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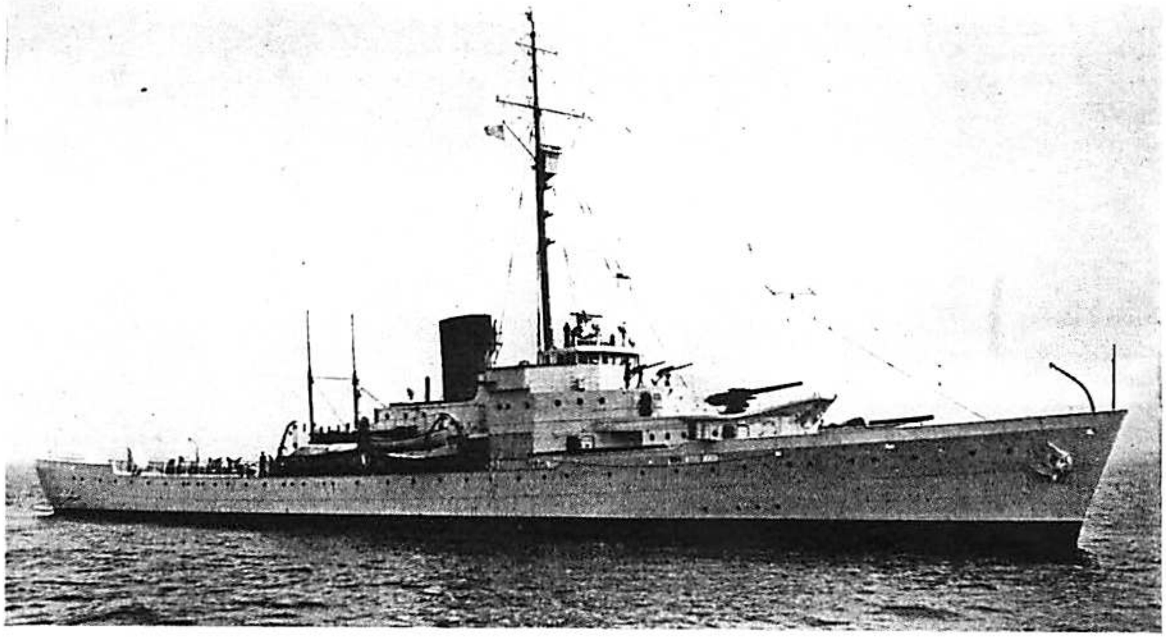

FIG. 1.—UNITED STATES COAST GUARD CUTTER "ALEXANDER HAMILTON"

UNITED STATES COAST GUARD CUTTERS

BY COMMANDER FREDERICK A. HUNNEWELL, U.S.C.G., MEMBER*

HISTORY AND DUTIES OF THE COAST GUARD

History. Alexander Hamilton, the first Secretary of the Treasury, found a need for vessels to enforce the revenue laws of the new Republic, and he wrote to the newly appointed Collectors of the Ports on October 2, 1789, for information as to local conditions and requirements. On April 23, 1790, he asked Congress for an appropriation to build ten revenue cutters 36 to 40 feet in the keel, each to carry six swivels and a crew of captain, lieutenant and six seamen; later information showed that somewhat larger craft would be desirable, and the *Massachusetts*, for instance, built at Newburyport, Mass., was actually 50 feet long on deck.

In the course of time the first United States Congress, on August 4, 1790, officially established the new Service as the Revenue Marine; the seagoing law enforcement agency thus set up was later called the Revenue Cutter Service. On January 28, 1915, the United States Coast Guard was authorized combining the Revenue Cutter Service and the Life-saving Service, which had been separate organizations. Such is the historical outline of the Coast Guard of today, with a beginning nearly 150 years ago, and a continuing experience at sea through the years which have since elapsed.

The descriptive name of "cutters" for the vessels of the Service seems to have been in use from the beginning, and therefore is used in the title of this paper, in which are assembled, for the first time, some facts and figures of a technical character which may be of interest and value.

Duties. The Coast Guard has always been concerned with enforcement of maritime law, assistance to life and property on the sea, and national defense. In detail, the activities of the Service now have to do with customs and prevention of smuggling; navigation and merchant shipping; harbor rules and anchorage of vessels; immigration, quarantine and neutrality; international conventions on fur seals, game birds and fish-

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eries; law enforcement in Alaska; assistance to vessels in distress; flood and hurricane relief; destruction of derelicts and menaces to navigation; International Service of Ice Patrol in the North Atlantic; ice-breaking in rivers and harbors; and other work within the field of operations of its cutters afloat and its life-saving stations along the shore. A collateral duty of the Coast Guard is to act as a part of the Navy in time of war, and the efficiency of the Service is due in large part to the military discipline and training of its personnel and the high standards of conduct which have become a part of its tradition. The Coast Guard is unique among military Services, because in time of peace it is continuously employed as a producing branch of the Government, performing duties of a civil nature, on behalf of other executive agencies, which otherwise would require the provision of additional facilities at considerable total cost.

The Annual Report for 1936 describes the work by Service personnel as follows:

Lives saved or persons rescued from peril	7,510
Persons on board vessels assisted	37,553
Vessels boarded and papers examined	35,500
Regattas and marine parades patrolled	290
Instances of lives saved, vessels assisted, or miscellaneous services	14,746
Value of vessels assisted (including cargoes)	$65,425,470

As is obvious, activities of the kind described above can be reported in terms of tangible results, but preventive work, a part of law enforcement, is not so easily evaluated and sometimes it seems to be measured only by an assurance of accomplishment for the common good, without the satisfaction of any visible returns.

With Coast Guard cutters at many ports on the Atlantic, Gulf and Pacific coasts, and on the Great Lakes, and with small boats and life-saving equipment at Coast Guard Stations along the coast, it is not surprising that a major activity of the Service has come to be the saving of life and property at sea. It is a clear policy, however, not to interfere with private enterprise, and assistance is limited to cases of emergency and to cooperation with commercial services when they appear on the scene. Coast Guard cutters, boats and stations, supplemented by airplanes and the comprehensive communication system of the Service, make up the principal facilities afloat, ashore and in the air with which work is done; but the paper discusses chiefly Coast Guard cutters and boats with which the Society is most intimately concerned.

General Design of Coast Guard Cutters

Since 1790, the Coast Guard has specialized on the design, building, and operation of cutters and boats as the primary equipment for the performance of its duties. The popular conception of a "revenue cutter" is a distinctive, rakish and speedy craft certain to overhaul and capture any prospective smuggler, weather storms of every kind and proceed on a mission of assistance under the most adverse conditions of wind and sea. This visualization has always been reasonably correct, but the policies of administration and the observations of officers afloat have, from time to time, stressed particular duties to be done, and any changing emphasis has naturally been reflected in the design and building programs for cutters and boats. In the last analysis, the operating personnel makes known the general characteristics of the units to be added to the Fleet and the technical staff of the Coast Guard conceives, completes and perfects the compromise designs which best fulfill the need.

As a matter of fact, the technical staff continually studies probable future requirements as disclosed by inspections, reports, correspondence and conferences relating to actual experience afloat, and lays down alternate designs for cutters and boats to embody the latest developments in naval architecture and marine engineering which can be adapted for our use. Such preliminary sketches are submitted to the Service for general comment, as opportunity arises, and by this means we are well prepared for replacement building programs which are authorized from time to time.

