trials effort. Mr. R. J. Johnston, then of DTNSRDC, acting as overall manager of the program exercised his leadership with usual tact and diplomacy thus ensuring full cooperation of all agencies involved in the effort. The efforts of Messers Robert Krussel and Kevin Gordon of Cross Sound Associates, Seattle, Washington in the development, assembly and calibration of the instrumentation system are deeply appreciated. Mr. Neil Miller of Westinghouse Digital Data Systems, Silverdale, Washington was responsible for programming the data recorder used in the trials and for its completely satisfactory operation throughout the trials period. The authors are very grateful for the effort expended by Mr. W. S. Bond of the Boeing Aerospace Company, Seattle, Washington in meeting the full responsibility for the calibration, installation and operation of the instrumentation system prior to and during the trials. Mr. Bond also provided indispensable support over many long and tedious hours in the post-trial data reduction effort. His level of committment was extraordinary. Mr. Robert Cashmore and Ms. Loraine Hauschild of Art Anderson Associates, Bremerton, Washington have earned an appreciative well done for their work in preparing the graphics used in this report. Ms. Terri Morris and Ms. Cynthia Ponciroli of DTNSRDC-HYSTUDET are sincerely thanked for their assistance in all of the tasks associated with the final preparation of this report. The report was edited by John Meyer and Robert May of the Advanced Hydrofoil Office at DTNSRDC.

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APPENDIX A

ANALYSIS OF USER PERCEPTIONS OF HYDROFOIL SERVICE

By

Service Assessment Division

June 1983

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

This memorandum presents the findings from a survey of hydrofoil passengers in Southern Italy. This hydrofoil service links the port of Palermo and Naples with a stop in Ustica, a resort island off the northern coast of Sicily (see Figure I). The vessel used in this service is a hydrofoil model RHS 200 manufactured by Cantieri Rodriquez.

The survey, an English version of which appears in Appendix A, was administered on board the vessel over the period June 1 to September 22, 1982 (a total of 46 separate trips including one charter trip from Palermo to Vulcano, an island northeast of Palermo). A total of 1734 questionnaires were returned by the passengers and form the basis of the analysis presented here. Also available for each trip is the captain's trip log (see Appendix A) indicating sea conditions and travel times.

The primary purpose of the analysis is to examine passenger perception of hydrofoil service characteristics, segmenting the responses by user group (e.g., first-time vs. repeat users, and business vs. non-business users) and sea conditions. Because no data is available on alternative travel modes linking Palermo, Ustica, and Naples, it is not possible to identify the comparative advantages of the hydrofoil over more conventional modes of transport. Also, the procedure of administration of the survey does not ensure that the sample of respondents is representative of users. Specifically, when the questionnaires are distributed at random, as was the case here, frequent users are interviewed with a higher probability than infrequent users; this generates potential biases in the results of the analysis (for a more detailed explanation of this issues see, for example, Lawrence B. Doxsey, Respondent Trip Frequency Bias in On-Board Surveys, mimeographed, U.S. Department of Transportation, December 1982).

ANALYSIS

The detailed analysis of the results is reported in the Figures II, III, and IV, and in Tables II, III, and IV. The figures consist of histograms and pie charts which convey at a glance the more detailed information provided in the tables. While the figures and tables are self-explanatory, several highlights are of particular significance and are reported in the text below.

Two-thirds of the hydrofoil trips were taken for pleasure (Figure II.A); this does not come as a surprise given the touristic appeal of the island of Ustica. Also, the reason cited by three-fourths of the passengers for choosing the hydrofoil was that it saves time, while convenience was cited by only one in seven passengers (Figure II.B). Three-fourths of the passengers had taken the hydrofoil prior to their current trip, and few people cited problems with the service, the accessibility, the motion of the vessel, or the noise level during the ride (Table II).

Again, confirming an earlier point, the speed of the hydrofoil was perceived as being very important by the majority of the passengers. Also described as very important by the majority of the passengers was ride comfort and service reliability (Figure IV and Table IV). Most people found that the level-of-service and the amenities were satisfactory, and they reported that they would recommend the hydrofoil trip to their friends (Table II).

No significant difference in perception of vessel motion and noise level exists between passengers who had taken a hydrofoil before the current trip (6 out of 10) and those who had not (4 out of 10). It also appears that sea conditions (as measured on the Beaufort scale defined in Table I) had practically no impact on perceived vessel motion and noise level (Figure III and Table III). This latter finding comes as no surprise considering the dimensions of this hydrofoil (the displacement of the RHS 200 is 115 tons) and the electronic stability augmentation system of the bow and stern foils of the vessel.

CONCLUSIONS

The analysis of the survey suggests that hydrofoil is a convenient mode of transportation. The speed of the vessel and the ride comfort are judged favorably the large majority of the passengers.

It should be stressed, however, that the hydrofoil service examined here is primarily seasonal and geared to the tourist market, and it covers relatively long distances. These site-specific characteristics, coupled with potential biases in the survey sample, should be kept in mind when applying the findings of this analysis to the planning of hydrofoil service in other environments.

THE CAPTAIN'S TRIP LOG AND THE PASSENGER SURVEY FORMS

Table A.I illustrates the English version of the captain's trip log. The hydrofoil captain would fill out one of these forms, and would attach it to the surveys completed by the vessel passengers. Table A.II illustrates the English version of the passenger survey. This survey was distributed by the captain during the trip and collected 15 minutes later.

