U.S. COAST GUARD

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CONCEPT TO COMPLETION

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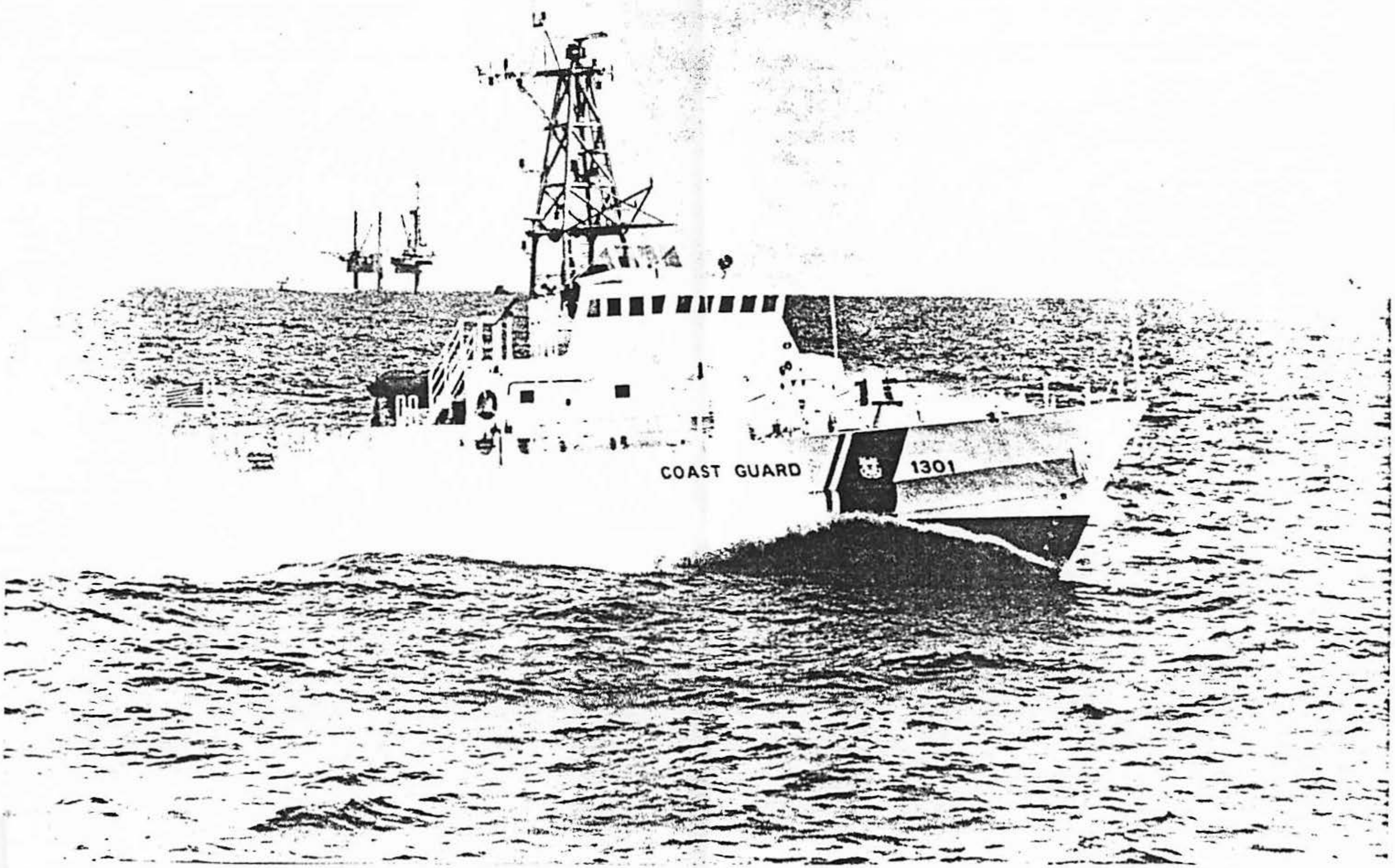
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Wm. Gary Rook, Cdr. William M. Simpson, Jr., U.S.C.G.

THE AUTHORS

Lt. Robert M. Latas is a 1975 U.S. Coast Guard Academy graduate and received M.S. degrees in Mechanical Engineering and Naval Engineering in 1980 from the University of Michigan. His engineering duty assignments have included two (2) Coast Guard cutters and the Coast Guard Yard. His current duty assignment is as Executive Officer of the Resident Inspector Office at Lockport, Louisiana. Lt. Latas is a member of ASNE, SNAME, and ASME.

Lt. Frank McCarthey graduated from the United States Coast Guard Academy in 1977 with a B.S. degree in Marine Engineering and Naval Architecture. In 1981 he received a Masters degree in Marine Engineering and Naval Architecture and an Engineer's degree in Ocean Engineering from the Massachusetts Institute of Technology. He served on the USCGC TANEY (WHEC-37) (1977-1979) as a student engineer, on the USCGC DILIGENCE (WMEC-616) (1981-1983) as the Engineering Officer, and since then has been the Headquarters Naval Engineering Division, Island Class Patrol Boat, Project Officer.

William Gary Rook is the Design Engineering Manager at Bollinger Machine Shop & Shipyard, Inc. He is also a vice-president of the company. He received his bachelor's degree in Marine Engineering from Mississippi State University in 1972, graduating with honors. In his present position, Mr. Rook is responsible for the preparation of all studies and designs prepared by Bollinger Shipyard. In his tenure at Bollinger Shipyard, he has designed over thirty (30) specialty vessels including tugs, supply vessels, lift barges, and fishing vessels. He was totally responsible for the technical portion of the bid for the U.S.C.G. WPB's, along with various other military and commercial bids. Prior to joining Bollinger Shipyard, he was employed as Chief Engineer at American Gulf Shipbuilding and as a Naval Architect at Main Iron Works, Inc. He has authored several technical papers, one of which appeared in the publication, Marine Technology. He serves on the Technical Committee of the Louisiana Shipbuilding & Repair Association, and the Offshore Marine Service Association. In addition to Service Association. In addition to being a member of ASNE, he is a member of SNAME and the Marine Engineering Technology Society.

Cdr. William (Bill) M. Simpson, Jr., U.S.C.G., received a B.S. degree in engineering from the United States Coast Guard Academy, and a M.S. in Naval Architecture and Marine Engineering and a Naval Engineer degree from Massachusetts Institute of Technology. He served as deck watch officer on a 255 foot cutter and as executive officer on a 125 foot cutter. He served in the U.S. Coast Guard Merchant Merchant Marine Technical Office in New York and taught fluid mechanics and ship design at the Coast Guard Academy. He was Assistant Chief of the Design Branch and then Chief of the Boat Construction and Maintenance Branch in the Coast Guard Headquarters. He is presently assigned as Commanding Officer, Resident Inspector Office, Lockport, Louisiana, and is overseeing the construction of the Island Class Patrol Boats.

ABSTRACT

The U.S. Coast Guard is having sixteen (16) 110 ft. Island Class patrol boats built by Bollinger Machine Shop & Shipyard, Inc. The patrol boats are based on an existing design by Vosper Thornycroft (UK) Limited of England. The twin screw boats are powered by two (2) Paxman diesels. They have active roll fin stabilizers. Armament is a 20mm manual machine gun on the foredeck and 7.62mm machine guns on the 01 deck. The procurement which was based on the use of a proven design "parent craft" is described and the characteristics and special features of the patrol boats are presented.

INTRODUCTION

The new U.S. Coast Guard 110 foot Island Class patrol boats are in production today as a result of a speech made by Vice-President Bush on February 16, 1982. In his speech in Miami, regarding the special task force responsible for stemming the flow of illicit drugs into the Southeastern United States, the Vice-President directed the Coast Guard to significantly increase their resources in the battle against drug smuggling. The U.S. Congress, in turn, made this possible by the specific appropriation of capital acquisition funds for the procurement of, among other things, Coast Guard patrol boats.

The sudden requirement to obtain additional patrol boats quickly created this unique acquisition and construction program. The goal of the Coast Guard was to obtain eight (8) additional patrol boats which could quickly create an impact upon the drug smuggling activities. This called for an emphasis on decreasing the inherent risks in procuring new equipment.

In order to hasten the introduction of the new patrol boats into the Coast Guard inventory, an off-the-shelf buy of existing technology was to be accomplished. By procuring off-the-shelf patrol boats, it was hoped the schedule risks associated with production would be reduced. By virtue of having been built before, there would be a higher degree of confidence in the ability of a shipyard to produce the patrol boat. In the same manner, once the boats were built, there would be a reduction in the technical risks because of the proven performance of the previously built boats. By going with an off-the-shelf proven patrol boat design, the post delivery developmental work often required for new designs would be reduced, if not eliminated.

The new patrol boats were to serve primarily in the Southeastern United States in the enforcement of laws and treaties, i.e., combating drug smuggling activities. The patrol boats would also have to be capable of performing search and rescue missions as well as filling a military preparedness role.

After struggling with what 'off-the-shelf proven design' meant, a notice was published in the Commerce Business Daily (C.B.D.) requesting industry comment on some generic requirements. A copy of that notice, published in August, 1982, is provided as Appendix A. The Coast Guard received more than fifty (50) responses from ship builders and ship designers. From the evaluation of these responses, it was concluded that the concept of using an existing design was feasible, but the requirements and restrictions had to be clearly defined.

Using the information provided in the responses to the first C.B.D. notice and their operational experience, the Coast Guard more fully defined the requirements for the patrol boats. These requirements are summarized in Table I.

TABLE I

Design:	Existing technology, proven design.
Length:	Approximately 100'-130'
Hull Form:	Semi-displacement or planing type
Profile:	Low silhouette
Beam:	No restrictions
Draft:	8' maximum
Speed:	Maximum speed in excess of 26 knots
Propulsion:	Diesel powered with multiple screws, twin rudders
Endurance:	5 days minimum
Range:	1800 N.M. minimum
Small Boat:	One (1) 5.4 meter rigid hull inflatable boat with a single point davit
Communications:	VHF-FM, HF, UHF, teletype
Navigation:	Omega, Loran C, surface search radar, gyro compass, auto pilot
Accommodations:	18 (2 officers, 2 CPO's, 12 enlisted, 2 spares)
Habitability:	Minimum twenty (20) square feet per crew member
Fresh Water:	Minimum tank storage 1200 gallons, desalination plus tank capacity must provide 2200 gallons for a 5-day mission.
Electrical:	Twin generators capable of operating in parallel with capacity to carry load on one generator with a 20% growth margin
Armament:	Single 20mm or 25mm machine gun with 2 light machine guns on the bridge wings
Damage Control:	2-compartment subdivision; U.S. Navy intact and damage stability standards

From the onset of the project, it was obvious that the new patrol boats would depart significantly from the Coast Guard's own 82' and 95' patrol boats. The new patrol boat would have to have more speed, endurance, and accommodations capability.