As intimated above, changing emphasis on duties is bound to be reflected in the tentative designs, thus acting as an offset to whatever advantages may lie in the duplication of existing cutters throughout. As far as practicable, however, there is a perpetuation of standard details for economy in repair, but, here again, duplication is difficult as cutters are built in widely separated sections of the country, and insistence on absolutely uniform details is of doubtful propriety. It is the usual custom, therefore, to approve first-class practices as found in various shipyards, but progress in the art and science of shipbuilding is consistently incorporated in the cutters, with the result that in several cases they have been notable examples of up-to-date construction.

Categories. On account of the conditions surrounding the design of cutters and the long-time process of their development, the vessels in the Fleet cannot be exactly classified, but for convenience those in commission at the present time may be grouped in the general categories named subsequently. Where the length of a cutter or boat is given, length overall is used, unless otherwise stated; this full length is important for clearances in operations and for berthing and docking, and the cus-

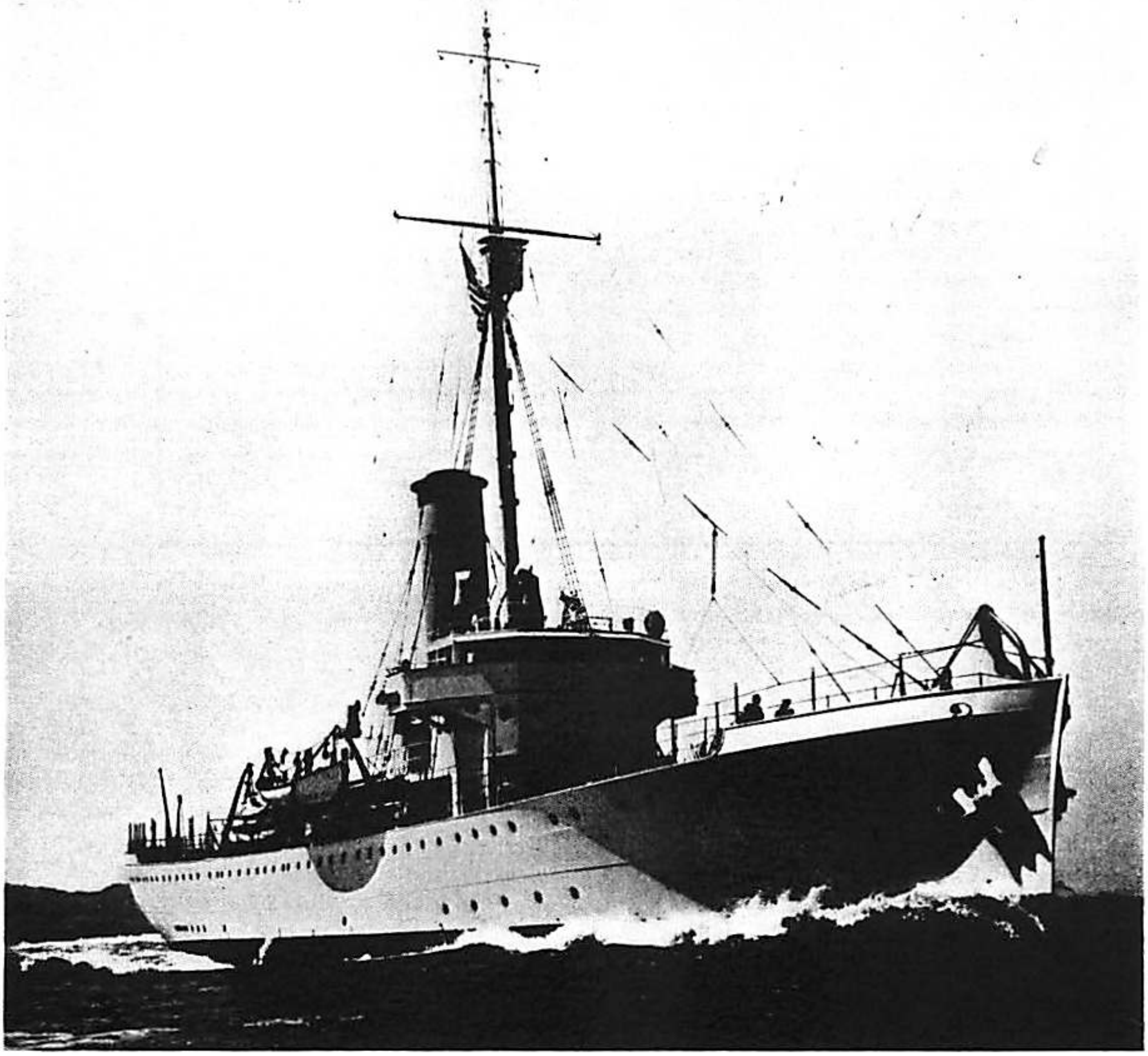


FIG. 2.—UNITED STATES COAST GUARD CUTTER "ITASCA"

tom has grown up of using it instead of waterline or other length. Within the general categories or classes there are many groups and individual units, and Table 1 (page 96) gives some technical information on the designs.

Cruising Cutters. About 32 sea-going vessels, for unlimited operations and all-round work.

Harbor Cutters and Launches. About 45 smaller vessels, for service in harbors, bays and sounds.

Coastal Patrol Boats. About 53 sea-going vessels of a rather special type, adaptable for all-round service. Supplementing patrol boats are about 36 airplanes for duty along the coasts; planes generally equipped with stretchers to transport injured persons ashore for hospital treatment.

Local Patrol Boats. About 90 able boats, intended to be operated from a base in moderately exposed waters.

Special Craft. About six miscellaneous craft for various purposes, such as cable laying, cargo carrying, sailing ships, crane service, etc.

Small Boats. About 1800 wooden boats under 50 feet in length, comprising picket boats, motor lifeboats and pulling boats assigned to Coast Guard stations, and motor and pulling boats carried at davits on the cutters.

It might be expected that the experience of the Coast Guard would lead to the production of only a few classes of standard cutters, and efforts in this direction appear in all the design work; however, we seem to be subject to the irresistible trend toward specialization which appears in all current technical developments. As far as practicable, of course, it is sensible to subordinate the building of a cutter, which might be ideal for a particular mission or locality, to the building of a cutter adapted to average undertakings on the Atlantic, Pacific, Gulf or Lakes, as emergencies of the Service may determine its assignment. Aside from these general remarks, it is imperative that definitely special units, such as river patrol boats, sail boats, cadet practice ship, tunnel stern small boats, cable laying vessels, cargo boats and other unusual craft, be available in any Fleet represented in a wide variety of tasks.

Priority of Technical Elements. While competent officers will differ among themselves, it is believed that under a basic requirement for reliability the major technical characteristics of a typical Coast Guard cutter can well be given the following sequence of priority: Seaworthiness, speed, cruising radius, deck equipment for assistance work and accommodations. The relative importance assigned to these major elements vitally affects the whole design; incidental thereto are facilities for boat and airplane handling, and provision for radio and ordnance installations. To a greater or less degree the elements apply to patrol boats and to small boats, but in such latter cases there is usually a special concern with some one or two elements sufficient to settle priority and thus automatically determine the nature of the design. An important factor not emphasized above, but back of all decisions made, is the element of cost, which undoubtedly will continue to appear in all the problems relating to the cutters.

