NAVAL ENGINEERING

High Endurance Cutter 1963

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Background

In 1966, the Coast Guard will commission her first new high endurance cutter in 20 years. A service life of 25 years for Coast Guard ship replacement purposes was established for planning by a 1949 management survey (EBASCO report). In 1959 a "Committee Report on Requirements for Coast Guard Vessels" laid the basis for ship renewal through 1970. This called for construction of a new high endurance class ship to replace the 327-foot WPG Class (hull numbers 31-37), the 311-foot WAVP Class (370-387), and the 255-foot WPG Class (39-44, 64-70). Thirty-eight new ships were projected, with 24 being completed or under construction by 1970. Lack of money has slowed the program to the present 10-year-replacement program which would complete the 38th new ship in 1977.

The Fiscal Year 1964 budget includes $14 million for the construction of one high endurance cutter. Figure 1 is a 1962 concept of the design. The topside configuration is more clearly defined in Figure 2, an artist's 1963 conception. Preliminary design was started in July 1961; the hull lines were drawn in August and September 1962; and the contract plans and specifications were completed in July 1963. The ship will be built in a commercial shipyard with a machinery package furnished by the Government. The separate machinery contract calls for an 18,000 shaft horsepower gas turbine, a 3500 shaft horsepower diesel, a reduction gear, a controllable pitch propeller, and an integrated control system for each of two shafts.

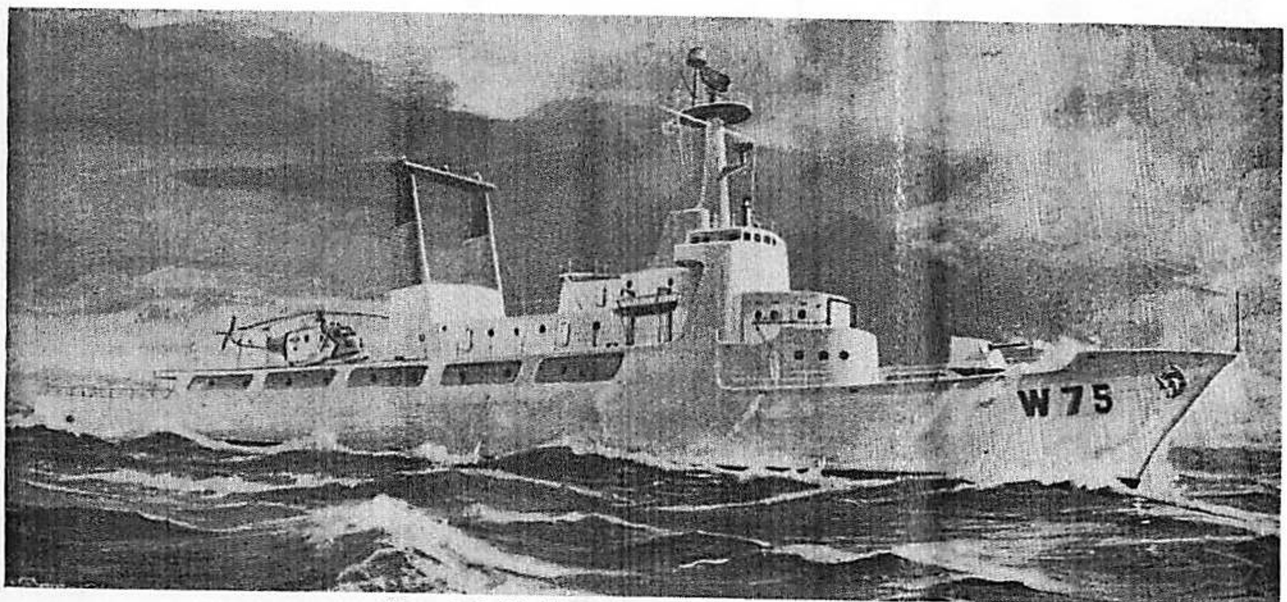

Figure 1. Original Design Conception of 350-foot WPG.