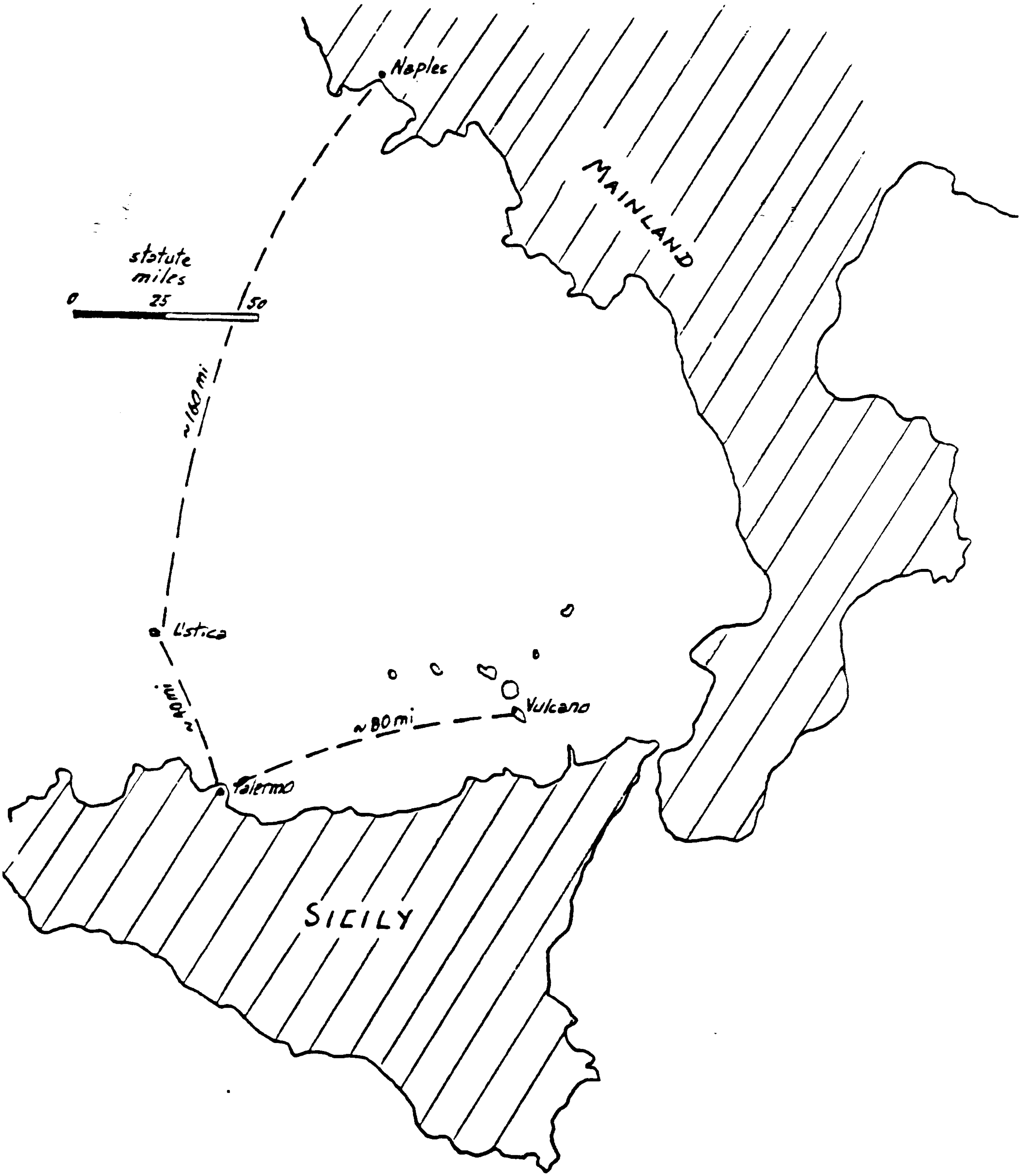
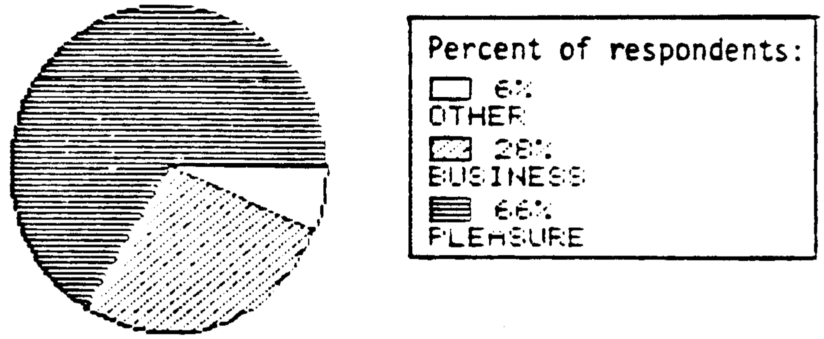