Extended discussion of the relative standings of the primary elements named above is hardly necessary as the advantages of each are obvious; regarding speed, however, some general comments may not be out of place. For enforcement of law, sufficient speed to overtake a smuggler promptly is essential, and mere equality is a handicap to be accepted with reluctance. For assistance work, immediate departure and speed for prompt arrival at the casualty are, of course, expected. In search at sea for a disabled boat or airplane or a derelict, speed is definitely useful, and on ice patrol speed allows advantage to be taken of clear weather to identify and chart the bergs and floes before visibility is lost by fog or storm. On the other hand, economy at cruising speed extends the time which can be spent at sea, if necessary, without return for fuel and while propulsion is therefore utilized in the full range from high power to low power, possibilities of speed are eminently desirable.

Radio, Ordnance and Airplanes. Comment on the cutters would be incomplete without mention of the prime importance of radio in Coast Guard operations at sea, and recently on shore, as, for instance, in midwest valley areas under flood conditions. From a small beginning many years ago, there has been consistent improvement and expansion of radio equipment until now communi-

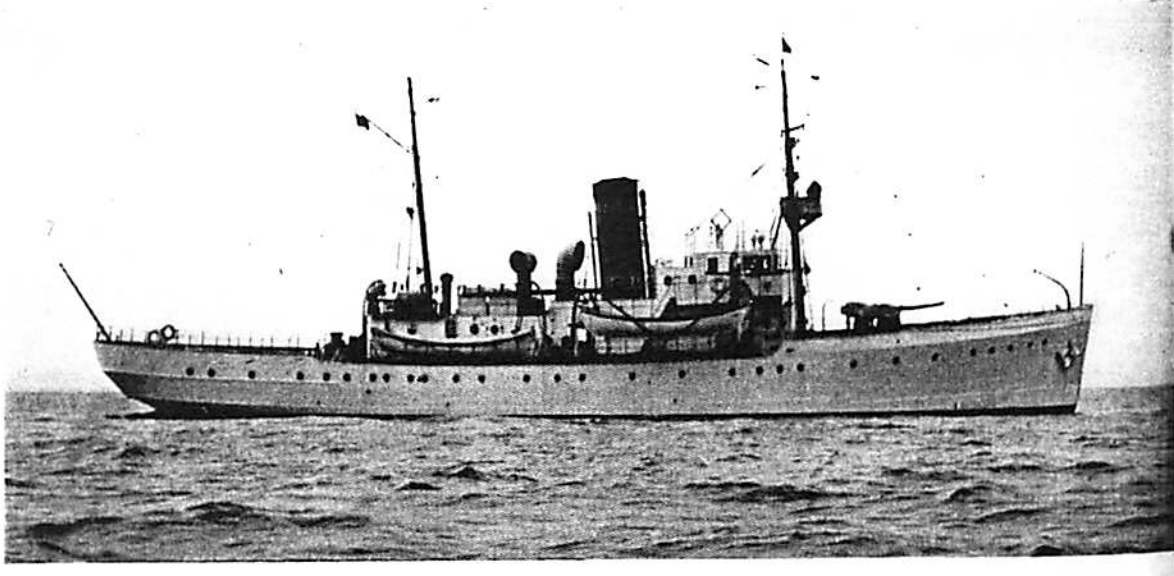


Fig. 3.—United States Coast Guard Cutter "Algonquin"

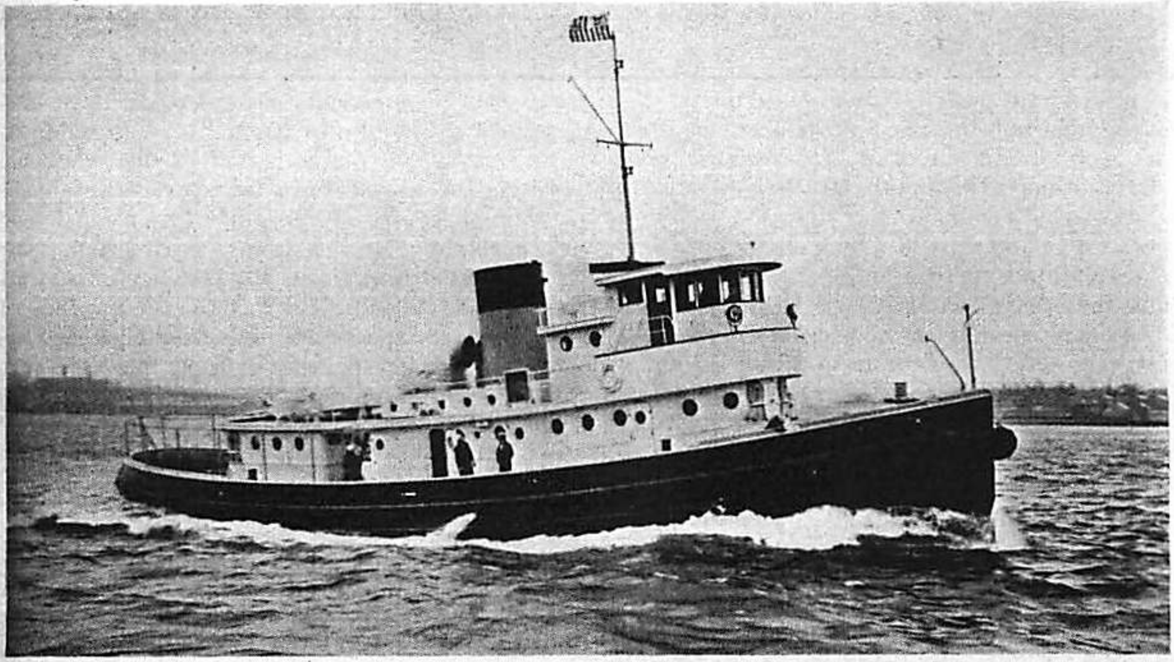


FIG. 4.—UNITED STATES COAST GUARD HARBOR CUTTER "HUDSON"

cation by radio among the vessels, boats, airplanes and stations is over a unified network tying in all the extensive operations of the Service.

Ordnance on the cutters is provided to the extent necessary for training, drill and target practice, with occasional use for law enforcement purposes. Target practice with the larger guns on the cutters, and with small arms, builds up a spirit of competition and emulation among the personnel, but armaments on the Coast Guard cutters are subsidiary to the arrangements and facilities for continuous peacetime activities. Line-throwing guns, which are frequently used for assistance work, have recently been perfected with better aim and far longer range. Wrecking mines are furnished and stowed in magazines for use in derelict destruction.

Within the last few years, airplanes have been included in the Coast Guard Fleet to supplement the cutters and perform the functions for which they are best adapted. There is complete co-ordination in the use of all facilities now available to officers and men in carrying out their duties, and the high regard in which the Service is held is a compliment to its efficiency under the rapidly changing conditions surrounding maritime affairs.