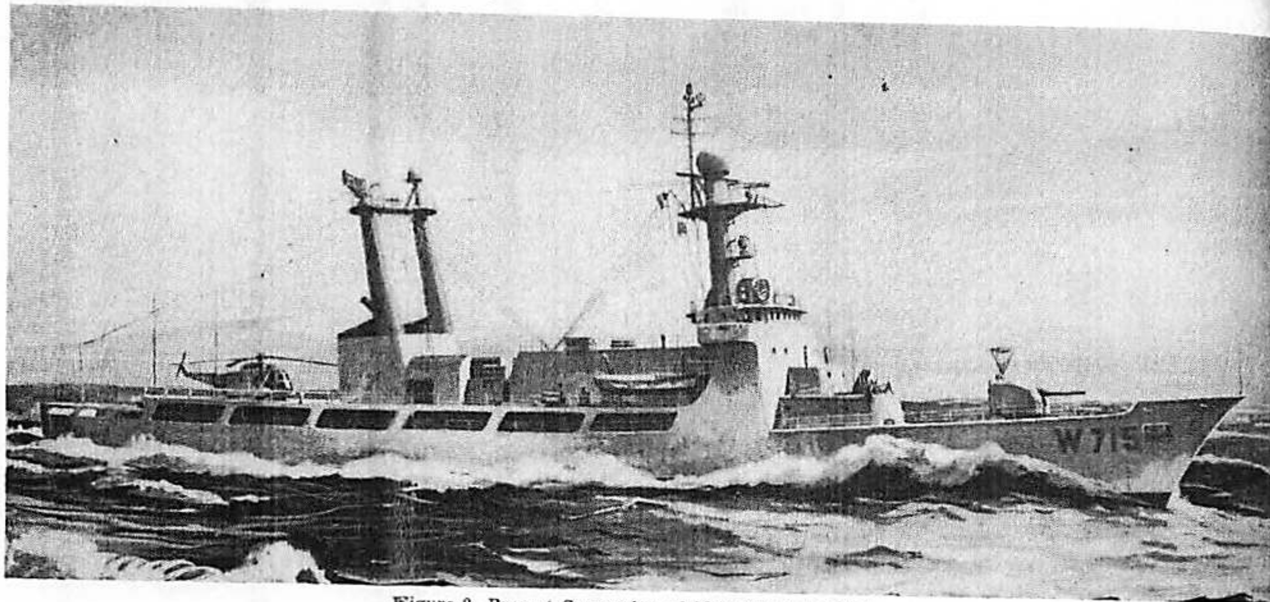

Figure 2. Present Conception of New 350-foot WPG.

Similar Ships

There are no combined diesel gas turbine ships in the world with 18,000 shaft horsepower gas turbines installed. The Danish Navy has plans to install a comparable size gas turbine soon. The German Navy has four controllable pitch ships of the KÖLN Class, first commissioned in 1961. Each has two 3,000 horsepower diesel engines plus a 13,000 horsepower gas turbine on each shaft for a total of 38,000 horsepower at full power. The British Royal Navy has two classes, the frigate HMS ASHANTI with several others of her class and the destroyer leader HMS DEVONSHIRE and her class. HMS ASHANTI has single shaft fixed-pitch propeller with a steam turbine of 15,000 horsepower, and a gas turbine of 7500 horsepower. HMS DEVONSHIRE has two similar gas turbines plus the steam turbine on each of two shafts. The Royal Navy uses clutches and reverse gears for maneuvering. No U. S. Navy gas-turbine ships of this size are expected before 1963. The displacement and length of the new WPG is close to the DE 1037 class of destroyer escorts (DE 1037-1038) and the DD 692 class of World War II destroyers. The latter class of ships is still the backbone of the Navy detroyer fleet. The high endurance cutter is bigger than the DE 1006 class and smaller than the DE 1040 class now being constructed by the U. S. Navy. All of the above DE's are post-war-built single screw, steam-turbine powered burning Navy special fuel oil. Recent destroyer escorts use diesel oil in their boilers. Table 1 compares these ships and the new high endurance cutter. Table 2 compares the new with the existing Coast Guard Cutters.

Table 1.

Nationality	Germany	United Kingdom	United Kingdom	United States	United States	United States	United States	United States	United States
Name / Class	KOLN Frigate	ASHANTI Frigate	DEVONSHIRE Missile Destroyer	DE1040 Destroyer Escort	WPG Coast Guard	DE1006 Destroyer Escort	DE1033 Destroyer Escort	DE1037 Destroyer Escort	DD692 Destroyer
Displacement (F.L. Tons)	2800	2700	6200	3400	2750	1900	1950	2600	3300
Length (Waterline)	345′	350′	505′	—	350′	—	—	350′	—
Length (Overall)	358′	360′	520′	414′	378′	314′	312′	371.5′	376.5′
Beam	34′	42.5′	54′	44′	42′	36.7′	39′	40.5′	40.7′
Draft	12′	13.2′	16′	18′ (max)	13.5′	9.2′ (mean)	10′ (mean)	18′ (max)	19′ (max)
Diesel/Shaft	2-3,000	None	None	None	1-3,500	None	4-3,000	None	None
Steam Turbine/Shaft	None	15,000	15,000	35,000	None	20,000	None	Yes	30,000
Gas Turbine/Shaft	1-13,000	1-7,500	2-7,500	—	1-18,000	None	None	None	None
No. of Shafts	2	1	2	1	2	1	1	1	2
Total SHP	38,000	22,500	60,000	35,000	36,000*	20,000	12,000	?	60,000
Speed Max (Knots)	32	28	32.5	—	29	25	—	—	33
Propellers	V.P.	F.P.	F.P.	F.P.	V.P.	F.P.	F.P.	F.P.	F.P.
Completed	1960	1961	1962	Building	Planned	1954	1959	1963	1944

*Diesel engines not used at maximum speed.

Data on the above ships, except for the planned Coast Guard WPG, was taken from *Jane's Fighting Ships*, 1962-1963 Edition.