Figure I. Map of Hydrofoil Service

A. PURPOSE OF TRAVEL



B. REASON FOR USING HYDROFOIL

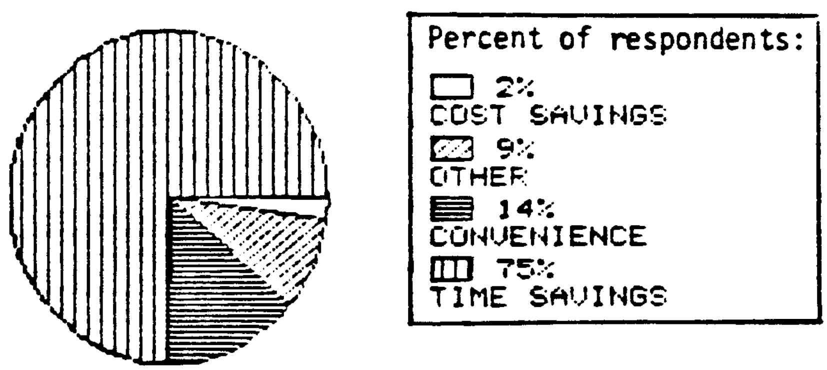


Figure II. Purpose of Travel and Reason for Using Hydrofoil

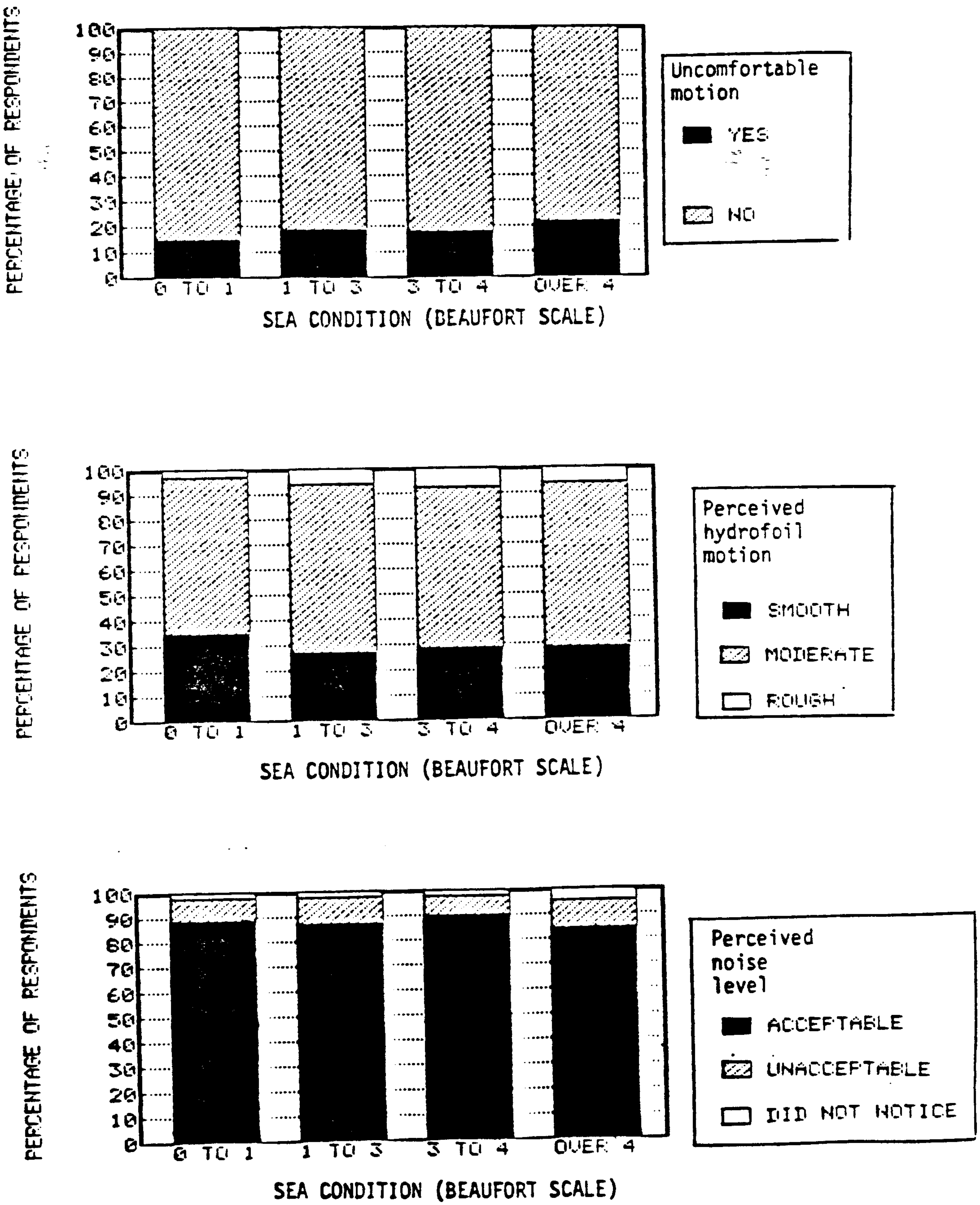


Figure III. User Perception of Hydrofoil Service Characteristics