The operating profile of the new patrol boats would also vary from the 82' and 95' patrol boats. The new boats would provide expanded law enforcement coverage in offshore areas within the Southeastern United States. The law enforcement coverage involves independent offshore patrolling, conducting surveillance, and boarding operations. In order to extend this operation, the patrol boats were to be capable of refueling at sea. The seakeeping capabilities required of the boat were to allow the safe conduct of boarding operations through Sea State 5.

The new WPB's would be clustered in squadrons of four (4) boats each. The initial procurement was aimed at buying eight (8) new patrol boats and thus, two (2) squadrons would be formed. In order to maximize the underway time of each new boat, the squadrons were to be comprised of six (6) crews for four (4) boats. This would allow approximately a fifty (50%) per cent increase in the underway time for each boat.

Due to the increase in the tempo of operation when compared to a single crewed patrol boat, each squadron would be staffed to accomplish the increase in maintenance.

PROCUREMENT APPROACH

In order to define the requirements applicable to the existing design and the Coast Guard patrol boats, a Circular of Requirements (COR) was prepared. The concept of using a circular of requirements was first suggested by RAM, Inc. of Rockville, MD, based on their experience in preparing COR's for the U.S. Navy. RAM prepared the initial draft of the WPB COR which then went through a series of reviews and modifications at the hands of both RAM and the Coast Guard.

The COR laid out the requirements for the existing design which was tagged the 'parent craft'. These requirements are briefly stated in the following quote from the COR:

> "In order to be acceptable, the proposed parent craft shall meet the requirements of this Section.
>
> "The parent craft shall have been previously designed, built, and operated as a patrol craft. Craft originally designed and built for other service, that have been successfully modified for patrol service, and have operated successfully in such patrol service, are acceptable. Modifications of vessels designed and built for other than patrol service but as yet unproven in patrol service are not acceptable.
>
> "Patrol service shall mean (1) that the craft incorporates accommodations, armament, and extensive electronics and communications equipment similar to that required for this WPB and (2) has operated in search and rescue, enforcement of laws and treaties, and/or military service similar to the service in which this WPB will operate.
>
> "The parent craft shall have operated in offshore patrol service for a minimum of three years with at least 90 days at sea per year.
>
> "The parent craft shall possess the same hull form and dimensions (defined as underwater body and hull up to the sheer line), principal hull structure, underwater appendages, and propulsion configuration as the WPB.
>
> "The parent craft shall meet the requirements of COR 100b (Structure), 200a (Propulsion Plant), and 200b (Propulsion Plant Rating).
>
> "The parent craft shall have demonstrated the speed and seakeeping specified in Section 070b for the displacement and LCG shown in the Contract Design Weight Estimate for the WPB.
>
> "A complete set of parent craft drawings shall be available to the Resident Inspector for inspection and reference during the term of the Contract.
>
> "The parent craft shall have no unresolved defects which significantly affect operational performance, reliability, or maintainability."

It was originally required that in addition to successful service, the parent craft structure must meet ABS requirements. This was found to be overly restrictive and the requirement to meet ABS structural rules was deleted.

The COR defined general, and in some cases specific, requirements for the WPB which were not governed by parent craft. This covered accommodations, the electrical system, electronics, auxiliary systems, and armament. The endurance was also specified. This, in turn, required changes from the parent craft fuel tank arrangements. The RHI boat handling requirements also turned out to be significantly different from the parent craft proposed.

It was these general and specific requirements that controlled the transition from parent craft to Coast Guard WPB. Some of the significant COR requirements which differed considerably from the available parent craft characteristics were:

1. Noise standards.
2. Decks and joiner bulkheads of non-combustible material.
3. 5-day endurance.
4. 2-compartment damage stability.
5. Both-side launch and retrieve of 5.4 meter RHI.
6. Large electrical load and growth margin requirements.
7. Electrical system in accordance with IEEE-45.
8. Electronics suite.
9. Number and type of antennas.
10. Navigation lights.
11. Material requirements for pumps, valves, and piping.
12. Separate duplex sea water strainers for the main engines, the generators, and the fire pumps.
13. Single point on-deck fuel and water transfer capability.
14. Sewage collection, holding and transfer system (vacuum flush system).
15. Towing.
16. Number and type of accommodations.
17. Pilot house and open bridge equipment requirements.
18. Type and amount of outfit.
19. Gun mounts.
20. Magazine.

In parallel with the COR preparation, a procurement strategy was being developed and a request for proposal (RFP) was being prepared. A second, more detailed notice was published in the Commerce Business Daily on March 3, 1983. One of the purposes of this second notice was to determine if a small business set-aside was possible. Numerous favorable responses were received and the procurement was set aside for small businesses.

The procurement was governed by the Federal Procurement Regulations (FPR) and by Department of Transportation (DOT) Order 4200.11 entitled Source Selection. The DOT order set forth DOT policy and procedures for soliciting and evaluating proposals and selecting sources for the award of large negotiated contracts.

The RFP was issued on 9 May 1983 with a proposal submission date of 20 June 1983. The request for proposal (RFP) published the required deliverables, the delivery dates, the proposed contract terms and conditions, requirements for the proposals, and proposal evaluation criteria. The proposals were required to be submitted in three (3) basic parts. A technical proposal consisting of an engineering sub-part and a mission suitability sub-part was to provide a technical and physical description of the proposed patrol boat. This was required to include a specification, drawings, and textual descriptive material. The other two parts were the business management proposal and the cost proposal.

The business management proposal was to provide a description of the company resources, management, and man power. It was also to address the license arrangement (no one was able to offer their own design), past performance, and evidence to support the proposed schedule. The cost proposal was to present a detailed cost break-down showing labor categories, rates, hours, bill of materials, and all other direct costs and an explanation of how these costs were developed.

The RFP as originally issued was 148 pages. It was amended nine (9) times prior to contract award. The COR, as first published, was 215 pages. It was amended five (5) times prior to contract award. A pre-proposal conference was held on 24 May 1983 and the proposal submission date was extended to 11 July 1983.

BMS PROPOSAL

Bollinger Machine Shop & Shipyard, Inc., like many other small shipyards, saw the announcement of the United State Coast Guard's intention to procure a group of WPB's in the Commerce Business Daily (C.B.D.). Like most small shipyards in early 1983, Bollinger was sorely in need of work, and proceeded immediately to look for a vessel to bid ('parent craft'). Bollinger felt that any U.S. yard already having a design meeting the C.B.D. announcement guidelines would be bidding to the Coast Guard on their own, so no time was wasted looking for a U.S. designed and built vessel. Through the use of trade journals, publications, and recommendations from engine manufacturers, a list of potential parent craft designers/builders was developed. Each of these builders was contacted to see if they would be interested in participating in this program by licensing Bollinger to build their vessel. The interested builders were given a general list of particulars paralleling the C.B.D. announcement, and asked to submit to Bollinger for evaluation the vessel of their design that most closely fit the requirements.

Several foreign yards responded to Bollinger's requests, and submitted general characteristics of vessels within the guideline parameters. These responses were analyzed by the management of Bollinger, and a decision was made to utilize a craft designed and built by the British firm of Vosper Thornycroft (UK) Limited. This decision was based as much on the reputation of Vosper as it was on the vessel. Vosper had been building high speed vessels for over 100 years and had built 24 vessels of the design they offered to Bollinger. In addition to shipbuilding, Vosper had extensive experience of supporting construction of their designs out of country, just as this project would be. They also had complete facilities to handle Integrated Logistic Support (I.L.S.), and a staff of advisors that were ready to assist Bollinger on-site throughout the project. A response was sent back to the Coast Guard informing them of the intent of Bollinger to submit a bid on the project utilizing the Vosper vessel under a licensing agreement.

In May of 1983, when the RFP was officially issued by the Coast Guard, a meeting was set up between the design sections of Vosper and Bollinger to ensure that the selected craft would meet all COR requirements. This meeting was held at the Vosper yard in Portsmouth, England, as all technical data was located at this facility. This joint meeting of the technical teams determined that the original assumption of a vessel had been correct, and that all parent craft identicality requirements would be met with no problems. It was also determined that through minor modifications to the design, all other COR requirements could be met as well. It was agreed that Vosper would support the Bollinger design staff in certain areas, as they were the original designers and had all the necessary data on file. In general, Vosper agreed to provide all necessary support in the way of parent craft information, verification of parent craft performance, and also verification of all technical data generated by Bollinger.

As noted previously, the RFP laid out specific guidelines for all phases of the proposal---business, cost and technical. To go through the way that Bollinger handled each of these areas in detail would be a paper in itself, so only a brief description of how each phase was handled will be discussed.

A. Business Management Proposal

This section required that data on the company and its past history be submitted. Each division of the company, if applicable, had to be detailed. The number of subcontractors to be utilized was discussed along with the backlog of work at the building site. The license agreement was provided along with a detailed plan for technical support by Vosper at the Bollinger yard. A list of past contracts was supplied along with their history and contacts at each company. Planning and support proposals along with rosters of key personnel were provided in this section.

B. Cost Proposal

This section included company financial information such as financial statements, labor rates, overhead charges and rationale, and accounting methods. A priced bill of materials for the project was prepared and included along with pricing summaries and supporting details. In addition, the proposed plan for financing the project, including cash flow projections, was provided.

C. Technical Proposal

Part 1 - Engineering Proposal

This section included the technical specifications for both the parent craft and WPB. Parent craft drawings, as required, were also provided. Contract drawings and contract guidance drawings, as prepared by Bollinger, were included along with the contract design weight estimate and stability analysis. Calculations for all phases of design were included in this section; i.e., fuel consumption, propeller, powering, structural, and hydrostatic. A proposed drawing list was developed along with a weight control plan. A preliminary list of equipment was developed and submitted (this list was used in the development of the proposed bill of material in the cost proposal). Parent craft information such as performance, warranty, and trials' reports were supplied. Main propulsion engines/gears information and data along with recommended overhaul intervals and estimated cost was supplied. The

Bollinger Organizational and Quality Control manuals were submitted. Seakeeping information on the parent craft along with estimates for the WPB were submitted for review. The antenna/electronics system arrangements were provided along with engineering rationale for each decision made.