Class
Displacement (Tons)
Length (Waterline)
Length (Overall)
Beam
Draft
Superstructure
Hull
Shaft Horsepower
Speed (Max)
Speed (Cruising)
Endurance (Miles at max. speed)
Endurance (Miles at cruis. speed)
Fuel Capacity (Tons)
Fuel Capacity-Aviation (Tons)
Fresh Water (Gals)
Number of Generators
Installed Generating Capacity

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Table 2.

Class	350' WPG	327'WPG	255'WPG	WAVP
Displacement (Tons)	2750	2827	1913	2800
Length (Waterline)	350'	308'	250'	—
Length (Overall)	378'	327'	255'	311'
Beam	42'	41'	43'	41'
Draft	13'-6"	15'	17'	14'
Superstructure	Aluminum	Steel	Steel	Steel
Hull	Steel	Steel	Steel	Steel
Shaft Horsepower	36,000	6,200	4,600	6,200
Speed (Max)	29	20	18	18
Speed (Cruising)	20	15	15	15
Endurance (Miles at max. speed)	2000	3500	5720	8,000
Endurance (Miles at cruis. speed)	9600	7350	9700	14,000
Fuel Capacity (Tons)	732	516	440	533
Fuel Capacity-Aviation (Tons)	18	—	—	—
Fresh Water (Gals)	16,000	48,370	22,760	19,690
Number of Generators	3	2	2	4
Installed Generating Capacity	1500kw	680kw	430kw	600kw

Hull Design

The development of hull lines stressed seaworthiness as the primary consideration, with high speed a secondary consideration. Electronics said, "The longer the better for our antennas", and Naval Engineering, "The longer the better for seakeeping and speed." The jump to 29 knots was hopefully requested by ship operators. They sadly noted a lack of progress since the 1898 dash of the Revenue Cutter McCULLOCH from Manila to Hong Kong with the news of Dewey's victory. She made 18 knots. Today's CGC McCULLOCH does the same.

The bow sections were shaped to present a gradually increasing horizontal section to lifting seas. Two sets of lines, one with U sections and one with V sections forward, were drawn. Twenty-foot models of each and the 327-foot cutter, chosen for its seaworthiness capability, were built and tested at the David Taylor Model Basin. The U. S. Navy uses U vertical sections forward for improved speed and seaworthiness. The British Navy uses V vertical sections forward for the same reasons. Little difference was found in speed and seakeeping, but the better damage stability of the V lines, which increase in breadth at the waterline as the ship sinks, led to its selection. The horsepower-speed curve in Figure 3 shows the price paid for higher speed. The seakeeping model runs demonstrated that the new hull is superior to the 327-foot WPG. To further improve seakeeping, an anti-rolling tank of the Frahm passive type is installed. It takes up the full beam of the ship between frames 256 and 272 from the third deck up to the second deck. The flow of water in the tank from side to side is slowed by dams or weirs so that the water is out of phase with the motion of the ship. The flow of water to starboard while the ship is starting to roll to port reduces rolling amplitude 40 to 60 percent. Fin stabilizers were rejected because of their dependence on ship speed for stabilization. Gyro stabilizers were considered to be unsatisfactory because of weight. While the full passive tank system weighs 60 tons, it is considered a benefit in that it adds to the fuel capacity when the ship leaves port. To compensate for the loss of strength in the hull structure due to the large area required for the intake and exhaust ducts (9 by 6 feet) for each gas turbine, it was necessary to make the 01 deck a strength deck. High yield 80,000 psi (HY-80) tensile strength steel is used in the 01 (helicopter) deck from frame 175 aft and in the main deck, frames 183-273. This high strength steel was used to reduce the design weight of the helicopter deck.

Careful consideration was given to areas which are inaccessible and difficult to maintain. A special anti-corrosion feature is the "boxed-in" construction of structural members exposed to the weather. This type of construction replaces structural shapes, such as angles and T's, which are less than 5 inches in depth. Foundations for deck equipment will also be construc-

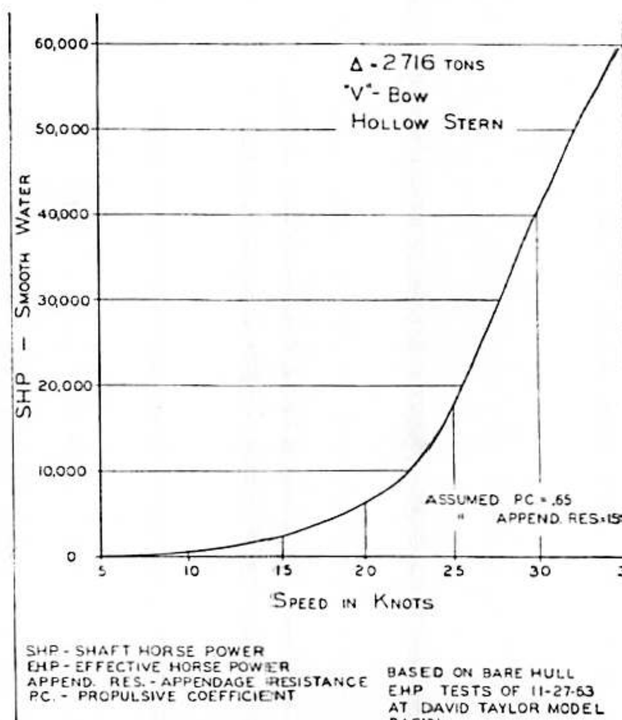


Figure 3. Preliminary SHP curve.