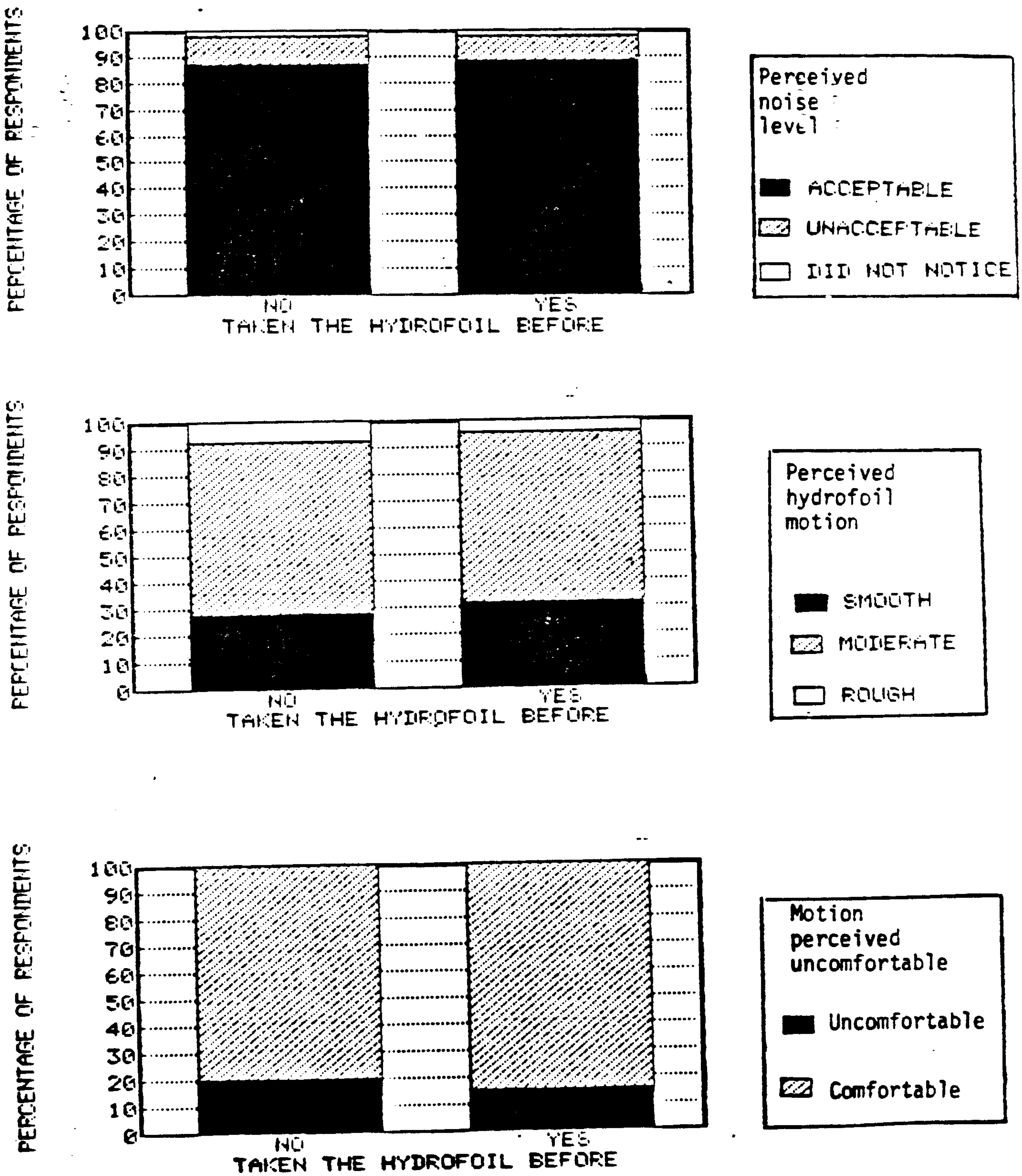


Figure III. User Perception of Hydrofoil Service Characteristics (Continued)

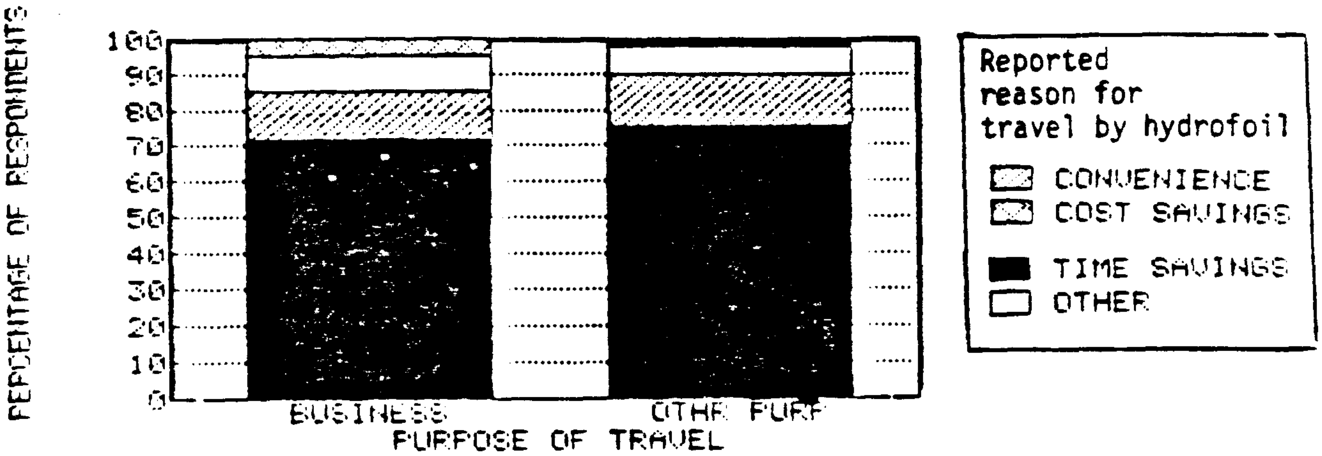
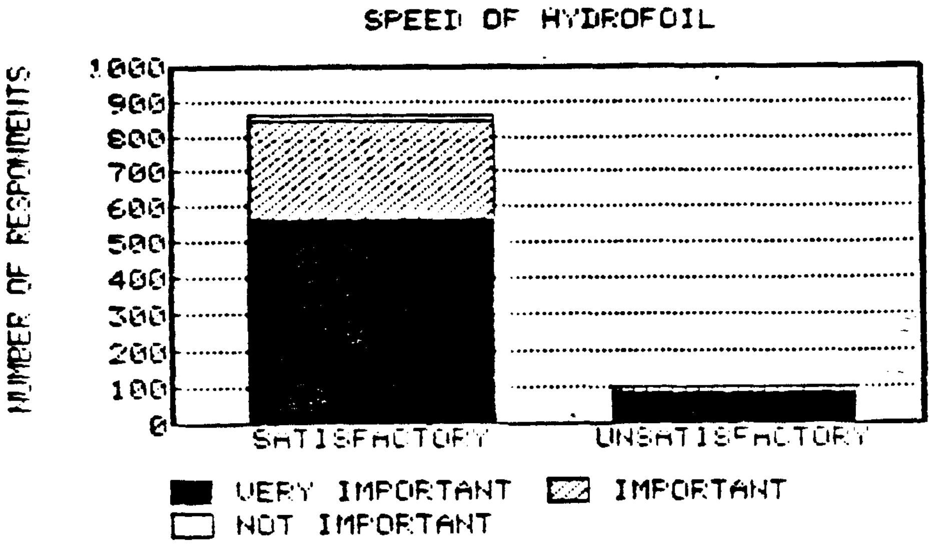
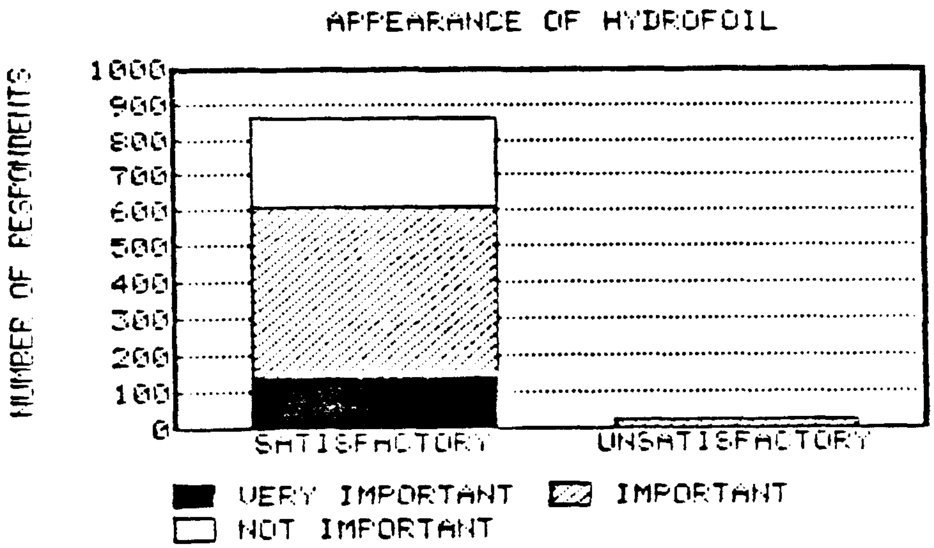