International Conferences. In connection with the small boats which are the chief equipment of the Coast Guard stations, there is one item which deserves a favorable notice. International Lifeboat Conferences are held at intervals of about four years, and it is a satisfaction to report that the Coast Guard is represented at these meetings; the last took place at Gothenburg, Sweden, in the summer of 1936.

At all the conferences there is a gratifying interchange of ideas and experiences among responsible officers of the life-saving services of many different countries, and the full and frank description of facilities and methods utilized along the coasts is helpful to all concerned. The International Conferences have been well attended and the Coast Guard has made worthwhile contributions of an informative and technical nature to the nations carrying on assistance work.

The agency charged with this important service may be a private or public institution, maintained by contributions or appropriations as the case may be, but the lifeboats and the gallant lifeboat men are universally admired, and the Coast Guard is proud to be the agency of the United States to carry on the corresponding service for this country.

HULL CHARACTERISTICS OF COAST GUARD CUTTERS

The design and building of the Coast Guard cutters can well be outlined in the sequence of the steps which finally fix the shape and the character of the hull itself.

Dimensions and Stability. The dimensions and consequent displacement of a cutter are vitally affected by the relative importance approved for the primary elements. It is doubtful if a cruising cutter ought to be much over 300 feet in length, or over 2400 tons displacement, since increase in this length or weight is bound to be a serious handicap in maneuvering under the difficult conditions which frequently arise in service operations. The 250-foot cutters are reported to "handle like a tugboat" and such a qualification is certainly an asset when assistance work in close quarters is to be undertaken; any feasible gain in speed by an indefinite increase in length is more than offset by loss in maneuverability. It is probable, therefore, that our new cutters recently commissioned will be the longest and heaviest cutters in the Fleet for some time to come; this from the operating and technical viewpoint as well as the financial viewpoint.

The breadth of beam is ordinarily in excess of that found in commercial ships and a somewhat larger proportion of beam to length is adopted with due consideration of the gains and losses which result. One definite advantage in the generous beam is usually a shorter length reserved for the propelling machinery and auxiliaries, with an even larger volume in machinery spaces and a more convenient layout. The location of boilers athwartship, for instance, simplifies uptakes and stack, and by cutting down the length of trunks for machinery spaces, without adverse effect on machinery layout, adds to the deck area forward and abaft the machinery spaces available for accommodations. The gain in stability due to beam is important, in that a safety provision is thus allowed for excessive and unknown deck loads which may be imposed. Indefinite high-up weights may be composed of ice, people who are rescued, airplanes, ordnance, unknown mechanisms and equipment, or additional structures, the weight and location of which are now imaginary, but in the future may prove to be the contrary, as it is expected the cutters will be in service for 25 years or so during a period when chance and change are always busy. Furthermore, stability to spare adds to the peace of mind of a commanding officer who, in an emergency, is justified in subjecting his cutter to unusual hazards such as grounding, damage by floating wreckage, or collision as a result of dangerously close maneuvering to rescue persons in peril, if the situation calls for risks of any sort. In other words, a cutter must meet the normal hazards of the sea and also those incurred by our legitimate assistance work, and breadth of beam provides reserve stability for a damaged condition which may possibly eventuate, should a compartment becoming flooded bring about any reasonable loss of waterline area.

The considerable metacentric height resulting from the generous beam naturally affects the behavior of the cutters at sea, and there is undoubtedly a shortening of the period of roll. For vessels the size of our cutters, however, it is probable that the effect of waves, dependent upon course and speed, is fully as much a factor in the motion as the rolling period inherent in the stability characteristics of the cutters. The most feasible means of quenching the roll is the fitting of bilge keels as deep as conditions permit, and such bilge keels are fitted amidships in the full-speed streamlines as traced by model tests.

Lines. The persistent endeavor in considering items of hull design and construction is to obtain the most vessel for the least money; and this attempt is quite consistent with priority of elements desired by the operating officers for the particular design in prospect. For instance, a simple flush-deck vessel has advantages so convincing that since 1913 this type of hull has been adopted for almost every cutter and boat laid down. Some of the older cutters had a raised forecastle and poop with well deck, or a raised forecastle and stepped-down quarterdeck, but the flush deck with ample freeboard and bold sheer has proved itself and superseded other arrangements. The long, clear weather deck assures a strong and seaworthy hull, permits convenient access fore and aft for wrecking work, provides a large area and good platform for stowage and handling of boats, airplanes and other gear, and gives the maximum deck area and cubic space below the weather deck for accommodation of personnel.

For the cruising cutters, it is intended that freeboard amidships shall be high enough to keep green seas off the weather deck as far as possible, and yet low enough to minimize the distance which boats at davits must be lowered, and thereby expedite their use in an emergency. The bold sheer lifts the bow and stern for dryness, and, to allow the faster cutters to be driven hard at sea, bulwarks have been added on the forecastle. Bulwarks or an equivalent are fitted on patrol boats to advantage, but experience has not as yet disclosed whether a notable gain in seaworthiness will result for cruising cutters; the possibilities fully justify a test.

A stem raked forward in the part above the waterline, bow sections with pronounced flare, midship section with nearly vertical sides for clearance in lowering boats, cruiser stern, and buttocks with easy slopes at the ends combine as the typical body lines for weatherliness and speed. It