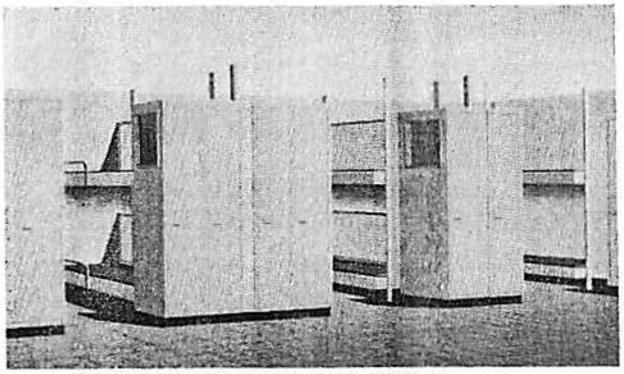


Figure 4. Crew's berthing.

ted in this manner using stainless steel studs in lieu of bolts for securing equipment.

The ship is longitudinally framed. It is of all welded construction except for the aluminum-to-steel connection. This joint depends on stainless steel Huck bolts for strength and the use of epoxy coal tar and rubber compounds for dissimilar metal isolation. The forward portion of the superstructure is steel up to and including the pilothouse deck. The superstructure is aluminum aft of frame 120 and above the 01 deck.

Small internal voids will be filled with polyurethane foam. No cofferdams are installed between fresh water and fuel oil tanks. The location of the fuel tanks below the third deck leads to a minimum number of voids and the maximum utilization of hull volume.

Arrangements

The sad truth is that not everything or everyone can be satisfied in an arrangement plan. Just as there are not enough billets for all the starlets journeying to Hollywood, so there is not enough deck space to install every-

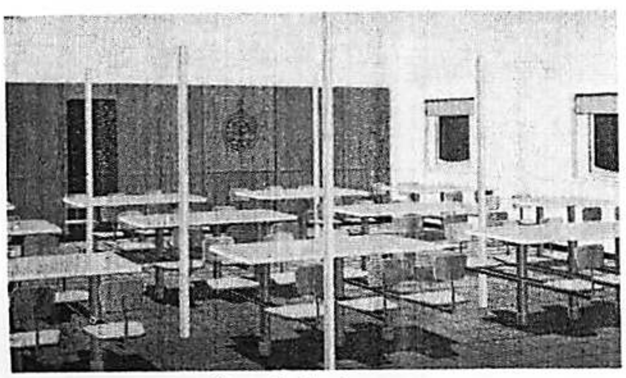


Figure 5. Crew's mess.

thing topside: that is, unless we do not object to capsizing on the maiden voyage as the HMS CAPTAIN did a century ago. Also, sadly, perhaps luckily, each person has incompatible ideas. The present outboard profile, inboard profile, and arrangements is a compromise of the conflicting ideas. The bridge is not on the same level as the Combat Information Center (CIC). Greater visibility is obtained by locating the bridge on the 03 deck. For better internal communication, a pneumatic tube message system is installed between CIC, Radio Room, and the Pilothouse. A mockup at the Coast Guard YARD will determine the exact configuration of the Pilothouse and CIC.

The balloon shelter doubles as a helicopter nose hangar and is big enough to allow attach-

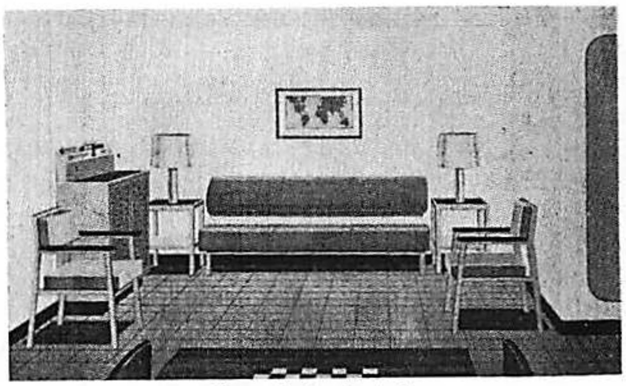
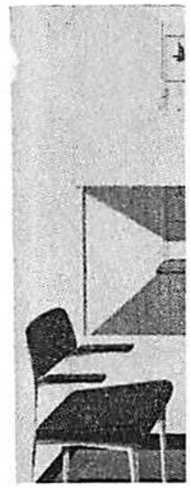
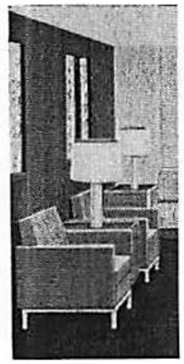


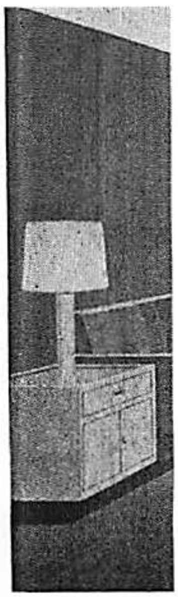
Figure 6. Crew's study.

ment of a telescoping hangar if service warrants. The twin aftermast serves a dual purpose, incorporating the separate exhaust stacks and giving another high platform for the installation of electronics equipment, each piece of which must be higher than every other. The gas-turbine intakes face inboard between the 02 and 03 deck levels. The engineroom ventilation intakes face outboard.