Figure III. User Perception of Hydrofoil Service Characteristics (Continued)





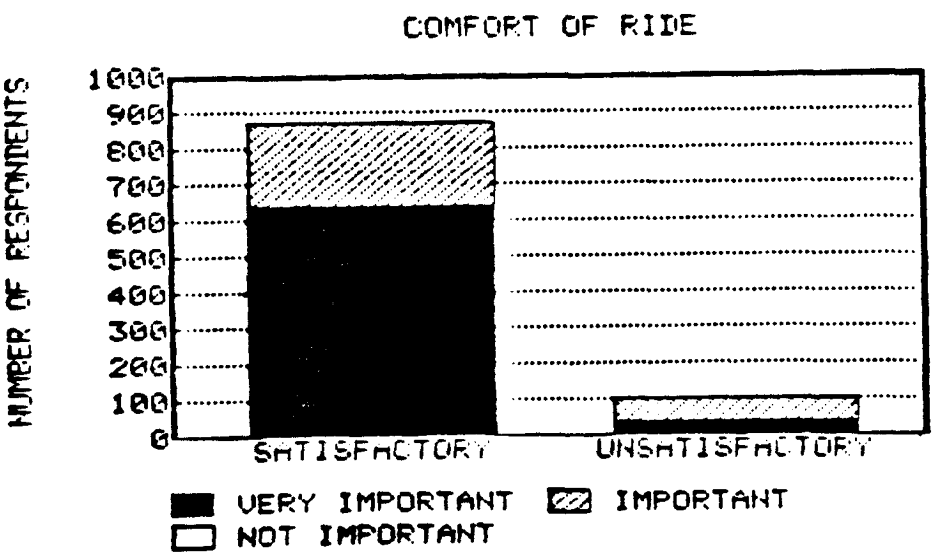
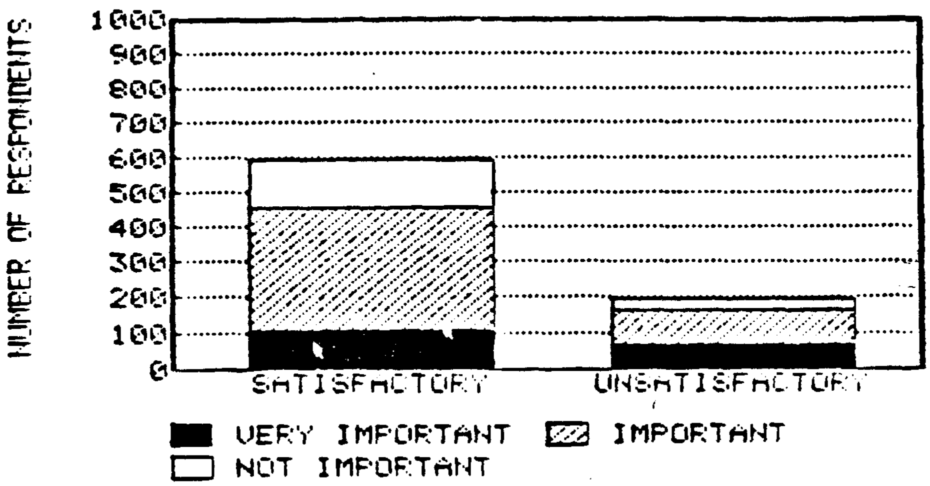
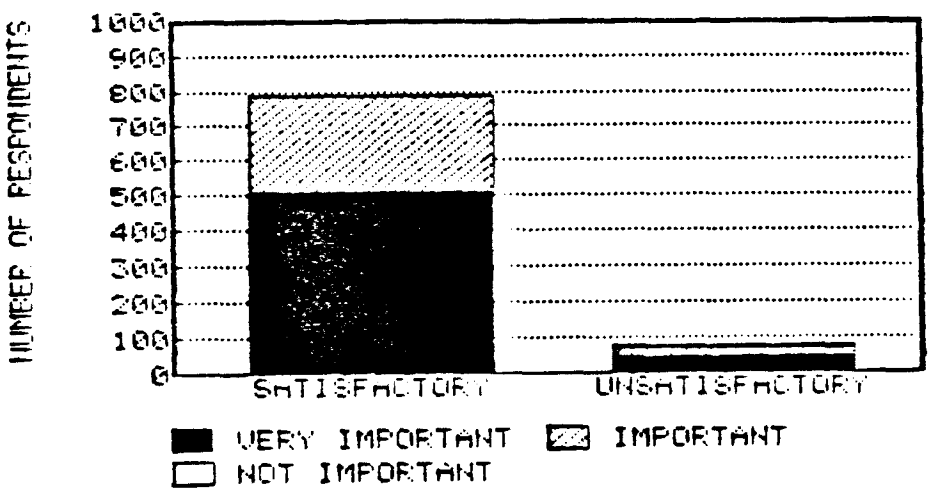


Figure IV. Cross-Classification of Hydrofoil Characteristics by Satisfaction and Importance Levels