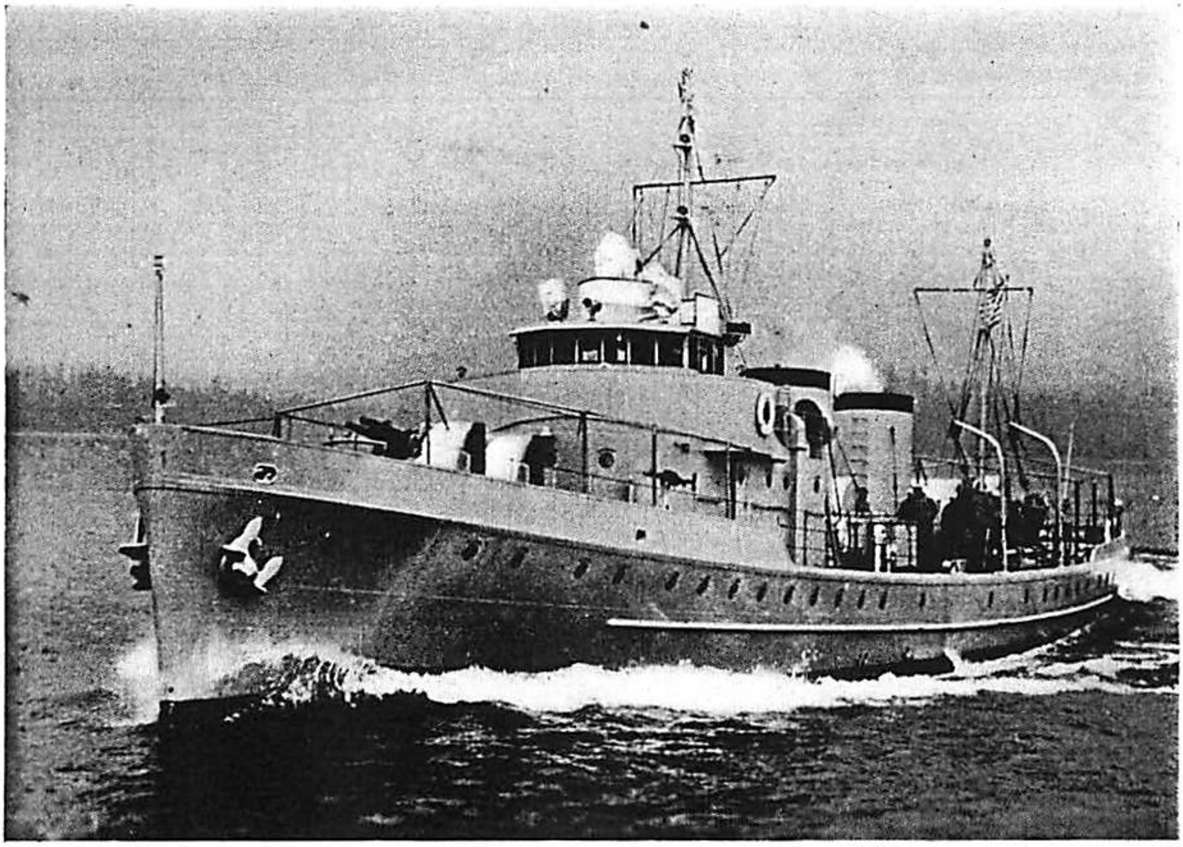


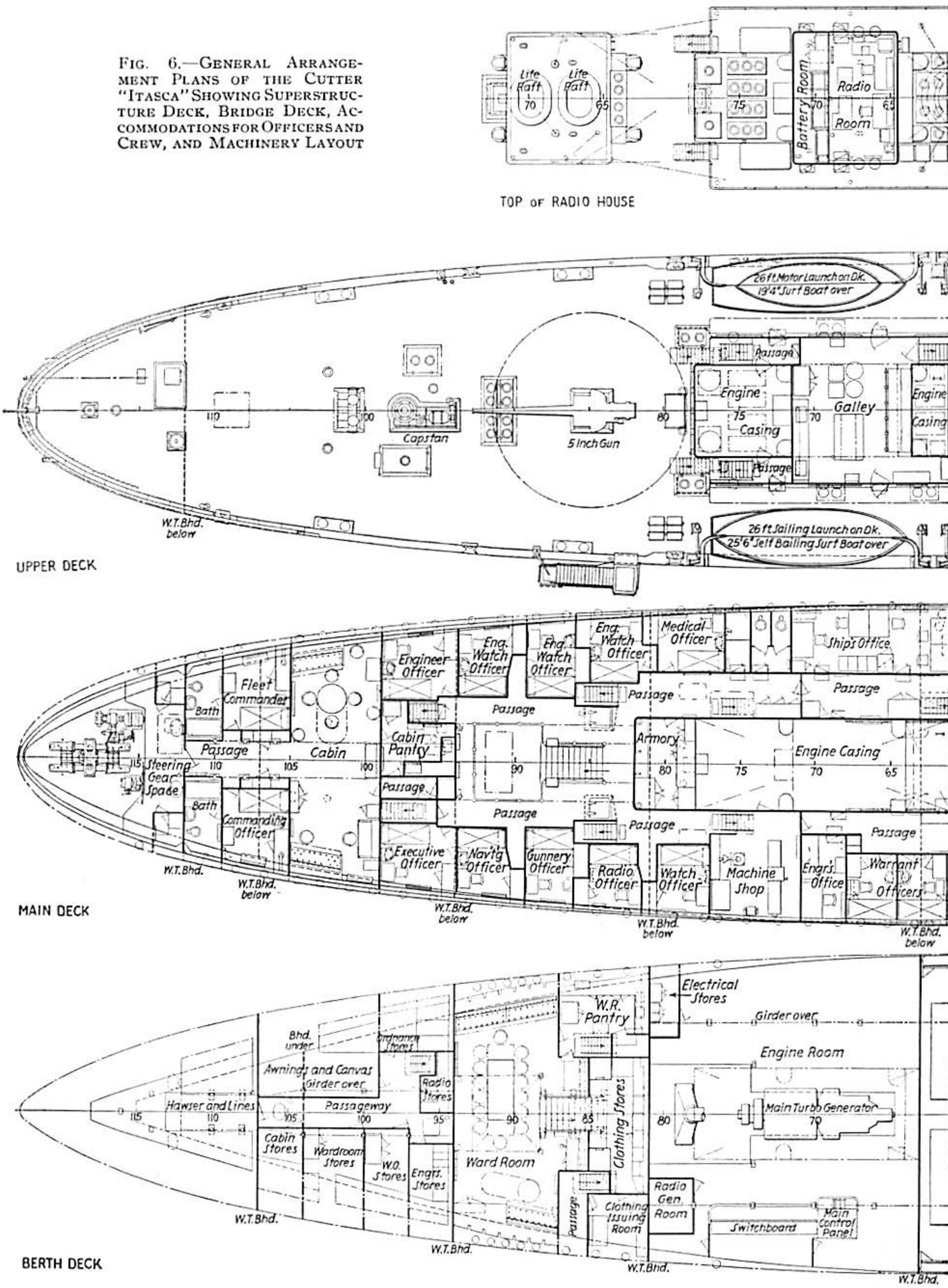
FIG. 5.—UNITED STATES COAST GUARD PATROL BOAT "THETIS"

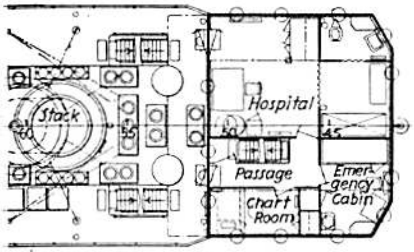
is interesting to note the old-time clipper stem, next the ram bow and receding stem, then the plumb stem, and now the stem with a forward rake, all of which have appeared in turn on the cutters as on other vessels. There seems little doubt that the general approval of a semi-clipper stem and flaring forward sections has come from their good effect in a moderate sea and the additional deck space for working ship.

Deckhouses. As far as deckhouses are concerned, there is a positive intention to minimize them to the utmost, in the belief that money put into the hull itself gives greater returns, in essential elements, than money put into deckhouses; in other words, size which can thus be paid for will add to seaworthiness, speed, accommodations or other important features. Deckhouses, therefore, are usually arranged to contain no more than bridge and wheelhouse, radio room, quarters for the commanding officer, trunks for machinery spaces, and, in some cases, the galley and hospital; incidentally, windage is reduced and easy handling of the cutter thus improved.