Part 2 - Mission Suitability Proposal

Documentation of the parent craft and data showing that it met the COR requirements were provided. Detailed layout and procedures were provided for the RHI crane, armament, magazine, anchoring, towing, refueling at sea, boarding capability, and storage layouts. Future weapons retrofit was also addressed. Speed, endurance, and range were addressed with supporting calculations provided. Detailed layouts of the command/control/ electronic spaces were prepared and submitted. Maneuverability information on the parent craft along with estimates for the WPB were provided. Habitability was addressed and detailed layouts of accommodation spaces were provided.

This information was compiled and ten (10) copies were submitted to the United States Coast Guard in Washington, D.C. on 11 July 1983. Modifications to this proposal and additional information were later developed and submitted due to Coast Guard comments and requests during the evaluation stages.

PROPOSAL EVALUATION/SELECTION PROCESS

Prior to the receipt of the proposals, an evaluation organization was developed. As mentioned above, negotiated procurement by the Coast Guard was governed by Department of Transportation (DOT) Order 4200.11. DOT 4200.11 provided the basic structure and guidelines for the proposal evaluation and selection process.

A Source Evaluation Board (SEB) was created specifically for the WPB acquisition. The SEB membership, approximately fourteen (14) strong, was comprised of both Coast Guard personnel and DOT staff members. The SEB was the governing group for the acquisition for the duration of the evaluation. The SEB reported to the Source Selection Officer (SSO) who was responsible for actually selecting the competitive range and the eventual winner. The SSO was aided in his decision making process through communications with the SEB.

Assisting the SEB with the actual proposal evaluation was the task of the technical teams. There were three (3) teams for the WPB acquisition: engineering, mission suitability, and business management. Each team was headed by a SEB member who was responsible for reporting the team's findings to the SEB. The individual team members, 5-10 per team, were not SEB members nor were they permitted to know the results of the other team evaluations. This assured the SEB and SSO the information and scores received from the individual teams were unbiased.

Upon receipt of the nine (9+) plus proposals, the evaluation process began. The sheer volume of each proposal and the large number of offerers ensured the technical teams that there would be many long evenings and weekends in the months to come. A typical engineering proposal consisted of up to 6-10 full size binders, each filled to capacity.

The first task tackled by the evaluation teams was to read the proposals and determine if there was any ambiguous information. An example of a typical ambiguity would be if an equipment list called out a specific main engine and the propulsion configuration drawing showed a different model. The intent of finding the ambiguities was so that, upon their resolution, the Coast Guard would fully understand the proposals. Once a proposal was completely read, a list of ambiguities for each offerer was compiled and forwarded to the respective bidders.

Upon the resolution of all the ambiguities in early August 1983, the proposals were then screened for deficiencies. A deficiency was defined as a deviation from the RFP or COR requirements. An example of a deficiency, would be the proposal of a combined potable water stowage and 5-day production capacity of 2000 gallons rather than the COR-required combined storage and production capacity of 2200 gallons for the 5 days. Each proposal was carefully evaluated for deficiencies and the offerers were notified in writing of the deficiencies in late August 1983. In any communications with the offerers, extreme care was taken to treat each identically. In the written notification of deficiency, only the deficiency was described, not the remedy.

Once the offerer's responses to the deficiencies were received, the actual proposal evaluation and scoring began. The evaluation criteria was established by the RFP as previously discussed. The intent of the initial evaluation was to aid the SEB, and ultimately the SSO, in determining the competitive range. The initial evaluation was completed in October 1983, and the proposed competitive range was established. However, the SSO determined that another round of deficiencies was required prior to excluding any offerers. Thus, if any offerer could not resolve the identified deficiency, they would be deleted from the competitive range.

In early November 1983, the letter containing the final round of deficiencies was issued. Since an improper response to these deficiencies spelled elimination, the offerers were given the opportunity to discuss the deficiencies face-to-face with the Coast Guard. Nearly all of the offerers took this opportunity to present their case.

Selected members of the SEB and the evaluation teams visited operational parent craft during this time period. They traveled to Europe, the Middle East, the Far East, Central America, and South America to inspect and ride on the proposed parent craft.

Following the receipt of the deficiency responses in November 1983, the technical teams once again evaluated the proposals and forwarded the results to the SEB. The SEB then determined the final competitive range eliminating a number of the offerers.

The Coast Guard then conducted fact finding visits and pre-award surveys on the remaining offerers. The purpose of these visits was to gain further information on the various technical aspects of the proposals as well as to survey the offerer's proposed construction facilities. Fact finding and the pre-award surveys occurred in mid-December 1983.

Following the production site visits by the Coast Guard, the offerers traveled to Washington, D.C. to participate in both technical and cost negotiations. It was during negotiations in January 1984 that, for the first time, the offerer could discuss in detail all the strengths and weaknesses of their proposals with the Coast Guard. Negotiations in Washington lasted approximately one week but did not formally conclude until 'best and final' offers were received.

All had progressed rather smoothly until the final competitive range had been set. Following the elimination of the non-competitive offerers, the WPB procurement's history of court actions commenced. Eastern Marine Incorporated of Panama City, Florida, sought to enjoin the Coast Guard from awarding the WPB contract in January 1984. This action was brought forth in the U.S. Court of Claims. Although Eastern Marine failed to gain an injunction, a trial date in March 1984 was established. Eastern Marine also sought relief through the Government Accounting Office (GAO).

Eastern Marine's contention held that their removal of the centerline propulsion system, thus creating a twin shaft WPB, did not violate the parent craft concept. The Coast Guard maintained this action, which modified a triple shaft parent craft into a twin shaft WPB, violated the parent craft concept by changing the propulsion configuration and underwater appendages. In both the GAO protest and U.S. Court of Claims, the Coast Guard prevailed over Eastern Marine.

Over the course of the negotiations, the RFP was amended to include options for up to seventeen (17) WPB's. The increase from options for nine (9) to seventeen (17) WPB's was guided by the knowledge that the aging 95' WPB fleet would require replacement in short order.

Best and final offers were requested in late March 1984. The best and final request also included the increase in quantity for optional boats to seventeen (17). The receipt of the best and final offers from the contractors meant yet another round of evaluations. Each of the proposals was completely evaluated and strengths and weaknesses for each design and yard were compiled.

In a negotiated procurement, the SSO selects the awardee on a basis which need not be the lowest price. Thus, it was important for the SEB, through the use of the technical team reports, to give the SSO their most accurate assessment of the remaining offerers. In making the award selection, the SSO had the following to assist him in the decision: cost information, contractor performance on prior contracts, and detailed technical information on the boats.

The WPB contract was awarded to Marine Power and Equipment Co., Inc. of Seattle, Washington on 11 May 1984. The 76-million dollar contract was for the construction of sixteen (16) WPB's. The parent craft for the Marine Power WPB was a Korean PKM Class patrol boat. The WPB was to be 109' in length overall and was to be powered by twin MTU 12V538TB92 diesel engines.

It was not long after the award to Marine Power that an unsuccessful competitor, Bollinger Machine Shop & Shipyard, Inc., of Lockport, Louisiana, sought to enjoin the Coast Guard from continuing the construction contract with Marine Power. In a series of court actions in the U.S. District Court, Bollinger attacked the award to Marine Power. The basis for their court case rested in the parent craft concept.

Bollinger argued that Marine Power had made an improper main engine substitution in the process of converting the parent craft to a WPB. The WPB was to be equipped with 12-cylinder 538 series MTU engines, whereas the parent craft had employed the 538 series MTU engines with more cylinders. Bollinger argued that this type of substitution violated the propulsion configuration identicality requirements in the COR since the 12-cylinder engine did not possess superior power over the parent engine. The superior power was required by the COR for unequal equipment substitutions.

In a U.S. District Court hearing which occurred over 9 and 10 July 1984, Bollinger presented this and other arguments to the Court. On 13 July 1984, the U.S. District Court judge presiding over the case rendered his decision in favor of Bollinger. However, in his decision, the judge acknowledged that he did not have the authority to award the contract to Bollinger but remanded it to the Coast Guard for action consistent with his decision.

On 16 July 1984, the Coast Guard issued a stop work order to Marine Power and began to evaluate the various options available. It was not until 8 August 1984 that the Coast Guard terminated the Marine Power contract for the convenience of the government and subsequently awarded the contract to Bollinger for fifteen (15) patrol boats.

Prior to the award to Bollinger, Marine Power had sought to enjoin the Coast Guard from awarding to Bollinger in the U.S. Court of Claims. Marine Power did not prevail in this case and the Coast Guard awarded a contract to Bollinger on 8 August 1984. Following the award, Marine Power sought relief in the U.S. District Court before the same judge who had heard the Bollinger case. Marine Power did not prevail in this case either. There have been subsequent court actions regarding the WPB contract, however, they remain relatively insignificant compared to the prior cases discussed.

WPB CHARACTERISTICS/DESCRIPTION

The principal characteristics of the Island Class Patrol Boats are as follows:

Length overall	110'-0"
Length between perpendiculars	104'-0-1/2"
Beam, molded at deck amidships	21'-1"
Depth, molded at deck amidships	10'-11-1/4"
Drag in 104'-0-1/2" LBP length	2'-0"
Draft, mean to design waterline	6'-5-3/4"
Hull	Steel
Superstructure	Aluminum
Framing	Longitudinal
Design displacement (7'-3" baseline draft)	165.12 L. tons
Displacement, light ship	117.3 L. tons
Complement	18
Provisions for	5 days
Fresh water (100%)	1,760 gallons
Fuel oil (95%)	10,382 gallons
Main engines	Two (2) Paxman Valenta 16 - RP200M V type; 3000 BHP at - 1500 RPM (max)
Shaft horsepower	2910 SHP @ 802 RPM (max)
Propellers	Two (2) 49.6" dia., 61" - pitch (0.7R), 5-bladed, - skewed
Generators	Two (2) Caterpillar 3304T, - 99KW
Armament	One (1) 20mm gun, MK-16 - Two (2) machine guns, M-60
Maximum speed	For official use only
Maximum sustained cruising speed (M.S.S.)	For official use only
Economical cruising speed (B.E.S.)	12.8 knots (at half load)
Maximum cruising range at B.E.S.	3,380 N.M.
Maximum cruising range (24 hrs. @ M.S.S.) (96 hrs. @ B.E.S.)	1,853 N.M.

The below deck volume of the patrol boats is arranged to accommodate sixteen (16) people. Just aft of the forepeak is a compartment with six (6) bunks and lockers and a head with shower and wash basin. The next compartment aft includes the CPO quarters with two (2) berths, a head with shower and wash basin, and the magazine. Below this space is the forward auxiliary machinery space containing the fresh water pumps and the sewage system pump. Next aft is the mess area with seating for twelve (12), the galley, a storeroom, and a head. Next aft is the engine room. Aft of the engine room is a berthing area with eight (8) bunks and a head with shower, urinal, and wash basin.