RELIABILITY OF SERVICE



BAR/SNACK SERVICE

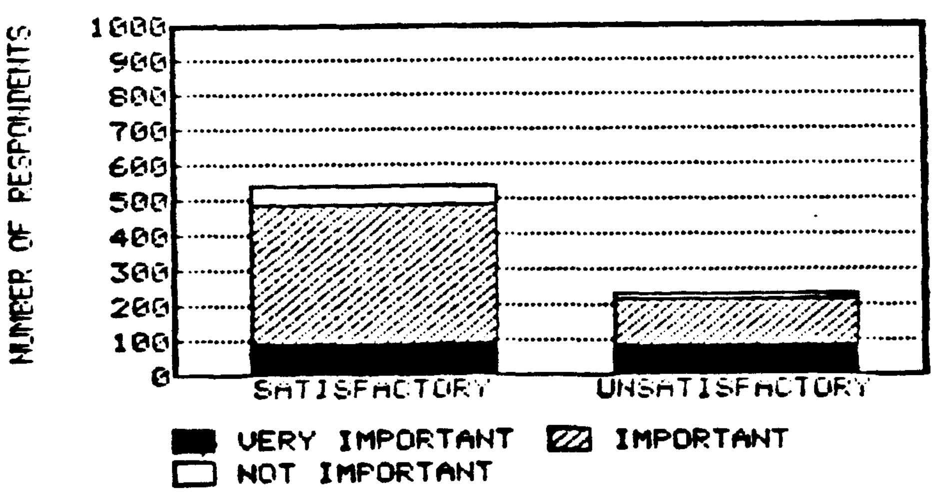


Figure IV. Cross-Classification of Hydrofoil Characteristics by Satisfaction and Importance Levels (Continued)

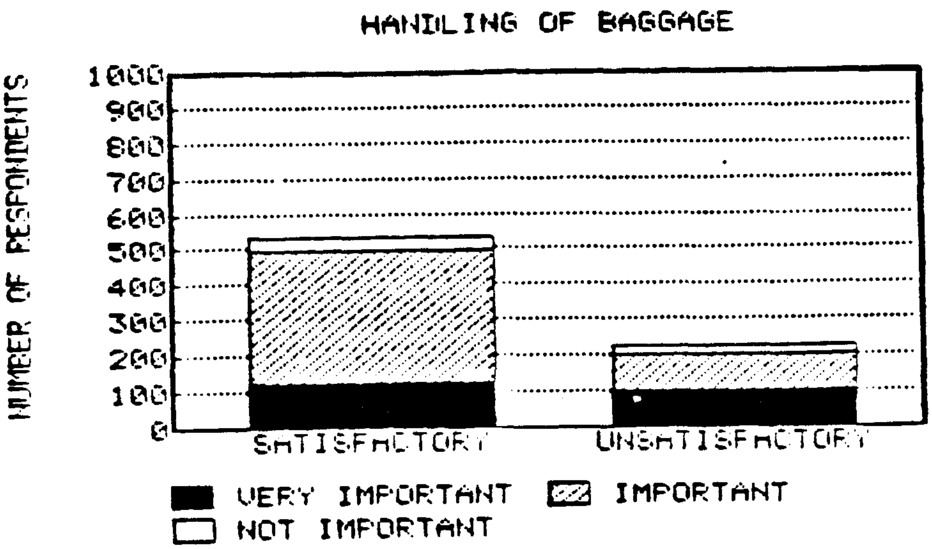


Figure IV. Cross-Classification of Hydrofoil Characteristics by Satisfaction and Importance Levels (Continued)

Table I. Beaufort Wind Scale

Code Number	Wind Velocity (m.p.h.)	Description
0	0-1	calm
1	1-3	light air
2	4-7	light breeze
3	8-12	gentle breeze
4	13-18	moderate breeze
5	19-24	fresh breeze
6	25-31	strong breeze
7	32-38	moderate gale
8	39-46	fresh gale
9	47-54	strong gale
10	55-63	whole gale
11	64-75	storm
12	over 75	hurricane

Table II. Survey Results (One-Way Cross-Classification)

TOTAL QUESTIONNAIRES RETURNED: 1,784

Are you traveling for No response: 12	business	28.44%
	pleasure	65.86%
	other, please describe	5.70%
Did you take our hydrofoil service because it No response: 30	saves cost	2.28%
	saves time	75.14%
	is convenient	13.85%
	other, please describe	8.72%
Have you taken our hydrofoil before? No response: 7	yes	73.94%
	no	26.05%
Were you able to get on our hydrofoil No response: 32	easily	91.67%
	with some trouble	6.74%
	with a great deal of trouble	1.60%
Is the cabin No response: 25	fine, no complaints	80.96%
	acceptable, any comments	17.62%
	unacceptable, explain	1.42%
Is the noise level No response: 11	acceptable	88.04%
	unacceptable	9.48%
	did not notice	2.48%
Do you find the motion of the hydrofoil No response: 9	smooth	30.08%
	moderate	64.56%
	rough	5.35%
Did the motion make you uncomfortable in any way? No response: 62	yes	17.54%
	no	82.46%

Table II. Survey Results (One-Way Cross-Classification) (Continued)

Please indicate the importance of the following features and whether you find them satisfactory or unsatisfactory.

		IMPORTANCE			
		No Resp.	Very Important	Important	Not Important
a.	Speed of Hydrofoil	277	67.95%	30.39%	1.66%
b.	Appearance of Hydrofoil	339	20.62	48.72	30.66
c.	Comfort of Ride	307	71.50	28.03	0.47
d.	Convenience/Appearance or pier	458	23.38	50.60	26.02
e.	Reliability of Service	376	63.28	35.37	1.35
f.	Bar/Snack Service	502	23.71	63.73	12.56
g.	Handling of Baggage	504	30.55	58.98	10.47

		Satisfactory	Unsatisfactory	No. Resp.
a.	Speed of Hydrofoil	89.46%	10.54%	664
b.	Appearance of Hydrofoil	96.71	3.29	721
c.	Comfort of Ride	95.19	4.81	683
d.	Convenience/Appearance of pier	76.04	23.96	803
e.	Reliability of Service	91.25	8.75	756
f.	Bar/Snack Service	69.92	30.08	800
g.	Handling of Baggage	71.58	28.42	813

Table II. Survey Results (One-Way Cross-Classification) (Continued)