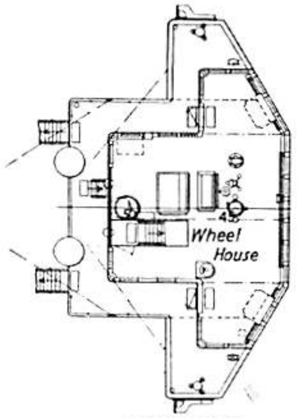
Speaking generally, the clean-cut appearance in profile of the Coast Guard cutters is inherent in the simplicity of the design; this principle of simplicity, wherever possible, controls many decisions exhibited by the cutters, and does not take away the opportunity to style the profile in the current fashion even including whatever "streamlining" may be desired. The single mast, which stands abaft the wheelhouse on many cutters and patrol boats, was adopted years ago for the definite purpose of keeping the weather decks as clear as possible and by this means reducing the interference of spars and rigging with towing, boat handling, arcs of fire for guns, airplane handling booms, and other necessary gear. The single mast provides for signals and for radio equipment, and incidentally saves in cost of construction and repair. Smokestacks high and small in diameter as installed some years ago, gave a natural-draft condition for the boilers, but the newer steam generators usually contemplate some sort of mechanically assisted draft. Deckhouses as laid out in years past show the flat-front square-corner,

Fig. 6.—General Arrangement Plans of the Cutter "Itasca" Showing Superstructure Deck, Bridge Deck, Accommodations for Officers and Crew, and Machinery Layout