Interior arrangements, Figures 4 through 11, stress improved habitability. CPO's will be berthed in double staterooms amidships, one deck below the CPO mess. Crew's berthing is divided into three areas, each consisting of two compartments. The after compartment, in each case, has two high berths which provide accommodations for 30 men. One full-height locker, Figure 4, is available for each man in the berthing area. The forward compartment in each case has two 10-man berthing areas and







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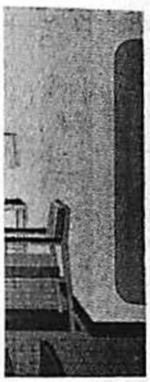

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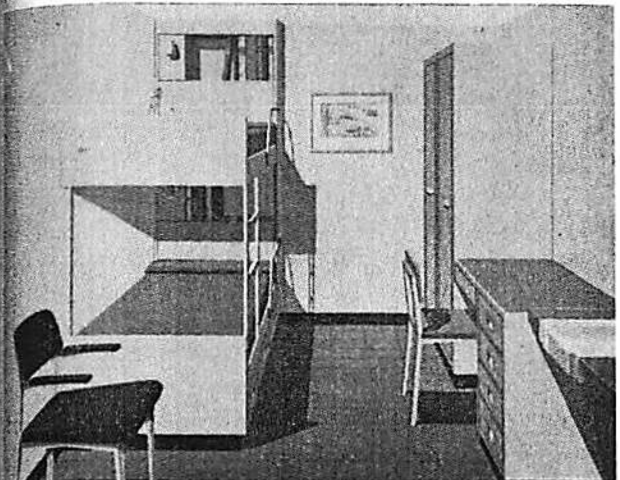

Figure 7. CPO's stateroom.

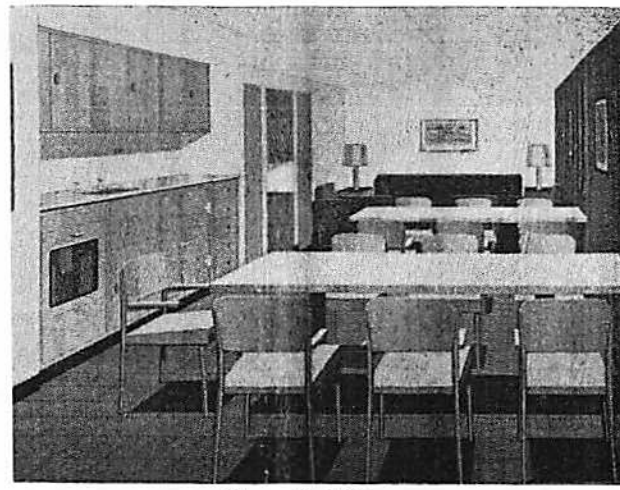

Figure 8. CPO's mess.

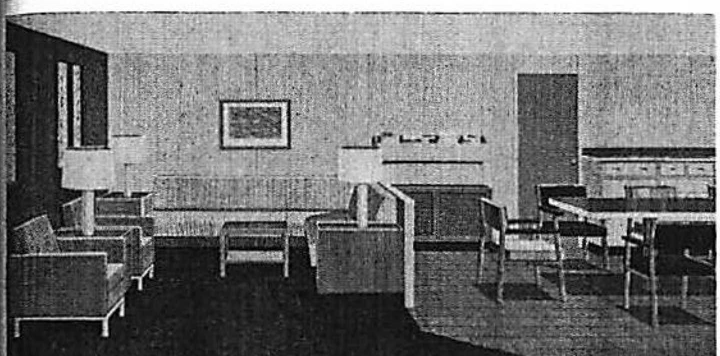

Figure 9. Wardroom.

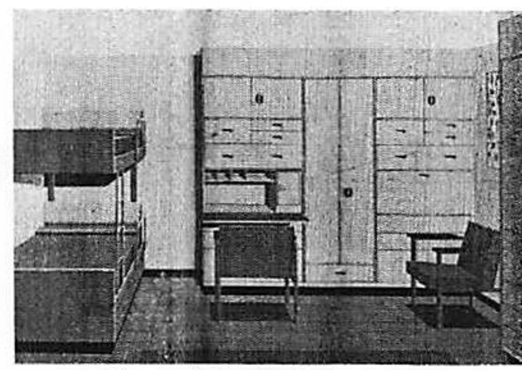

Figure 10. Double officer's stateroom.