Entertainment centers are provided in both the mess area and the after berthing compartment. Each center includes a color TV and an AM/FM stereo receiver with cassette deck. The center in the mess area also has a VCR. Interior access is provided all the way from the forward 6-man berthing compartment to the aft 8-man berthing compartment by watertight, quick acting doors in the transverse watertight bulkheads. Access to the engine room is through noise isolation vestibules.

The after two compartments contain the batteries and the steering gear respectively. Access to these compartments is via main deck hatches. The battery compartment also houses the battery chargers, the air conditioning compressor, the spare RHI outboard motor, the towing hawser stowage reel, and other miscellaneous storage. The steering gear compartment also houses the RHI davit hydraulic power pack and miscellaneous storage.

On the main deck level forward in the deckhouse is the electronics space. Aft of the electronics space on the starboard side is the executive officer's stateroom with private head and shower. Aft in the deckhouse is the commanding officer's stateroom with private head and shower.

The pilot house is on the 01 level and includes a rather complete set of patrol boat command and control equipment. The open bridge is a half level above the pilot house and duplicates some of the equipment in the pilot house. The patrol boat can be fully controlled from either location. A listing of the electronics and control equipment is not provided because of the law enforcement mission of these patrol boats.

Aft of the deckhouse is the removable engine room hatch. This bolted hatch comes off in two (2) pieces to allow access for major maintenance and main engine replacement. The two (2) hatch pieces can be lifted on and off using the RHI davit.

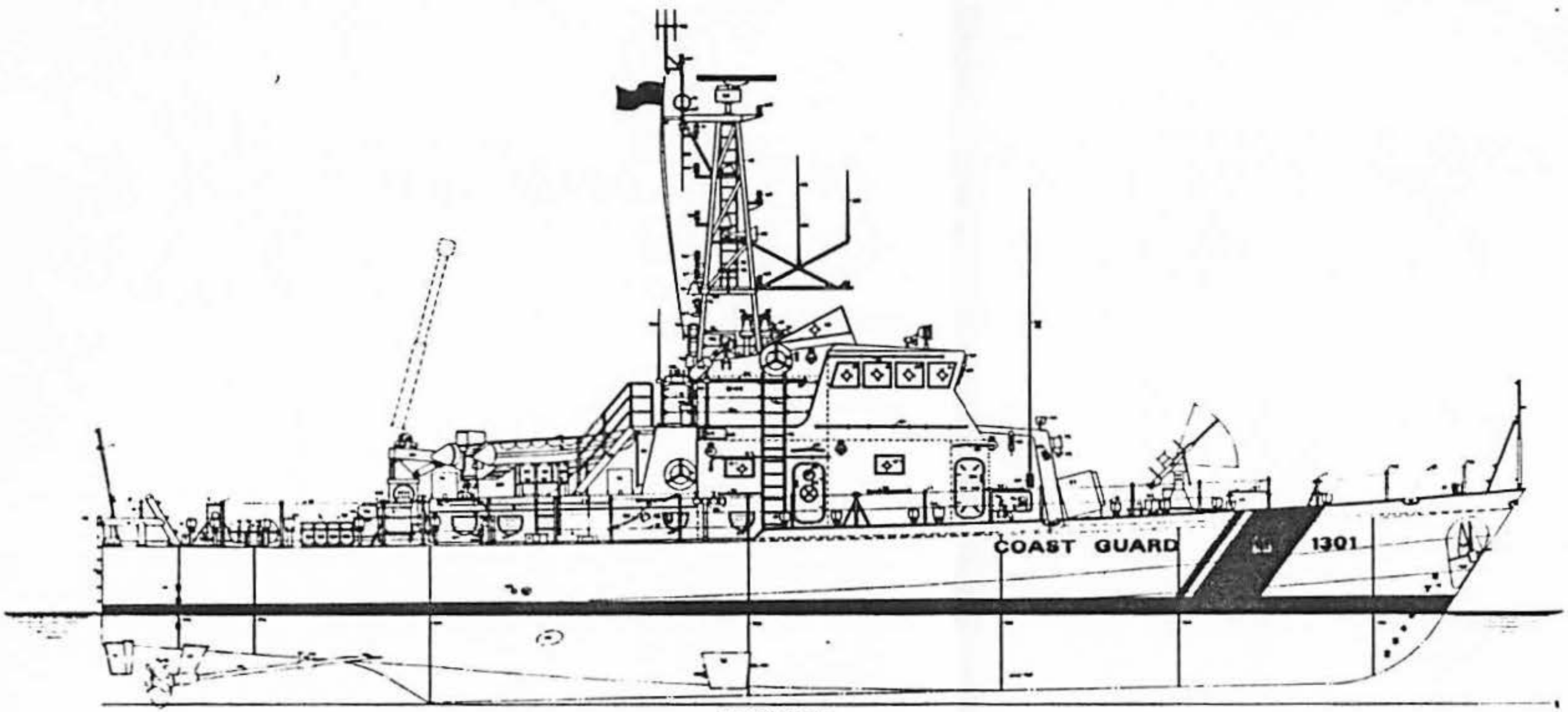
<u>Structural Overview</u>

The Island Class WPB hull structure has remained unchanged from that of the parent craft. The shell plating of the vessel is British Standard 4360 GR 43A steel which has a yield strength of 40 ksi and an ultimate strength of 60 ksi with better notch toughness than A36. The shell plating varies from 7# for the underwater body to 4# in the transom and bow areas. Insert plates of 10# and 5/8" are used in various areas.

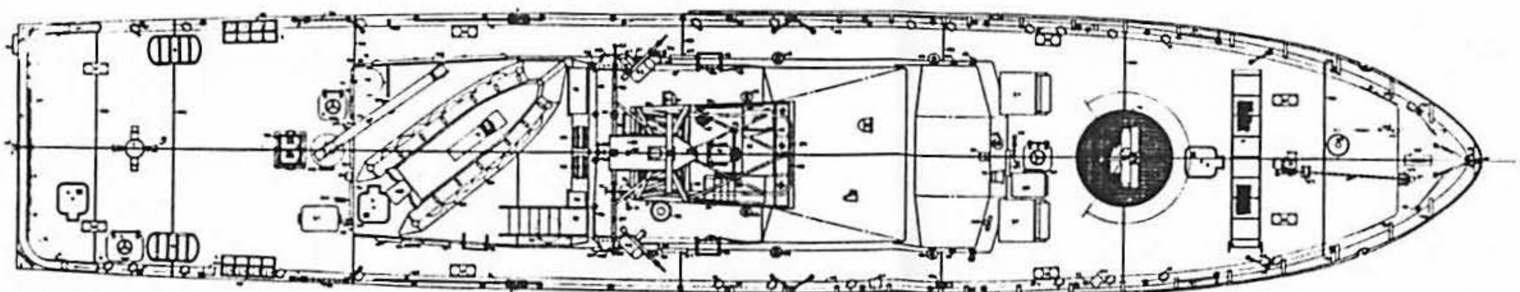
The hull structure is based on a primary system of longitudinal framing with eighteen (18) longitudinals either side of centerline and a maximum spacing of fourteen (14") inches. Longitudinal girders incorporating the main engine foundation start at transverse bulkhead 17 and continues aft to the transom. A secondary transverse system incorporating deep frames is employed using a variable frame spacing to save weight. The spacing used is 12" and 24" in the bow and transom sections respectively to a maximum of 48" in some portions of the midbody. The transverse bulkheads are corrugated for additional strength and are located at Frames 8, 13, 17, 22, 38, 31.5, and 33. This results in dividing the WPB into eight (8) watertight compartments. Placement of these bulkheads is according to parent craft except the forepeak bulkhead was moved aft one (1') foot and an additional bulkhead was added at FR 31.5. These changes were dictated by stability considerations.

Non-integral interior foundations are constructed of A36 steel since the superior strength of the parent craft steel is not required.

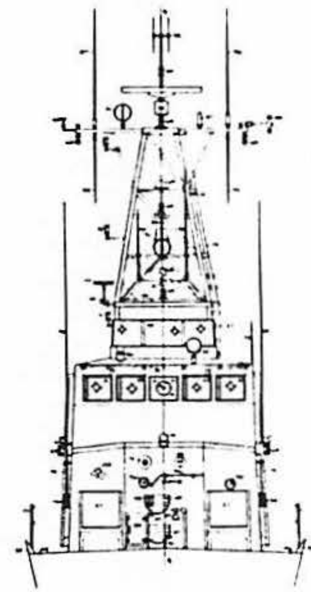
The main deck and superstructure are constructed of 5086 aluminum. The main deck contains nine (9) longitudinals either side of centerline. One noticeable departure from the parent craft construction technique is the use of a DuPont developed Detacouple joint to provide the transition between the aluminum main deck and the steel hull. This joint and the main deck plating were riveted on the parent craft. Past Coast Guard experience on the 82 foot and the 95 foot WPB's has indicated that riveted steel to aluminum joints are susceptible to leaking and have a tendency to develop excessive corrosion during the latter part of the vessel's service life. Detacouple is well



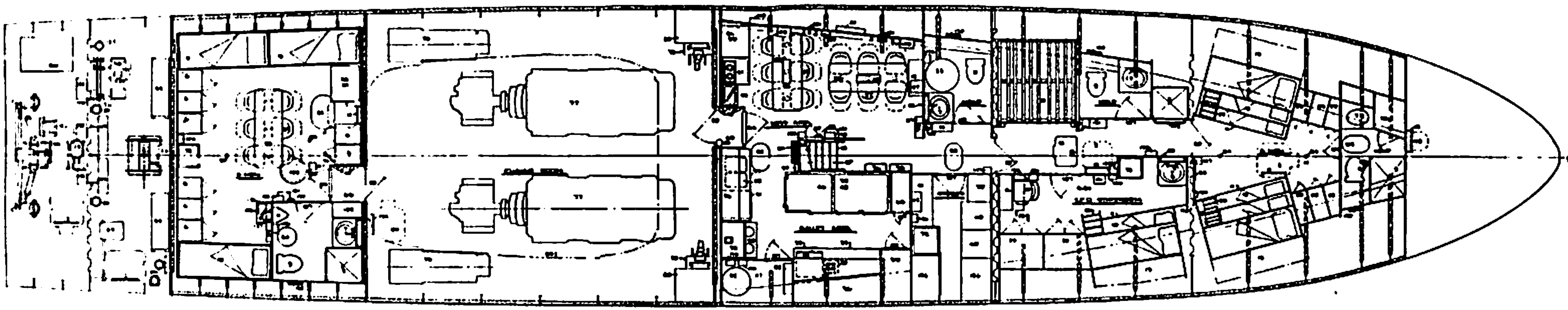
OUTBOARD PROFILE



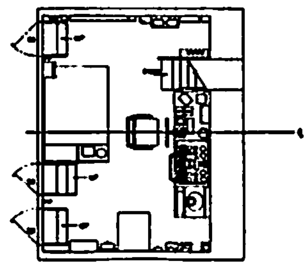
PLAN - WEATHER DECK



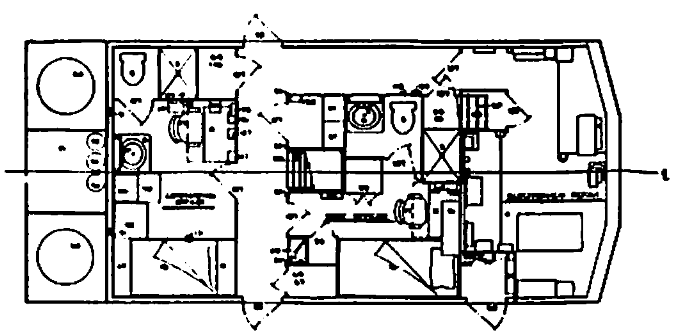
VIEW LOOKING AFT



PLAN VIEW



PILOT HOUSE LAYOUT



MAIN DECK HOUSE LAYOUT

proven in service and allows the use of welding in joining the aluminum and steel. The use of Detacouple for steel to aluminum structural joints was required by the COR.