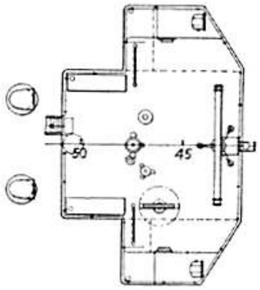




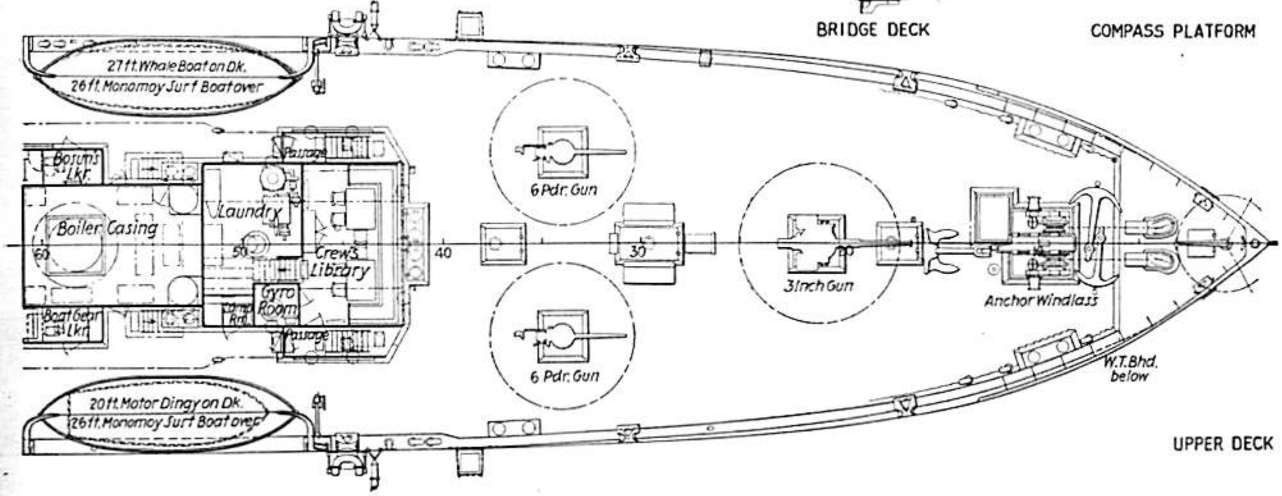
SUPERSTRUCTURE DECK



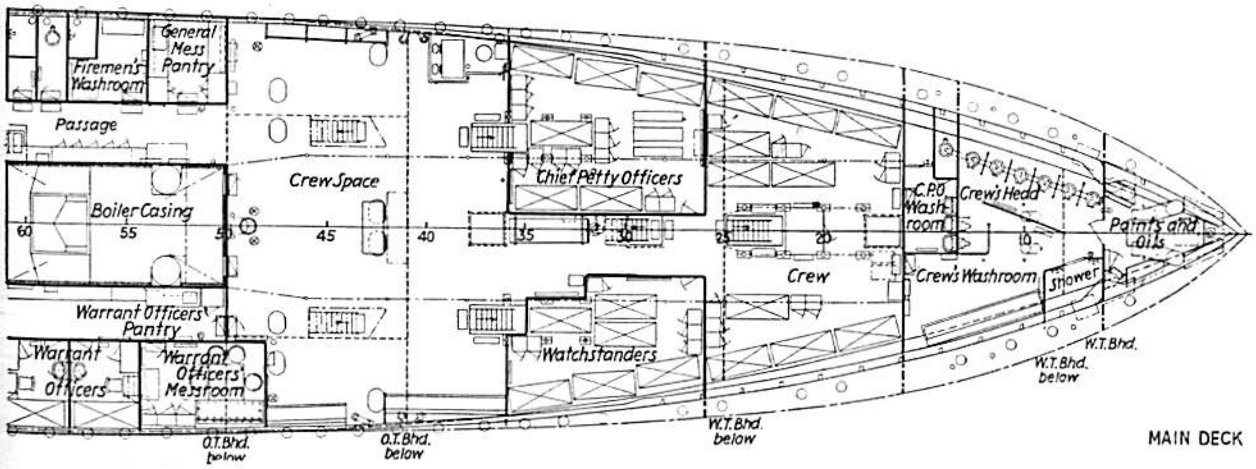
BRIDGE DECK



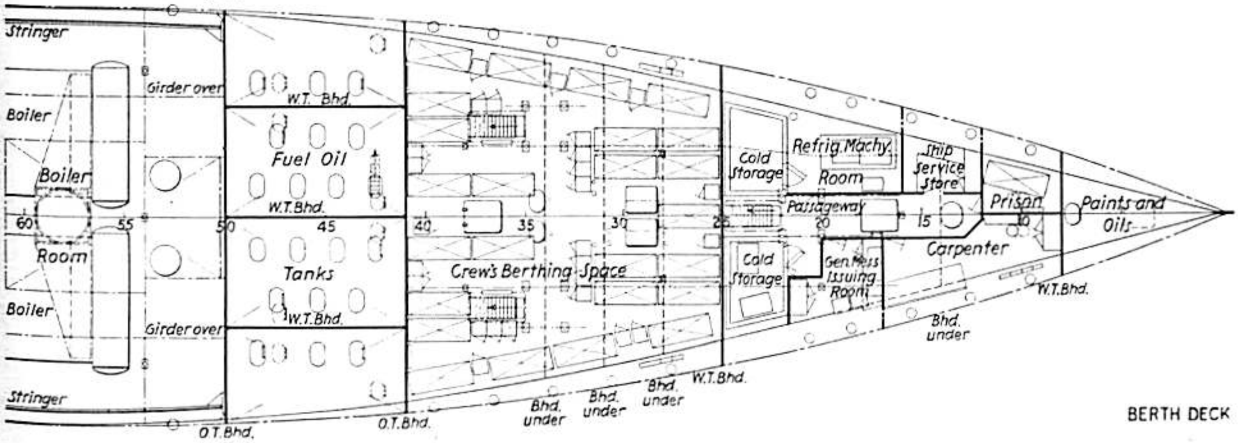
COMPASS PLATFORM



UPPER DECK



MAIN DECK



BERTH DECK

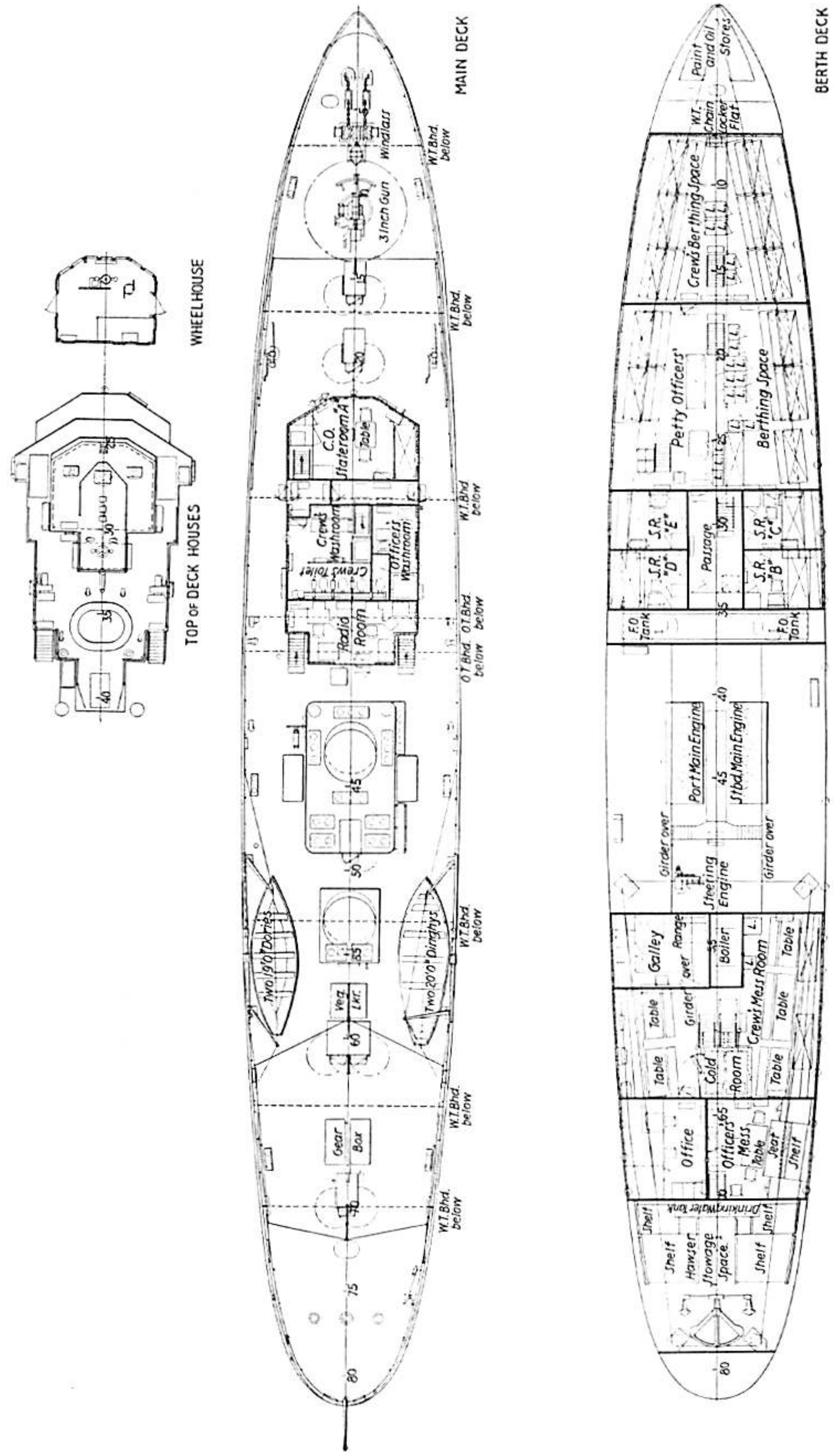


FIG. 7.—ACCOMMODATION PLAN OF PATROL BOAT "THETIS"

straight-line shape then in vogue, but stacks and deckhouses have been transformed in recent times, and we are governed accordingly in our new designs.

A certain satisfaction can be taken by all concerned in the feeling that a cutter looks up-to-date and thought and effort along this line are well expended, with only insignificant cost involved. It goes without saying that for the units of the Fleet there is a definite attempt to obtain similarity of appearance in drawing up profiles of the various classes, and perfecting prominent and distinctive features for identification by the public eye. Solely from a law enforcement point of view, there may be two sides to this question with a collection of nondescript craft an advantage, but, from the larger point of view, uniformity in conspicuous details of the Fleet is a legitimate choice for ready recognition by the general public.

Accommodations. As a matter of general information, a typical accommodation layout for a cutter is shown in Fig. 6 and for a patrol boat in Fig. 7. The simplicity and convenience of the quarters may be pointed out. There is segregation of the berthing spaces and the messing spaces; the former with toilet rooms conveniently adjacent, and the latter with messrooms, pantries and the galley disposed to the best advantage for convenient service. For a cutter, the officers are usually aft and the crew forward, except that recently it has become the practice for the quarters of the commanding officer to be arranged just beneath the bridge. The two accommodation schemes have proved so satisfactory that adaptations of the principles are applied, as far as practicable, to all the units of the Fleet.

Since the bridge of a Coast Guard cutter is, to an unusual degree, the control station under all conditions, bridges and wheelhouses are somewhat larger than is customary, and much thought is given to the details for convenience and efficiency. As indicating the facilities on the "bridge," using the term to include the areas both open and inclosed, a list of equipment for handling ship, navigation, signalling, and interior communication on a cruising cutter may be of interest, as follows:

Steering gear; rudder angle indicator; engine telegraphs; engine revolution counters and direction indicators; whistle and siren pulls; clear vision devices; magnetic steering compass; gyrocompass steering repeater; standard magnetic compass; radio direction finder; fathometer and recorder; electric taffrail log counter; rangefinder and keeper; peloruses; hooded chart table; chart boards; anemometer; barometer, thermometer and clock; high-intensity searchlight controls; incandescent searchlight controls; blinker light key; speed light controller; pulsator for truck light; running light control panel; signal light control panel; signal flag lockers and pin rails; aerial identification letters; telephones; voice tubes; call bells; ring buoy release; binocular and megaphone stowage; and other devices in special cases.

For the smaller cutters and patrol boats, some of this equipment may be omitted, but the bridges are always fitted out in a manner appropriate for the purpose. In general, simplifications which are attempted do not seem to develop as eliminations, but rather as the perpetuation of complete equipments on a smaller scale, with sometimes disappointing savings in space or weight or cost.