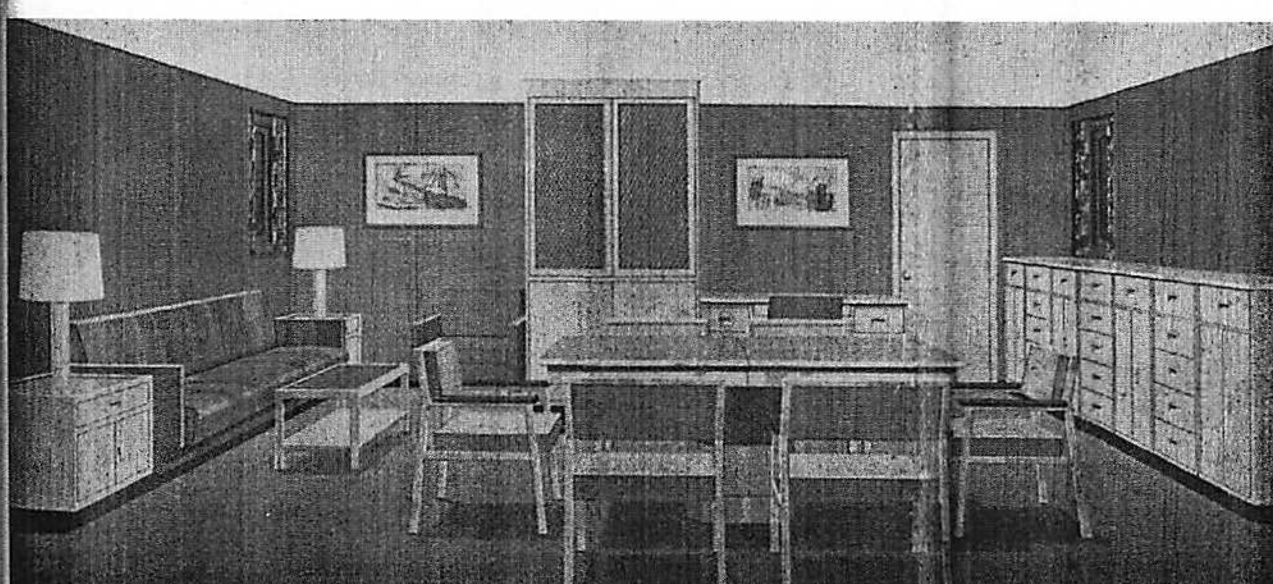

Figure 11. C.O.'s cabin.

a study area. Each of the 6 compartments has its own washroom and head facilities. The crew's mess seats 66, and is provided with a dispenser for milk or fruit juice, salad bar, ice cube maker, dual coffee maker, and utensil dispensers. The captain's cabin on the 02 level is flanked by his stateroom and a fleet commander's stateroom. There are four double and four single officer's staterooms just forward of the wardroom on the main deck. A head and shower is installed between each two adjacent staterooms. The executive officer's and engineer officer's staterooms are on the 01 deck just forward of a conference room and the operations office. The main deck wardroom is divided in eating and lounge areas.

Careful attention was given to the location of work shops and offices. The ordnance work shop is forward near the gun. The bosun's work shop and the first lieutenant's office are also forward on the second deck. The engineer's and electrician's work shops are just forward of the engineroom. The location of the engineer's storeroom, aft and remote from the work shops, is due to the absorption of the desirable amidships area by berthing.

Aerological and Oceanographic Features

The aerological office is located forward on the deck below the Combat Information Center rather than aft by the helicopter platform or balloon shelter as in present ships. This location improves weather data reception by shortening the antenna run from forward weather data-receiving antennas to the installed receivers. Externally-mounted weather probes will measure radiation, temperature, humidity and atmospheric pressure. By this means, personnel in the aerological office will have a continuous source of this vital surface information. Facilities for upper air observations will include a balloon inflation shelter which is larger than any presently projected balloon size.

Oceanographic features include a bow-mounted wave height sensor; a deep sea oceanographic winch, located within the superstructure and enclosed by a roller curtain door; an electronic bathythermograph winch; a standard bathythermograph winch; an oceanographic wet laboratory with Nansen bottle stowage; and an oceanographic laboratory.

Electronics

The uncertainties of ship operation in the year 2,000 are evidenced by the extra space devoted to electronics equipment. In the knowledge that any empty compartment designated in the design stages for future electronic equipment installation will be usurped by other activities, none was provided. Sufficient workbenches, tables and open areas are included in most of the electronic compartments to be used for future electronic expansion. The antenna array shown in Figure 2 gives a glimpse of the electronic capability of the ship.

On the foremast, radio direction finding, voice communications, balloon tracking radar, surface-search radar, searchlight and fire control radar antennas are installed. The air-search radar antenna is located on the starboard mainmast. A TACAN (Tactical Air Navigation System) antenna is located on the port mainmast. Other antennas are located as follows: receiving antenna on the gun mount; a vertical receiving array forward of the foremast; a transmitting array between the masts; radio beacon aft and various whips. For helicopter operations the radio beacon and whip antennas can be lowered in less than 15 minutes. During this period, a transmitting antenna midships will be utilized for radio beacon transmission.