A section of steel is present between the deck edge and the Detacouple joint. This avoids a stress concentration at the deck edge and also allows steel piping to be run without a galvanic couple. A steel flat bar with a section of Detacouple is used to tie the aluminum main deck into the corrugated bulkheads. Bollinger also elected to weld rather than rivet the main deck plating and deckhouse.

In response to Coast Guard requirements stipulated within the WPB COR, Bollinger incorporated the following structural elements into the WPB:

(1) A being towed arrangement;
(2) A rigid hull inflatable (RHI) boat davit with foundation;
(3) A towing bitt;
(4) Expanded fuel capacity; and
(5) Main deck strengthening for future weapons.

The being towed arrangement required placing a padeye between frames 0 and 1 with supporting structure.

The RHI davit foundation is located just aft of the engine room hatch. The foundation basically consists of a ringed support with brackets and attachments to transverse bulkhead 28 and transverse frame 29.

The towing bitt is designed to a factor of safety of 1.5 based on the yield strength of the material under an applied load equal to the breaking strength of six (6") inch circumference double braided nylon. The towing bitt structure consists of a ringed support and supporting brackets between transverse bulkheads 31.5 and 33. Further discussion of the towing bitt and the RHI davit are provided below in the special features portion of this paper.

The fuel tanks under the aft quarters, frames 28-31.5, were added to expand the WPB's fuel capacity by 2,322 gallons.

As required by the COR, the foundation for the 20mm machine gun on the foredeck was designed to carry the recoil of a 25mm machine gun to be retrofitted in the future. The after deck has also been strengthened to allow future retrofit of four (4) Penguin Missile Box Launchers.

Main Propulsion

The WPB's main propulsion plant consists of twin diesel engines, Paxman 16RP200M, capable of developing 4000 HP at 1600 RPM, coupled to Zahnradfabrik (ZF) type 1500 reverse reduction gears. The gears have a reduction ratio of 1.839:1 and are capable of transmitting full torque in both directions of rotation. The engines have rack limit stops set at 3000 HP in order not to over torque the four (4") inch parent craft shafts. The shafts are limited to 4" due to a COR requirements that the "WPB shall possess the same underwater appendage as the parent craft". The shafts are supported in three (3) locations by rubber cutless bearings. Thrust and directional control is accomplished using a single lever control connected by cable to a Regulateurs Europa (RE) (a subsidiary of Paxman) "CONSERV" unit. The CONSERV unit is an electro-hydraulic control unit which uses oil furnished by the reduction gear to operate a cylinder which, in turn, controls a push-push cable to the engine governor and microswitch actuated solenoids which control the direction of rotation of the reduction gear. The input to the CONSERV unit is via a sprocket which actuates a 4-way valve which ports oil to the cylinder. The system incorporates a manual feedback mechanism to re-center the 4-way valve. The system also incorporates time delays to prevent damage to the reduction gear during forward/reverse changes.

The main propulsion diesels exhaust through the side of the hull. There is a small, above water exhaust for slow speed operation and a larger underwater exhaust for high speed operations. An automatically controlled set of exhaust flapper valves shifts from the above water to the underwater exhaust at 1000 engine RPM. Main engine cooling water is discharged into the high speed exhaust pipe just outboard of the flapper valve.

Mechanical and Electrical Systems

The vessel's electrical system is comprised of three (3) distribution systems: 440 VAC, 117 VAC, and 24 VDC. Three-phase 440VAC is supplied by two (2) Caterpillar 3304BT engines driving 99 KW Kato generators. Single phase 117 VAC is furnished via a dry type 3-phase transformer. The 24 VDC system consists of two (2) battery banks and rectifier power supplies. The DC system provides for engine starting, ship's service, and emergency lighting. In addition, the system incorporates two (2) 1000 watt power inverters (24 VDC to 115 VAC) to provide emergency 115 VAC.

Auxiliaries

The HVAC system utilizes five (5) zones with air handlers to provide heating and cooling. Air conditioning is accomplished with a 10-ton compressor using a direct expansion system (selected to save weight) while heating is supplied by electric coils in the air handlers.

A normally dry, single firemain supplies five (5) fire stations and the magazine sprinkling system from either of two (2) 30 HP fire pumps.

A bilge system using two (2) 5 HP pumps and a common main, designed in accordance with ABS, is installed. This also includes a 2 GPM oil-water separator.

Fresh potable water is furnished from 1760 gallons of tankage supplemented by a 100 gallon per day reverse osmosis desalinator. Potable water pressure pumps and a pressure tank supply the ship's potable water system, including two (2) quick recovery type hot water heaters (120 gallon forward, 40 gallon aft).

A fixed Halon 1301 system is provided to extinguish fires in the engine room and is capable of being actuated from the pilot house or at the forward entrance to the engine room. The system automatically shuts down the main engines and generators before release of the Halon.

A hydraulic follow up steering system is furnished that allows steering from either the pilot house or open bridge consoles. The pilot house and open bridge helm pumps may be used as a manual backup in the event of power failure. There is an additional manual, emergency cable steering system in after steering.

Roll fin stabilizers are provided and will be addressed in the special features part of this paper.

The sewage collection, holding, and transfer system is a sewage-powered eductor vacuum collection type and includes a pump eductor loop which takes suction from the holding tank at ambient pressure. Waste water is propelled through the eductor suction chamber and discharged into the holding tank to maintain a vacuum in the collection piping. The pump cycles when required and an integral check valve maintains the vacuum in the collection piping.

SPECIAL FEATURES

Roll Fins

The COR established guidelines to be followed in determining the general seakeeping characteristics of the vessel. The vertical accelerations at the operator's station should not exceed 1.25g at 25 knots in sea state 3 (4.6 ft. significant wave height). At 28 knots, vertical accelerations should not exceed 1.5g in sea state 3.

A computer analysis of the seakeeping characteristics of the vessel was run by Vosper utilizing their in-house seakeeping program. The results showed that the vessel was well within the specified ranges for crew comfort, even though this analysis did not take into account an active fin stabilization system that was installed on the parent craft. The original intention of Bollinger was to offer the stabilizers as an optional item. However, after much deliberation on the words in the COR, it was decided that even though the vessel met requirements, and a substantial cost reduction could be offered without the system, this deletion could be interpreted as a change from parent craft hull form and appendages. Therefore, the stabilizers were included in the base price of the vessel.

The fin system utilized for the WPB is identical to the parent craft with the exception of the power pack assembly. The fin itself is of a rudder section configuration. The fins are semi-balanced and protrude through the vessel's side just aft of the forward engine room bulkhead, or just aft of midships. The fins are powered by individual power units, one located just above each fin assembly. The parent craft was fitted with one centrally located tank to power both fins, but due to the increased equipment located in the engine room, there was not enough space to do this so it was opted to utilize individual tanks and power packs. This concept does allow additional redundancy---should one tank become contaminated the vessel can operate on one fin with reduced stabilization. With one tank only, if there are problems, the entire system goes down.

The system is designed for a fin travel of 28 degrees at the best economical speed. For higher speed ranges, it is necessary to reduce the angle in order to keep the fin lift force constant. This is accomplished by a selector switch on the control panel in the pilot house. It is necessary to use reduced fin angle at speeds above 18 knots. It should be pointed out that the system is designed to withstand, without damage, the full fin movement at maximum vessel speed as a safety precaution should the control switch not be adjusted.

The amount of fin angle required is determined by a gyro unit and a pendulum unit which senses the rate and angle of roll of the vessel and transmits this signal to an amplifier unit where they are compared with the signals from the feedback indicator on the fin stock. The resultant error signal causes the fins to move a proportionate amount to compensate for the forces of the sea state.

It is, of course, optimum from a performance standpoint, to have the fins installed in the neutral flow line axis so the least amount of drag will be seen by the vessel. As no accurate information existed as to the definition of this flow line, the units were installed with the O axis parallel to the half load (trials condition) waterline. At trials, should it prove necessary, the top plate assembly could be slightly rotated in either plane with the fins centered until the neutral flow line was determined. As the vessel met speed requirements and there was no evidence of cavitation damage to the fins, it was determined that the fins were in, or very close to, the neutral flow line, and no adjustment was required.

RHI/RHI Davit

The COR required that the WPB be fitted with an Avon SR5 rescue boat with a 65 H.P. outboard motor. This boat is an RHI (rigid hull inflatable) that is 5.4 meters (17'-7" approx.) in overall length, not inclusive of the outboard motor. The davit (or davits) to handle this vessel had to be capable of launching/retrieving the RHI from either side of the WPB. The COR required that the davit be capable of power slew, and that it be operational in up to sea state 5.

The parent craft was fitted with a manual davit and a 12' dinghy, therefore, it was obvious that changes had to be made in this area. The first approach was to use two (2) electric slew davits, one port and one starboard. This met the requirements, however launching was a problem, as without powered lift and winching capability the sea state 5 requirement was virtually impossible to meet. The twin davit concept also gave a substantial weight penalty over that of a single davit, so it was elected to go with a single davit with a knuckle boom. Further investigation showed that the concept of the knuckle boom was not without problems. Regulatory body requirements state that 'personnel handling cranes' be designed and built utilizing a safety factor of 6 on the ultimate of the material. To design the knuckle boom crane to meet the 6:1 factor of safety, the weight of the unit would go up substantially above that allowable in the weight estimate.