(a) Other than our service, please check any of these commercial passenger boats you have taken. No response/None: 240	hydrofoil	18.72%
	hovercraft	1.04%
	conventional ferry	29.79%
	hovercraft & conv. ferry	0.52%
	hydrofoil & conv. ferry	43.52%
	hydrofoil & hovercraft	0.65%
	all three	5.75%
(b) If you checked question (a), did you enjoy the trip?	yes	71.48%
	it was OK	23.91%
	no	4.60%
Would you recommend this trip to your friends and associates? No response: 55	yes	96.01%
	no	3.99%
What is your age (check one)? No response: 23	5 to 21	15.50%
	22 to 39	50.03%
	40 to 54	26.41%
	55 to 64	6.42%
	65 or older	1.65%
Where do you live?	mostly Palermo (city)	
	mostly Sicily (region)	

Table III. Survey Results (Two-Way Cross-Classification)

	NOISE LEVEL			
Taken hydrofoil before?	ACCeptable	UNacceptable	Did Not Notice	Total
No	620[1] 0.8659[2]	77 0.1075	19 0.0265	716
Yes	941 0.8903	91 0.0861	25 0.0237	1057

	HYDROFOIL MOTION			
Taken hydrofoil before?	Smooth	Moderate	Rough	Total
No	199 0.2772	470 0.6546	49 0.0682	718
Yes	335 0.3169	676 0.6395	46 0.0435	1057

	UNCOMFORTABLE MOTION		
Taken hydrofoil before?	Yes	No	Total
No	137 0.1986	553 0.8014	690
Yes	165 0.1599	867 0.8401	1032

	REASON FOR HYDROFOIL				
Reason for Travel	Saves Cost	Saves Time	Is Convenient	Other	Total
Business	22 0.0447	355 0.7215	67 0.1362	48 0.0976	492
Other/NA	15 0.0143	963 0.7631	176 0.1395	105 0.0832	1262

[1]Number of respondents [2]Row fraction of respondents

Table III. Survey Results (Two-Way Cross-Classification) (Continued)

	NOISE LEVEL			
SEA CONDITION (Beaufort Scale)	ACCeptable	UNacceptable	Did Not Notice	Total
0 - 1	511 0.8934	49 0.0857	12 0.0210	572
1 - 3	574 0.8710	69 0.1047	16 0.0243	659
3 - 4	314 0.8997	27 0.0774	8 0.0229	349
4 - up	162 0.8394	23 0.1192	8 0.0415	193
	HYDROFOIL MOTION			
SEA CONDITION	Smooth	Moderate	Rough	Total
0 - 1	200 0.3513	352 0.6165	19 0.0333	571
1 - 3	177 0.2682	444 0.6727	39 0.0591	660
3 - 4	102 0.2906	224 0.6382	25 0.0712	351
4 - up	55 0.2850	126 0.6528	12 0.0622	193
	UNCOMFORTABLE MOTION			
SEA CONDITION	Yes	No	Total	
0 - 1	81 0.1457	475 0.8543	556	
1 - 3	119 0.1862	520 0.8138	639	
3 - 4	62 0.1813	280 0.8187	342	
4 - up	40 0.2162	145 0.7838	185	

Table IV. Survey Results - Hydrofoil Characteristics: Cross Classification of Satisfaction and Importance

			Very Important	Important	Important	Row Total
a.	Speed of Hydrofoil	Satisfactory	567[1]	281	16	864
		Unsatisfactory	90[1]	12	0	102
b.	Appearance of Hydrofoil	Satisfactory	146	465	258	869
		Unsatisfactory	6	18	6	30
c.	Comfort of ride	Satisfactory	639	235	2	876
		Unsatisfactory	39	6	0	45
d.	Convenience/ Appearance of Pier	Satisfactory	109	352	133	594
		Unsatisfactory	72	95	31	198
e.	Reliability of Service	Satisfactory	510	275	4	789
		Unsatisfactory	53	22	2	77
f.	Bar/snack Service	Satisfactory	98	389	52	539
		Unsatisfactory	86	133	19	238
g.	Handling of Baggage	Satisfactory	130	366	36	532
		Unsatisfactory	103	103	21	227

[1] Number of respondents

Figure A.I. Captain's Trip Log
(English Version)

SURVEY FOR UNITED STATES GOVERNMENT
DEPARTMENT OF TRANSPORTATION

URBAN MASS TRANSPORTATION AUTHORITY

HIGH SPEED WATERBORNE TRANSPORTATION

Voyage No. ____________ Date ____________

Captain's Log

Voyage ________________________________ to ______________________________

Scheduled Time ______________________________________

Actual Time ____

Sea State Encountered ___________________________________ (Beaufort Scale)

Wind Velocity ______________________ Direction ____________________

Sea Direction ____

Captain's Name: ____

The Captain will fill in the above log on each trip the questionnaire is issued.

The following questionnaire is to be handed out about halfway through the trip and picked up 15 minutes later.

Figure A.II. Text of the Passenger Survey
(English Version)

Please take a few minutes to fill out this questionnaire. Your comments will be used to make this trip and others a more enjoyable experience.

1. Are you traveling for
   - ________ business
   - ________ pleasure
   - ________ other, please describe

     ____

2. Did you take our hydrofoil service because it
   - ________ saves cost
   - ________ saves time
   - ________ is convenient
   - ________ other, please describe

     ____

3. Have you taken our hydrofoil before?
   - ________ yes
   - ________ no

4. Were you able to get on our hydrofoil
   - ________ easily
   - ________ with some trouble
   - ________ with a great deal of trouble

5. Is the cabin
   - ________ fine, no complaints
   - ________ acceptable, any comments

     ____
   - ________ unacceptable, explain

     ____

Figure A.II. Text of the Passenger Survey (Continued)

6. Is the noise level

- ____ acceptable
- ____ unacceptable
- ____ did not notice

7. (a) Do you find the motion of the hydrofoil

- ____ smooth
- ____ moderate
- ____ rough

(b) Did the motion make you uncomfortable in any way?