Rapid communication teletype machines will replace hand-keyed transmission and individual operator reception. Voice radio equipment is located next to CIC to allow rapid operator shifting by operating personnel. A TACNAV (Tactical Navigation) system is planned for installation in CIC. This system projects plots of aircraft, balloons, ships, or geographic (shore) features as selected on a vertical plot. The plot is recorded and can be periodically updated by data received from radar, etc. The information is accurately scribed on 35mm slides. These slides are then used to project present information and are an accurate, compact record of past information for later analysis. Plotting tables as backup means for evaluating CIC information are provided in the event of system failure.

Closed circuit television is provided for the internal transmission of CIC data, on-scene

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Main Machinery

Propulsion power requirements were estimated by textbook methods early in the design stage. A 20-foot self-propelled model of the hull, properly weighted to correspond to a 13-foot 6-inch ship draft, was tested at the David Taylor Model Basin. Extropolation of model test data to the full size ship indicated that 36,000 shp would be required for a speed of 29 knots and 7,000 shp for 20 knots, Figure 3. The 20-knot cruising requirement is satisfied with the installation of two 3500 shp diesel engines, one on each shaft. Maximum speed requirements of 29 knots were filled by two 18,000 hp gas turbines, one on each shaft. For speeds to 20 knots, the diesel engines will operate alone. The gas turbines will operate alone for speeds above 20 knots to the top speed of 29 knots. Clutches are provided for simultaneous running only during shift over from turbine or diesel-engine operation.

On the 210-foot WPC (RELIANCE CLASS) the 1,000 hp gas turbine and the 1500 hp diesel engine (per shaft) are operated together to meet the maximum power requirement of 2500 shp. The RELIANCE CLASS will cruise at 300 shaft rpm with the diesel engine operating at 1,000 rpm, producing 1500 horsepower. For maximum power requirements of 2500 shp, pitch is increased on the propeller to absorb the turbine power while the shaft rpm remains constant at 300 rpm. Because of the relative value of the power increase, it is possible to accomplish the "mating" of the gas turbine with the diesel engine in the above manner. The controllable pitch propeller provides for two functions: "mating" and reversing the blades for backing down. Other means are available to accomplish "mating" of the turbine and diesel engine. Speed changing gears for the diesel engine as per automotive practice could be installed to increase shaft speed as power requirements increase. A reversing clutch and gear would be required for both the gas turbine and diesel engine to provide for backing down. The use of the controllable pitch propeller eliminates the need for speed changing gears and reverse gears. It also improves maneuverability by giving a low reversing time of approximately 10 seconds from full power ahead to full power astern.

Because of the relative size of the gas turbines vs diesel engines, "mating" of the plant on the 350-foot WPG cannot be accomplished in the above manner. It is desirable that the propeller operate efficiently at the maximum power output of the diesel engine and also at the maximum power output of the gas turbine. The high endurance cutter will cruise at 20 knots on the diesel engines with the propellers turning at 147 rpm and the blades set at the design pitch for most efficient operation. It would be impossible for the system to increase the pitch of the blades to maximum pitch at a constant rpm of 147 and absorb the 36,000 shp of the gas turbines. As the pitch changes from the design pitch, propeller efficiency decreases.

If you operate the gas turbine plant alone, the requirement for "mating" with the diesel engines no longer exists. This eliminates the problem of propeller efficiency as shaft speed can be increased to absorb the extra power of the gas turbines without exceeding speed and power limitations of the diesel engines. For high efficiency at top speed, the propeller will turn at 235 rpm. Propeller pitch will be essentially the same for maximum power output of the gas turbines as compared to the pitch at maximum power output of the diesel engines. The controllable pitch propeller is used for backing requirements and increased maneuverability. Each propeller is 13 feet in diameter and extends 5-feet 4-inches below the keel line. Although extension of the propellers below the keel line is undesirable, it was necessary to size the propeller to absorb the high power requirement and to provide adequate tip clearance to eliminate the possibility of hull vibration induced by propeller forces.

Fuel consumption on the diesel engines is approximately 0.45 pounds per shaft horsepower hour. Fuel consumption on the gas turbine is about 0.55 pounds per shaft horsepower hour at full power. It increases to approximately 1.0 pounds at cruising speed. A comparison with a steam power plant indicates that the combination of the gas turbine-diesel plant has a lower fuel consumption at cruising or full power than an equivalent steam plant. However, each gas turbine consumes 250 pounds of air per second or 15 short tons per minute. This is the reason for the tremendously large intake air (9 by 6 feet) and exhaust ducts which are required. Since the gas turbines are hot (350 F or up), a hood is fitted over each gas turbine. Ventilation air passing through the annular space between each gas turbine and its hood will remove the excess heat caused by gas turbine operation from the engineroom.

For improved watchstander comfort, an air-conditioned soundproof control room is fitted in the after part of the upper engineroom level, facing forward. The control room will contain starting and maneuvering controls, switchboards for the two engineroom diesel generators, and control panels for auxiliary equipment.