A set of specifications was prepared and provided to numerous crane/davit manufacturers asking for proposals on their products to be submitted. A major concern was the weight of the unit, as the design weight estimate needed to be met. It soon became apparent that no off-the-shelf unit could meet performance parameters, while staying within the allowable weight range. It therefore became necessary to have a crane designed specifically for our application. A contract was entered into with a crane designer/manufacturer with performance parameters and weight as the design factors. It was determined that it was better to use aluminum for the crane pedestal, this being an added benefit as the tub/deck interface connection was much simpler. The crane was fitted with a telescoping boom which made stowage when not in use much easier. A separate hydraulic power pack was located in the machinery spaces. To provide ease of operation in higher sea states, 360 degree rotation, boom lift/lower, and winch in/out functions were included in the design. The results of the design effort was a compact crane that met all COR requirements and was within the budgeted weight.

As the davit was designed with a 6:1 factor of safety, it was necessary to exceed this with the structure supporting the davit. This was a problem as the lightly skinned vessel did not provide a great amount of structural rigidity. Investigations showed that the deck was insufficient to provide the strength required. It was necessary to penetrate the deck with the crane tub, and to transmit a portion of the load forward into the engine room bulkhead with brackets. Side and after support stanchions were added from the tub base downward to longitudinal bottom girders. These girders had to be locally increased in size to handle the transmitted loads of the crane. The crane was fitted with local controls on the pedestal, and also with remote electro-hydraulic control stations. These stations are located at the 01 deck level, just aft of the open bridge, port and starboard. The operator can handle all functions at either of these stations while maintaining maximum visibility of the launch/retrieve operation.

Towing Bitt

The COR requirement was for the towing bitt to be designed to handle the breaking strength of a 6" circumference double braided nylon line with a safety factor of 1.5 on yield. A towing bar was to be fitted across the transom to keep the tow line above the deck.

The parent craft, which was designed solely for coastal patrol with no consideration for SAR, was only fitted with a towing padeye near the transom. Again, it was obvious that major design changes needed to be made to meet the requirements.

Several factors made the design of the tow bitt a major undertaking: a) the towing bar raised the level of the tow rope approximately 24" above the deck, thereby creating larger moments in the tow bitt due to the elevated position of the crossbar; b) the towing bar allowed the rope to slide from one side of the vessel to the other in turns until contacting the stop posts, therefore the bitt had to be designed to withstand maximum pull within a range of 120 degrees (60 degrees either side of the vessel center line), not just fore and aft; and c) the light deck structure did not allow for easy structural reinforcement of the bitt.

The initial approach was to go with a double post towing bitt, so that each vertical post could assume its share of the load. However, when considering that the tow line can move from side to side, it can be seen that there is the distinct possibility of only one post seeing the major portion of the loading. This required that each post be designed to carry most of the design load, therefore, it was advantageous to design one single cross-type bitt that was sufficient for the entire load range.

As the resultant moment was so large, it was necessary to go with quite a large post to offer the required strength. This post penetrates through the main deck, where it is tied into a series of longitudinal and transverse girders, transmitting the loads forward and aft to transverse bulkheads and outboard to the side shell. It was also necessary to increase the strength of the transverse bulkheads to further transmit the loads downward into the bottom structure.

Mast

The amount of navigational and electronic antennas to be located on the WPB was much greater than that fitted on the parent craft. This required a much larger platform therefore, a new mast had to be designed. From a previous study on the antenna arrangements, the location of each antenna was known, therefore a mast was fitted around the antennas. Initial design efforts tried to parallel the mast of the parent craft as much as possible, just to a larger scale. The base was changed to a 'handle bar' configuration to allow maximum astern visibility with the radar mounted on this platform and the antennas on the structure above.

An analysis of this mast was run utilizing GSTRUDL. This analysis showed that the mast as configured was quite flexible, especially in a fore and aft axis. It was determined that to increase the stiffness of the mast to an acceptable level, a severe weight penalty would be incurred. It was decided to abandon the Parent concept and proceed with a totally different design.

The final concept utilized a lattice work truss structure extending upward from the after portion of the open bridge. This was determined to be the best concept in terms of strength/stiffness versus weight. For optimum weight reduction, a tripod (3-legged) structure would have been the best alternative, but as astern visibility was a very critical matter to the Coast Guard, it was opted to use a 4-legged structure with legs located at the outer perimeters of the open bridge. This structure, which proved to be quite stiff, allowed the relocation of the radar antenna at a much higher position, which offered better performance. It also provided a much more stable platform for the antennas, lights, and the increased strength was welcome when mounting the bell and navigation horn, both of which were much larger and heavier than initially assumed.

Noise Control

The noise control criteria was specified in the COR issued by the Coast Guard. A detailed discussion of these criteria will not be presented here. It is sufficient to say that they were quite rigid. It should also be noted that Speech Interference Level (SIL) requirements were in effect for the pilot house and electronics space.

To make noise control doubly difficult, the vessel did not easily lend itself to noise treatment. The vessel, as previously noted, is a light scantling, flexible vessel with extremely high horsepower. Weight was extremely critical to speed, and the design weight needed to be maintained, not only contractually, but in order to achieve guaranteed speed. Noise measurements taken on the parent craft showed values in some frequencies of as much as 20-30 Db excess. It should be noted that no noise control measures were fitted on the parent craft other than resilient engine mounts, which were a U.S. Coast Guard COR requirement also.

A noise study was performed on the vessel by Bolt, Beranek and Newman, Inc., and recommendations were made to Bollinger. The study showed that the major problem, based on the parent craft data, would be in the low frequency ranges, therefore, maximum effort was expended to find suitable absorption treatments for frequencies less than 125Hz. It was also necessary for this treatment to be as lightweight as possible, which, in itself, does not lend to low frequency absorption. The study showed that it was necessary to fit 'floating rooms' in certain areas to eliminate structure-borne noise. These areas were the after quarters, the galley/mess area, and the captain's stateroom. This treatment consisted of resilient pads glued to the structural deck with a false deck laying on the pads. The area between the structural and false decks was fitted with insulation. All equipment, furniture, and joiner walls in these areas were located on the floating floor. The joiner walls throughout the vessel were designed as floating walls to further eliminate structure-borne noise transmission.

It was also necessary to 'clad' certain bulkheads and overhead areas. The first approach considered was to use layers of leaded glass, but this proved to have installation difficulties, as well as being extremely heavy. The final decision was to use a foam type insulation that incorporated interior foil layers. Test results showed that this material provided equivalent noise attenuation to the leaded glass at only a fraction of the weight. The engine room bulkheads and the overheads of the lower quarters were fitted with this treatment.

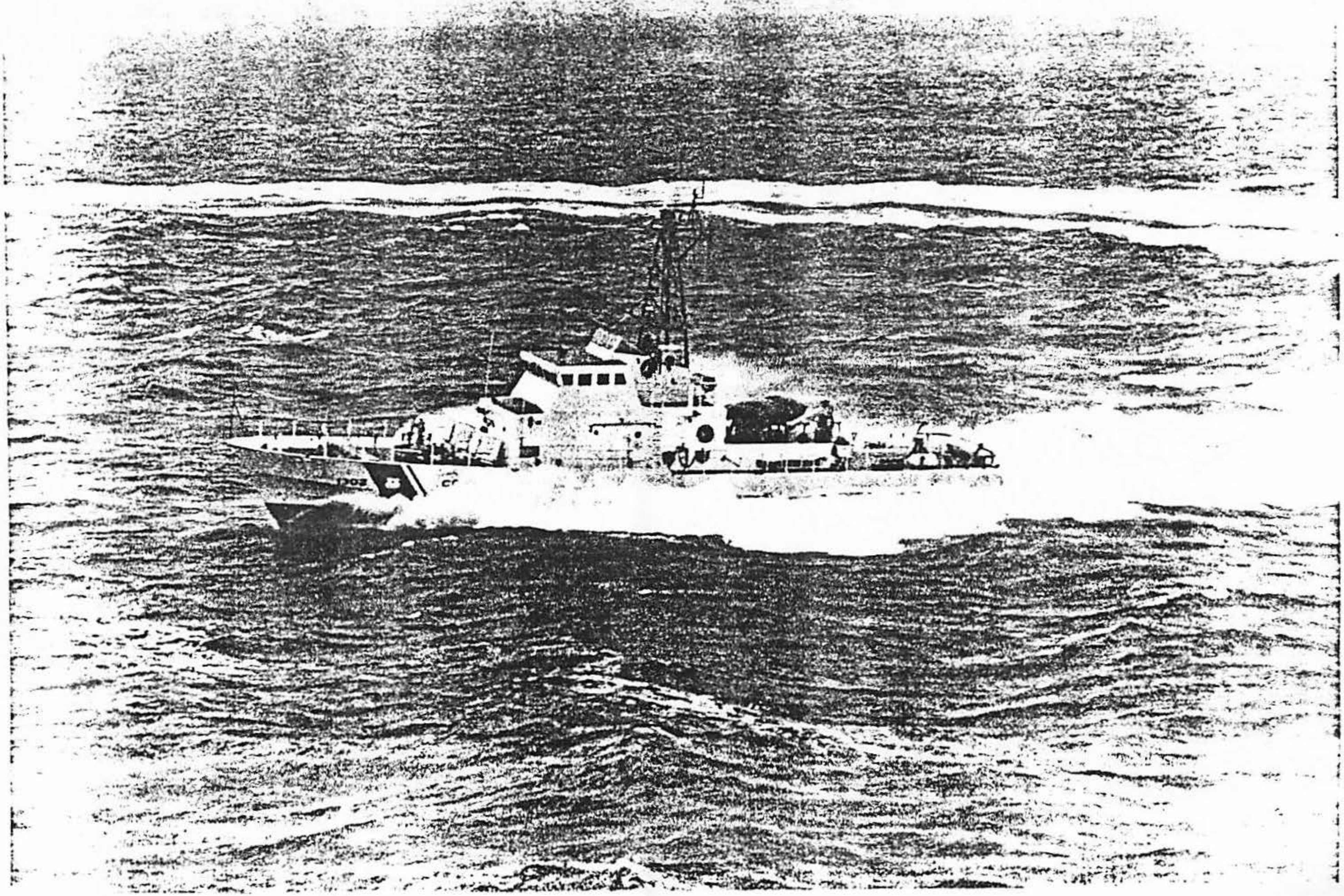
The major contributor of low frequency noise was the propeller. It was recommended that improvements could be made in the underwater configuration to reduce these problems. Due to the guidelines of the contract, this could not be done, so other options were investigated. It was finally determined that a cut-constrained damping layer fitted over the propellers would be the best solution for this problem. This consisted of a high density elastomeric damping material sandwiched between the hull plating and a cover plate. This layer was fitted on the bottom plating inside the battery room area and after steering (lazarette), or in the vicinity of the propellers and after strut. The cover plates were tuned to provide maximum low frequency damping. As previously noted, the COR mandated parent craft conformance required that the main diesels be isolation mounted. However, the same parent craft conformance also required the reduction gear to be hard mounted which was non-optimum for noise attenuation. To further reduce structure-borne vibration and noise generated by machinery, all equipment in the WPB was fitted on resilient mounts.