- ____ yes
- ____ no

8. Please indicate the importance of the following features and whether you find them satisfactory or unsatisfactory.

	Importance				
	Very Important	Important	Not Important	Satisfactory	Unsatisfactory
a. Speed of Hydrofoil	____	____	____	____	____
b. Appearance of Hydrofoil	____	____	____	____	____
c. Comfort of Ride	____	____	____	____	____
d. Convenience/Appearance of Pier	____	____	____	____	____
e. Reliability of Service	____	____	____	____	____
f. Bar/Snack Service	____	____	____	____	____
g. Handling of Baggage	____	____	____	____	____

Figure A.II. Text of the Passenger Survey (Continued)

9. (a) Other than our service, please check any of these commercial passenger boats you have taken.

		from where		to where
________	hydrofoil	________	to	________
________	hovercraft	________	to	________
________	conventional ferry	________	to	________

(b) If you checked question 9a, did you enjoy the trip?

________ yes

________ it was ok

________ no

10. Would you recommend this trip to your friends and associates?

________ yes

________ no

11. What is your age (check one)?

________ 5 to 21

________ 22 to 39

________ 40 to 54

________ 55 to 64

________ 65 or older

12. Where do you live?

________________ City

________________ Country

ANALYSIS OF USER PERCEPTIONS OF HYDROFOIL SERVICE

Passenger questionaires from 46 voyages of the RHS-200 are summarized below. A total of 1797 questionnaires organized in four volumes were submitted to the U.S. Coast Guard for evaluation.

ITEM NO.	VOYAGE NO.	DATE	FROM	TO	SEA COND.*	NUMBER OF QUESTIONAIRES
1.	Noleggio	6/1/82	Vulcano	Palermo	0	45
2.	1/A	6/2/82	Palermo	Ustica/Napoli	2	17
3.	2A/R	6/5/82	Palermo	Ustica/Napoli & ret.	0	60
4.	3A/R	6/6/82	Palermo	Ustica/Napoli & ret.	2	74
5.	4A/R	6/7/82	Palermo	Ustica/Napoli & ret.	0	7
6.	5A/R	6/8/82	Palermo	Ustica/Napoli & ret.	0	16
7.	6A/R	6/10/82	Palermo	Ustica/Napoli & ret.	0	43
8.	7A/R	6/11/82	Palermo	Ustica/Napoli & ret.	0	43
9.	8A/R	6/12/82	Palermo	Ustica/Napoli & ret.	5	35
10.	11A/R	6/16/82	Palermo	Ustica/Napoli & ret.	3/4	68
11.	12A/R	6/17/82	Palermo	Ustica/Napoli & ret.	3	8
12.	13A/R	6/18/82	Palermo	Ustica/Napoli & ret.	0	9
13.	14A/R	6/19/82	Palermo	Ustica/Napoli & ret.	3	79

ITEM NO.	VOYAGE NO.	DATE	FROM	TO	SEA COND.*	NUMBER OF QUESTIONAIRES
14.	15A/R	6/20/82	Palermo	Ustica/Napoli & ret.	0	113
15.	16A/R	6/21/82	Palermo	Ustica/Napoli & ret.	2/3	31
16.	17A/R	6/23/82	Palermo	Ustica/Napoli & ret.	2/3	5
17.	18A/R	6/24/82	Palermo	Ustica/Napoli & ret.	3	43
18.	19A/R	6/25/82	Palermo	Ustica/Napoli & ret.	3/4	12
19.	20A/R	6/26/82	Palermo	Ustica/Napoli & ret.	3/4	116
20.	21A/R	6/27/82	Palermo	Ustica/Napoli & ret.	6	33
21.	22A/R	6/28/82	Palermo	Ustica/Napoli & ret.	6	48
22.	23A/R	6/30/82	Palermo	Ustica/Napoli & ret.	2/3	39
23.	24A/R	7/1/82	Palermo	Ustica/Napoli & ret.	3/4	52

*Beaufort Scale

ITEM NO.	VOYAGE NO.	DATE	FROM	TO	SEA COND.*	NUMBER OF QUESTIONAIRES
25.	26A/R	7/3/82	Palermo	Ustica/Napoli & ret.	0	34
26.	27A/R	7/4/82	Palermo	Ustica/Napoli & ret.	0	41
27.	28A/R	7/5/82	Palermo	Ustica/Napoli & ret.	0	7
24.	46A/R	7/2/82	Palermo	Ustica/Napoli & ret.	2	41
28.	29A/R	7/7/82	Palermo	Ustica/Napoli & ret.	2	28
29.	34A/R	7/12/82	Palermo	Ustica/Napoli & ret.	0	14
30.	35A/R	7/14/82	Palermo	Ustica/Napoli & ret.	0	17
31.	37A/R	7/16/82	Palermo	Ustica/Napoli & ret.	0	8

ITEM NO.	VOYAGE NO.	DATE	FROM	TO	SEA COND.*	NUMBER OF QUESTIONAIRES
32.	40A/R	7/19/82	Palermo	Ustica/Napoli & ret.	3	38
33.	41A/R	7/21/82	Palermo	Ustica/Napoli & ret.	0	5
34.	42A/R	7/22/82	Palermo	Ustica/Napoli & ret.	0	23
35.	43A/R	7/23/82	Palermo	Ustica/Napoli & ret.	3/4	115
36.	44A/R	7/24/82	Palermo	Ustica/Napoli & ret.	5	19
37.	45A/R	7/25/82	Palermo	Ustica/Napoli & ret.	4/5	10
38.	46A/R	7/26/82	Palermo	Ustica/Napoli & ret.	5/6	29
39.	47A/R	7/30/82	Palermo	Ustica/Napoli & ret.	0	96
40.	48A/R	7/31/82	Palermo	Ustica/Napoli & ret.	2	42
41.	53A/R	8/6/82	Palermo	Ustica/Napoli & ret.	2/3	60

ITEM NO.	VOYAGE NO.	DATE	FROM	TO	SEA COND.*	NUMBER OF QUESTIONAIRES
42.	63A/R	8/18/82	Palermo	Ustica/Napoli & ret.	2/3	13
43.	70A/R	8/26/82	Palermo	Ustica/Napoli & ret.	2/3	87
44.	71A/R	8/27/82	Palermo	Ustica/Napoli & ret.	2/3	31
45.	83A/R	9/10/82	Palermo	Ustica/Napoli & ret.	2	24
46.	93A/R	9/22/82	Palermo	Ustica/Napoli & ret.	4/5	19