Auxiliary Machinery

Analysis of a normal ship's service power requirements indicates a need of 225-350 kw. Air conditioning alone consumes 100 kw. The virtues of split-plant operation with a separate generator for electronics lost out to a military specification generator with enough copper to sustain load surge with small voltage fluctuations and a torque-sensing governor. The 500 kw machine selected gives adequate margin for growth. The extra space and maintenance required for dual-generator operation favored the single-generator concept. A duplicate 500 kw generator for standby is also located in the engineroom. The selection of the 500 kw emergency generator in the steering engineroom was based on the possibility that electrical load growth may eventually require simultaneous use of both engineroom generators. The engineroom generators are diesel driven while the emergency generator is gas-turbine driven, exhausting through the counter. Fire-fighting protection is provided by two 500-gallon-per-minute fire pumps located in the engineroom and one located in the forward sewage ejector space.

Three dual pump sewage ejector sumps collect all sewage. The pumps discharge through hull connections fitted so that dockside hoses can tie the ship into a municipal sewage system to prevent dumping raw sewage into harbor waters. An aerobic sewage treatment plant was considered for installation but rejected because of the requirement for a 21,000-gallon aeration tank, a 21,000-gallon sedimentation tank, and 350-gallon chlorination and discharge tanks. An oily-water separator for bilge discharge is included so that bilges may be pumped in port without harbor contamination. A trash burner room between the masts should relieve the in-port or wartime fantail mess of trash awaiting disposal.

The evaporator is independent of the two steam boilers. Waste heat is received from the diesel ship's service generator jacket water and produces fresh water using a multistage, probably 5 to 10 stages, evaporator technique for economy and a fan air exhauster for vacuum. A steam heat exchanger provides an auxiliary heat source in the event of difficulty with jacket water use.

Another difference from present ships is the coalescent filters which purify the diesel

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oil. The full-power fuel consumption of over 60,000 gallons per day exceeds the capacity of the conventional centrifugal action fuel oil purifiers. One filter is located in the line between the fuel tanks and the service tank and another between the service tank and the engines.

A separate filter system is installed for the 7,000 gallons of JP5 helicopter fuel. The ship engines can use the JP5 as an emergency fuel supply. However, as the ship's range, about 10,000 miles at 20 knots or about 20,000 miles at 13 knots, is so much greater than existing ships, the use of this emergency supply is considered to be only a remote possibility.

Conclusion

The new ship merges the proven seaworthiness of the 327-foot WPG with the present high speed and high capability requirements to achieve performance worthy of a ship which may see the 21st century.

ABOUT THE AUTHOR

LCDR H. E. Russell, USCG, a native of Springfield, Mass., graduated from the Coast Guard Academy in 1950. He was a deck officer on the CGC SORREL and the CGC HUMBOLDT before taking engineering training on the CGC DEXTER and the CGC SEBAGO. He entered the Massachusetts Institute of Technology in 1953, and in 1956 completed the requirements for a degree of Naval Engineer, roughly the equivalent of a masters degree in Naval Architecture and one in Mechanical Engineering. Along with his degree, he was made a member of both honorary societies—Tau Beta Pi and Sigma Xi. After a year of ship superintending at the Coast Guard YARD, he went on Dewline in the Arctic and Deepfreeze in the Antarctic on the CGC NORTHWIND from 1957 through 1959. After one year in the 13th District naval engineering section, he was transferred to Coast Guard Headquarters (ENE) where he has worked as Chief, Cruising Cutter Section until his present job as High-Endurance Cutter Project Officer. He is scheduled to be Resident Inspector when the building contract is signed.

Stud Hole Thread Repair in Main Engine Base

By LT T. R. Grant, USCG
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Recently *The Engineer's Digest* published a material failure report on the breaking of main bearing studs in a Cooper-Bessemer GN-8 engine (April-May-June 1963, No. 139). Under "District Commander's Comment" appeared this statement:

> "A CSMP card should be prepared requesting permanent repairs when commercial facilities are available."

So as not to leave one guessing what "permanent repairs" for the situation described might be, the solution used by the engineering force of CGC STORIS is offered—for it was the STORIS' port main engine which provided the occasion for this failure report.

The situation reviewed: In 1960, the 1-inch studs holding the No. 1 main bearing cap broke off in the port main engine frame, which is a hollow iron casting. In removing the broken pieces, much drilling and chiseling was done so that the effectiveness of the threads in the frame stud holes was largely destroyed. Only the bottommost threads were unaffected. New studs with slightly oversize threads were made and installed.

In May of 1962, while running a full power trial, a noise was heard in the vicinity of the lower forward part of the port engine and was traced to No. 1 main bearing. Both bearing cap studs were broken, one in the lower threaded area and the other in the threads under the locknut. When both studs were removed from the engine, it was observed that only about three-fourths of an inch of threads had been holding the studs in place. The rest of the stud threads had been inadequately supported and were marked by working against the damaged hole threads. Lacking proper support, these studs had, instead of standing rigid, worked until failure by fatigue occurred.

The ENGINEER'S *Digest*

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