PERFORMANCE TRIALS

Prior to leaving the yard for builder's trials, an excessive amount of fuel/water was loaded aboard. When displacement figures were run just prior to trials, it was determined that the actual displacement was at 151 long tons instead of the 1/2 load trials displacement of 141 long tons. Rather than off-load fuel/water, it was determined to proceed with builder's trials at the increased displacement and bring the vessel back to the half load displacement for acceptance trials. The rack angle of the main engines was set so that the developed horsepower did not over stress the shaft which was identical to the parent craft. Speed runs were conducted over a measured course, both into the wind and with the wind. Runs were also done with the stabilizers active and then additional runs made with them centered at zero degrees and locked.

The weather for the speed test during builder's trials was less than ideal, with 25 knot steady winds and 4'-6' seas. The vessel, even in these conditions and being overweight, still performed very well. As the trials progressed, fuel and water were consumed and the displacement came down; the WPB easily exceeded the contract speed requirements even though several tons heavier than actual half load. The actual top speed cannot be published but it was in excess of 26 knots. It was also shown that the stabilizers being active did not have a measurable effect on the vessel's speed. This is probably due to the fact that the increased drag is offset by the truer course achieved with the stabilizers active. It was observed that with the stabilizers centered, more rudder corrections were required than with them active, thereby slightly increasing the time interval to transverse the course. As always, the shortest distance between two points is a straight line.

A representative speed/power curve



of the WPB is shown in Figure 1. As can be seen, even though the vessel has a displacement hull, the curve resembles that of a planing hull, with a well defined 'hump'. The curve is fairly steep up to 'hump', where it begins to level off. It should be noted that this curve is averages of down wind/up wind runs. This hump was very noticeable on trials, as when the vessel exceeded hump speed, it gave the sensation of starting down hill, with the speed very rapidly increasing.

As previously noted, the WPB is a displacement hull constructed of very light weight materials. A notable feature of the fore body is that of a spray chine or knuckle fitted below the main deck. This chine is designed to deflect the spray outward away from the hull to provide a dryer deck (see Fig. 2). This proved to work extremely well both at high speeds and in heavy weather.

The first day of builder's trials was run in moderately heavy weather with 6'-8' seas. There was a slight problem with the exhaust valve controller, so the speed achieved was only approximately 20 knots. Even with seas as rough as this, very little water came on deck. The only evidence of deck spray was that blown across by quartering winds. Figure 3 shows the WPB on trials, and the effectiveness of the spray chine is apparent.

The active stabilization fins proved to make the vessel very comfortable to ride. Several tests were run with stabilizers on/off to observe their effectiveness. With the vessel running across the waves (6'-8') with the stabilizers active at a speed of approximately 20 knots, the amount of roll was less than 5 degrees either side of center line. When the stabilizers were centered, this roll increased to 20-25 degrees either side of center line. In a high speed turn with maximum rudder, the heel angle increased from 11 degrees with the stabilizers operating to 15 degrees with the stabilizers centered.

The vessel, while being very maneuverable at speed, proved to be touchy to handle in docking. This is due to the small rudder area, the major portion of which is outside the slip stream of the propeller, and due to the high thrust produced by engine clutch-in. The small rudder area is necessary so that at the high speeds the vessel can achieve, the rudders do not stall out or the overturning moment created by the rudder cause the vessel to broach. It proved necessary to utilize the engines (twin screwing) when working the vessel in confined spaces.

Trials results showed that the rate of heading change at high speed was virtually unchanged at rudder angles greater than 20 degrees. Even though the rudders have the capability to turn 30 degrees either side of center line, 20 degrees proved to provide the same turning power, but produced less drag on the vessel allowing it to maintain better speed in the turns.

When the vessel returned from builder's trials and was drydocked, cavitation damage was apparent on the propellers. This erosion was at the root of each blade about 75 per cent of the chord length aft. It was determined that the best approach to solve the problem was to build a model of the propeller shaft and strut and test it in the cavitation tunnel at Vosper. This was done, and the cavitation pattern was duplicated. It began at the leading edge of the root at approximately 25 knots. Leading edge modifications were done, however, none reduced the cavitation to an acceptable level. Finally, it was determined that it would be necessary to put cavitation relief holes in the blades, which solved the problem in the tunnel. This fix was confirmed by trials on later vessels.

None of the parent craft experienced any cavitation problems throughout their operational history. It can only be assumed that the additional displacement of the WPB and associated heavier blade loading caused the cavitation patterns and erosion. This may have also been effected by the fact that contract required speed was exceeded. Thus, the propellers were operating at higher than design speeds.

As mentioned previously, extensive noise control treatments were designed for the WPB. A decision was made to purposely leave some of these treatments out for builder's trials with the hope that some of the recommendations were unnecessary. Specifically, the cut-constrained damping above the propellers and the side shell insulation in the engine room were left out.

Trials results showed that noise excesses were in evidence in many areas. Most of the excesses were in the low frequency ranges---63, 126, and 250 Hz. These are blade rate frequencies. It was obvious that the cut-constrained damping needed to be installed. Most of the higher frequency excesses were due to short circuits and unplugged holes through structure.

Between builder's trials and

110' WPB

SPEED VERSUS POWER

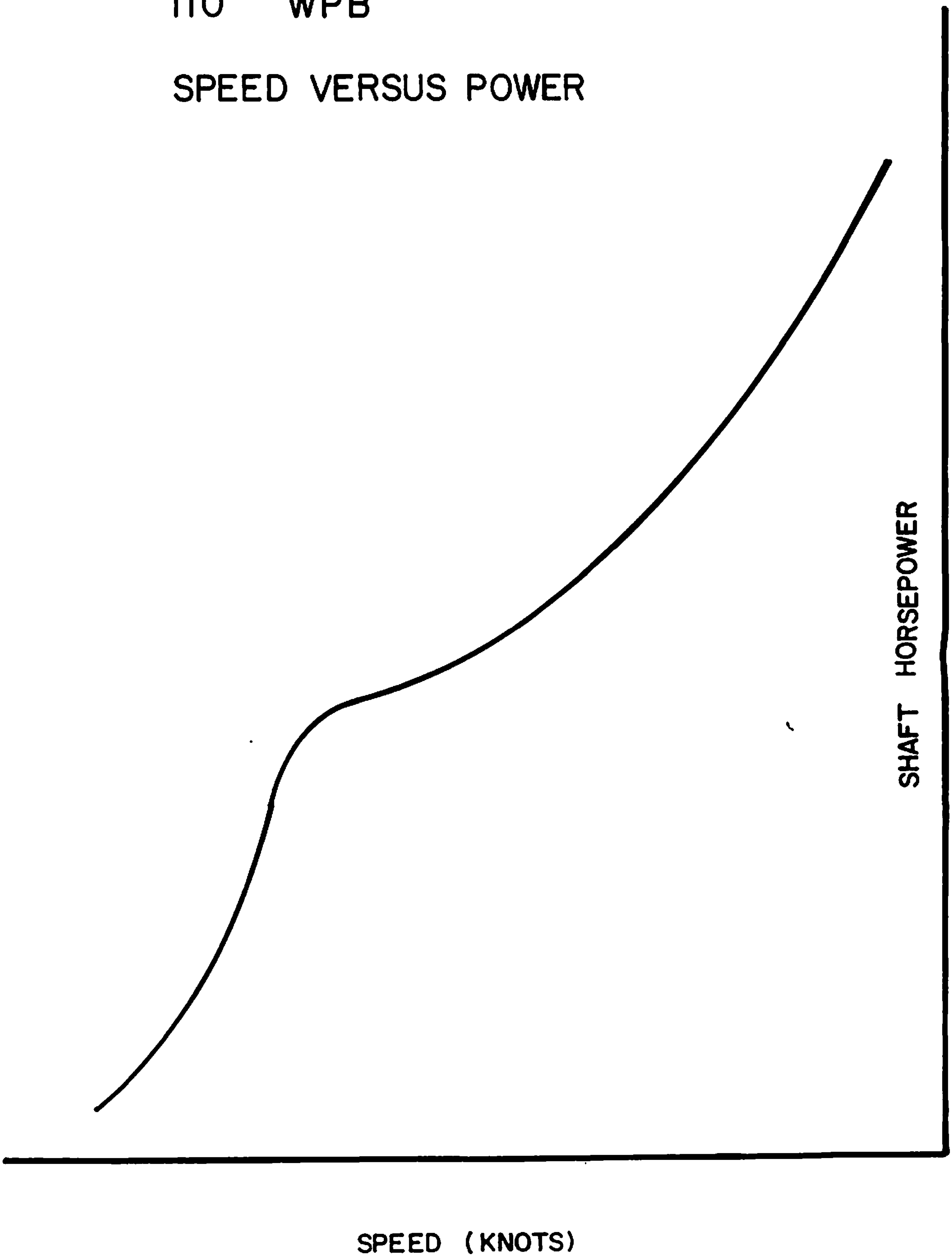


FIGURE 1

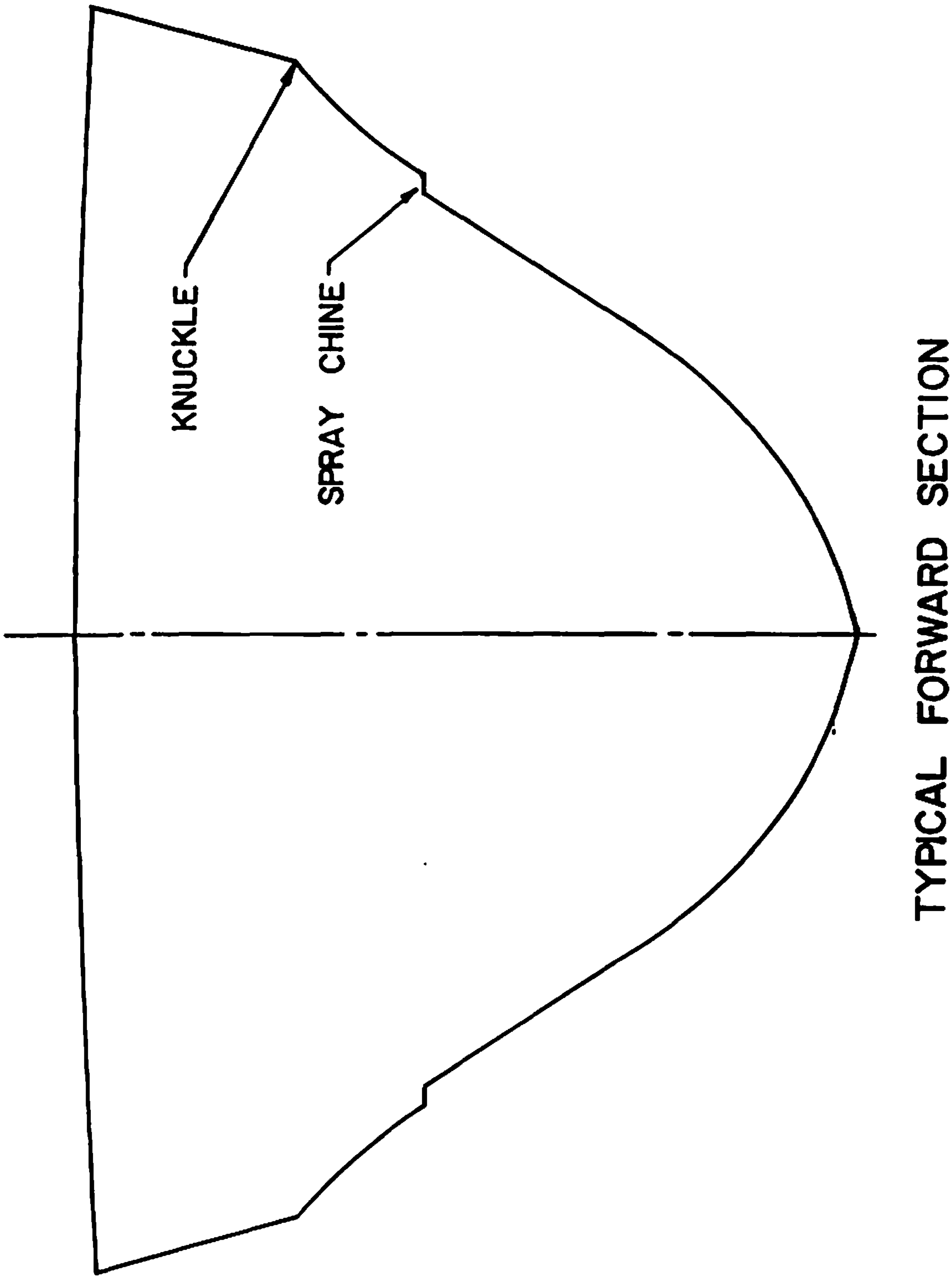


FIGURE 2

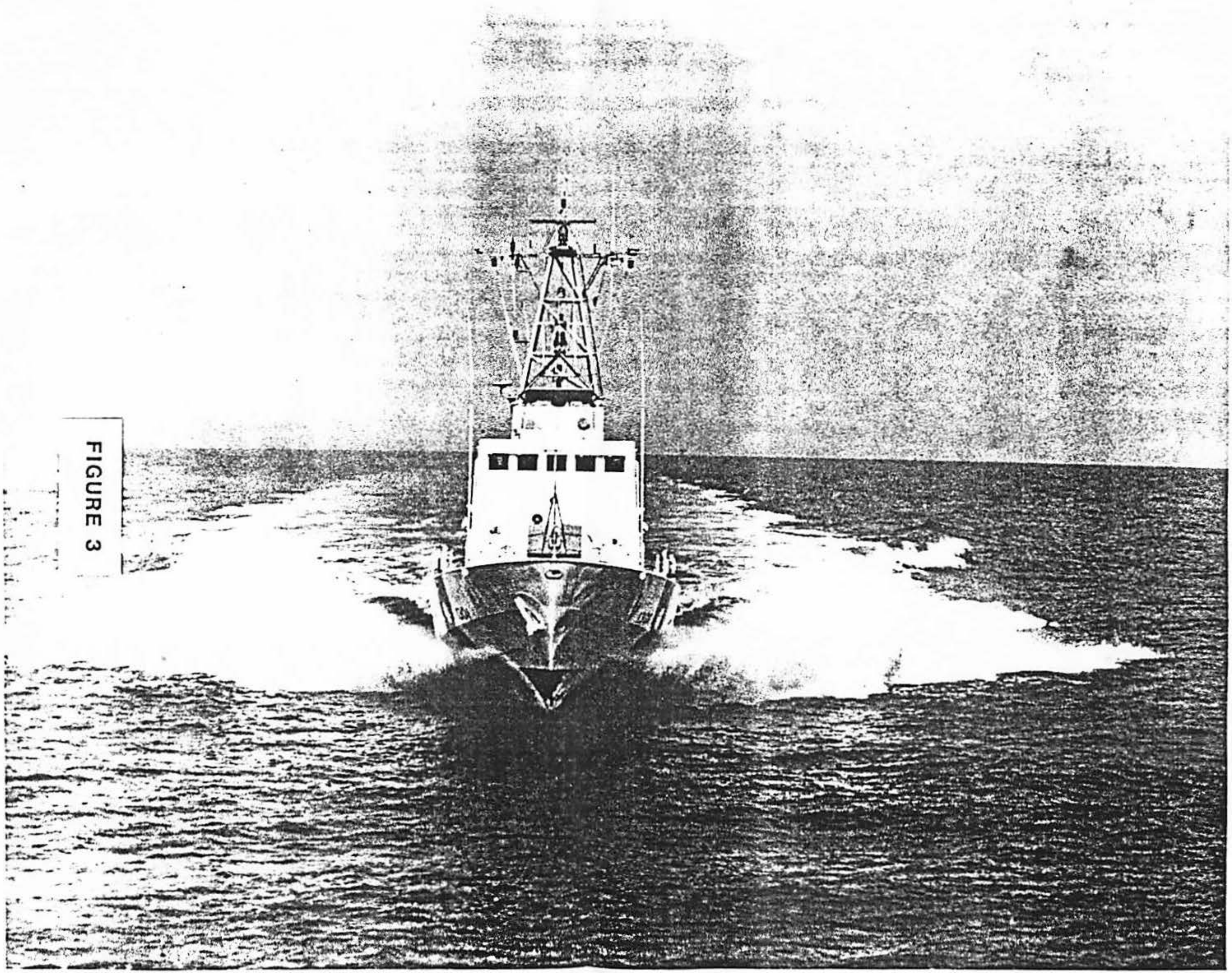


FIGURE 3

acceptance trials, all recommended noise treatments were installed, all short circuits repaired, and all holes plugged. Test results at acceptance trials showed a marked improvement in noise levels. All high frequency excesses were eliminated and, while low frequency levels in blade rate frequencies still exceeded the specifications, they were also markedly reduced. Noise levels, when measured at the center of the rooms were within specification, with the sides and corners of the room going above specification, due to the build up of pressure levels in these corners. The excesses were not of the magnitude that cause hearing damage, and being very low frequency, are not noticeable to the ear. It was anticipated that solving the propeller cavitation problems would reduce the low frequency levels even more, however, this was not confirmed from the trials of subsequent vessels.

CONCLUSION

The Coast Guard has contracted with Bollinger Machine Shop & Shipyard, Inc. for sixteen (16) new Island Class 110 foot patrol boats. The first boat of the new class was accepted by the Coast Guard on 15 November 1985. This procurement which had early delivery as one of its most important elements, has been accomplished in approximately 3-1/2 years. When the initial Commerce Business Daily notice is compared to the finished product, it can be seen that the requirements and their relative importance were adjusted some over the course of the program.

The parent craft approach has been successful in procuring a new class of very capable patrol boats with acceptable characteristics. In spite of using a proven design, there have still been some unanticipated problems such as the propeller cavitation erosion. However, there do not appear to be any uncorrectable problems which will prevent the Island Class patrol boats from being excellent Coast Guard cutters.

The procurement approach of using a 'proven design' to 'quickly' procure a new class of patrol boat does work, but it is not the same as buying a Chevrolet off the production line.

APPENDIX A

Excerpt from Commerce Business Daily, August 23, 1982

19. SMALL, HIGH SPEED CUTTERS

8 each---(patrol boats) for drug and alien interdiction in the Southeast U.S. and Caribbean. Early delivery of these patrol boats is critical to the national interest in stemming illegal maritime transhipments through the Caribbean region into the Southeastern U.S. Desired delivery is four (4) patrol boats by 30 November 1983 and four (4) more patrol boats by May 1984. Due to the need to put fully operational cutters in service as soon as possible, only proven designs to be produced by builders with proven past and present production capability will be considered. We are specially interested in patrol boat which are available for purchase, are currently under construction or can be built to meet desired delivery dates. Expressions of interest should include adequate information to fully define your performance characteristics. At the minimum, the reply should address each of the performance characteristics below, as well as the production rate and lead time achievable at the builder's facility. The government will, in this early stage of market research and analysis, entertain any patrol boat configuration suitable for independent offshore service as a lightly armed patrol boat. In order to solicit the maximum competition, only the broadcast of characteristics are listed below. This does not preclude the government from developing a tighter focus on the performance and hardware characteristics as more information becomes available to this office. Desired performance characteristics: Maximum speed: Minimum acceptable 25 knots---30 knots or more desired---Endurance: minimum 5 days---Accommodations: 2 officer, 2 CPO, 14 enlisted---Range: 24 hours at full power, 96 hours at cruise speed of 10 knots or greater---Small boat: 5 meter rigid hull inflatable---Seakeeping: Excellent---Armament: Manual 20 mm machine gun and small arms---Subdivision: two compartment damaged stability---Machinery & Electrical: supportable from U.S. sources.

2. The method of procurement has not been established at this time. Potential vendors may be required to demonstrate their design with model and/or full scale testing as part of the acquisition cycle. If such testing has been done, test data should be submitted. Any data or information marked proprietary will be safeguarded.

3. A second CBD notice will be issued which will provide potential vendors with better defined performance specifications. The most important factor in this anticipated procurement is the required delivery schedule. Interested firms are invited to submit the requested information and relevant

comments. To be useful, this information must be received within 15 days of this publication. This is not a request for proposal nor does the government intend to pay for the preparation or delivery of the information solicited.