Hull Structure. Up to the recent *Hamilton* class of 327-foot cutters, all vessels were built on the transverse framing system, with scantlings based on the American Bureau of Shipping rules. While not necessarily tied in with transverse framing, watertight subdivision is obtained by a considerable number of transverse bulkheads spaced to give two-compartment vessels, if practicable. In every case, however, for cutters and patrol boats a one-compartment vessel is obtained, so that the flooding of any one compartment will not endanger the safety of the vessel. For some cutters, an inner bottom is worked the full length of boiler and engine rooms, but with no inner bottom forward and abaft the machinery spaces, on account of the difficulty of access and upkeep. In lieu thereof, it is the practice to make the berth deck, which is usually near the waterline, a watertight deck structurally capable of withstanding any upward pressure which might be generated by a flooded hold and a change of trim thereby. The compartmentation resulting from the watertight deck and bulkheads had been demonstrated of value; for instance the *Comanche,* while breaking ice last winter in the Hudson River, was forced from the channel and aground and a hold was flooded. Watertight integrity of the structure was maintained, and after coming off the bottom, the *Comanche* proceeded without difficulty down the river for repairs. The spacing of the main transverse bulkheads of machinery compartments is fairly close, since the boilers are usually athwartship and the auxiliaries are outboard of the main propelling unit, thus providing ample room in short machinery spaces.

For the 327-foot cutters recently added to the Fleet, longitudinal framing was adopted as giving a better distribution of hull strength members for the longer cutters. The outcome has been eminently satisfactory as sea service has demonstrated the stiffness of the hull and the entire absence of vibration due to machinery or propellers. It is possible that the 300-foot length of hull may be a rough dividing point between transverse and longitudinal framing for cutters, but considering local outside plating damage due to handling in close quarters or corrugation due to ice pressure, the transverse system seems to possess some inherent advantages and probably will be specified for a typical cutter design.

The general remarks regarding hazards for the cutters apply with even greater force to the small boats of the Service, which undertake assistance work in the surf, in shallow water, and in the vicinity of boats in trouble where floating wreckage may seriously damage the Coast Guard boat. For motor lifeboats, close-spaced transverse watertight bulkheads are built into the hull, and for some of the smaller motor boats, balsa wood buoyancy blocks are fitted. These precautions are intended to make certain that the Coast Guard boat cannot founder, even should it be damaged to any reasonable extent. Some years ago, safety was secured by numerous metal or wood buoyancy boxes but insidious deterioration is a detriment, and, therefore, watertight bulkheads and solid buoyancy blocks are approved. Experience shows that for wooden boat compartments both ventilation and access are absolutely necessary to prevent dry rot and permit inspection and repair, and they are best obtained by the arrangements now found in the boats.

Materials and Workmanship. For cutters and patrol boats more than 100 feet in length, steel construction is specified in almost every case, but for boats less than 100 feet in length, wood construction seems to have its place and is usually adopted. Standard grades of medium hull steel are approved for hull construction throughout, and up to the present time it has not been necessary to consider special grades of steel for any structural purpose. There is no particular attempt toward extreme weight-saving, but, on the contrary, substantial framing and robust details are the practice for the cutters of the Fleet. The only exceptions which may be remarked are the steel patrol boats where some scantlings reduced under standard practice are accepted, but the resulting stresses do not require special steels.

For the patrol boats built of wood, standard grades of lumber available in the market, and suitable for boat-building, have been used, and, here again, with liberal scantlings and ample fastening to adequately stiffen the hull. In the few cases where speed is the primary element for a wood patrol boat, the frames and scantlings are fairly light, but so far no excessive reductions are permitted, and the handicap on speed of substantial wood construction has been accepted.

This consistent policy for steel and wood construction has entirely avoided the necessity for stiffening any cutters or patrol boats in commission due to weakness or vibration discovered as a latent defect. We follow the experimental and commercial development of new materials with interest and carry on some modest tests as limited funds and facilities permit, but so far we have given no approval for their extended use.

The trend to welding instead of riveting is recognized. As a matter of fact the Coast Guard pioneered in welding on the cutter *Northland*, built in 1927 at Newport News, where welding was approved to an unusual extent, and, so far, without regret as the *Northland* has made no adverse reports regarding the condition of the welds.

It is again remarked that the technical staff sets itself the problem of obtaining the maximum in a Coast Guard cutter for the minimum in cost, and forwards this effort by its plans, specifications and approval of good shipyard practice. Along this line, a middle course between so-called "Navy practice" and "commercial practice" has been followed in the past, but the implied differentiation seems to be rapidly disappearing, with shipyards standardizing on a grade of workmanship generally satisfactory to all concerned in naval and in commercial work. Whether this is the case or not, the Coast Guard is reasonable in its qualities of materials and in its grades of workmanship, and the policy is to avoid inconsistencies in materials and labor which might be arbitrary and out of line with the adequate requirements proposed.

Contracts. The usual procedure in connection with plans, specifications, contracts and payments leads to the issue of design plans and specifications by the technical staff of the Coast Guard, the plans and specifications being in sufficient detail to enable intending bidders to make close estimates of cost. The specifications cover the building of a cutter complete; that is, the hull, machinery, auxiliaries and all items of fixed equipment. Occasionally, however, it is advisable for the Government to furnish the machinery, and then the specifications require the shipyard to undertake the hull construction and the installation of machinery furnished by the Government.

In special cases, as for the recent 80-foot patrol boats and some smaller craft, the Coast Guard issues sketch plans only, with outline specifications to show the general characteristics of the boat desired. The specifications call upon a prospective bidder to retain a professional naval architect to develop the design for the bidder, who submits it as fulfilling the general requirements issued by the Coast Guard; the successful contractor continues the retainer. The detailed yard construction plans for the building of the cutter or patrol boat are prepared by the shipyard or the naval architect and submitted for approval by the Coast Guard; all yard plans being finally corrected to suit the vessel as actually built, so they may be filed as record plans for future use in maintenance and repair.

Both procedures, by which the Coast Guard issues complete plans and specifications or issues only sketch plans and outline specifications, are proving satisfactory but the first scheme is preferred, if time permits, and will be continued in the future. However, the second scheme has an advantage, in that outside professional naval architects work up the design for the contractor and a freer hand in building the boats is given the private concerns.

For contracts, partial payments in monthly installments are provided, based on monthly estimates of value of materials worked into the vessel or on hand at the yard, and labor actually expended on the contract, including overhead and profit. The total contract price is broken down to suit the convenience of the contractor so his monthly estimates of value may be compiled as easily as possible. Steps are taken by the Coast Guard to expedite payment of vouchers when received; if this can be done, financing costs to the contractors are naturally reduced.

We like to feel that satisfactory and cordial relations have been built up and maintained with the shipyards and the boatyards of the country, and this seems to be confirmed by the willingness to bid on Coast Guard business whenever tenders are invited. As the requirements for Coast Guard construction become better known to an increasing number of contractors, it is anticipated the spread between low and high bids will be reduced to the mutual advantage of the Government and the private yards whereby the satisfactory materials and workmanship required for the cutter will be combined with reasonable and proper profit to the builder.

Machinery Characteristics of Coast Guard Cutters

It seems to be correct to say that Coast Guard cutters and boats between 1790 and 1937 have been propelled by all the methods so far known. The earlier cutters used sailing rigs of various types, such as sloop, schooner and barque, and the transition from sail to steam witnessed the usual retention of masts, spars, sails and rigging until a few years ago. The cutter *Northland*, built in 1927, is the most recent instance; it is the successor to the historic cutter *Bear* on Arctic cruises, and the conference decision preliminary to the laying down of the design of the *Northland* called for a moderate sail spread to be available, if the propeller were seriously damaged in the ice. In 1935, however, instructions were issued to remove the sails and simplify the masts and rigging and therefore no cruising cutter at the present time is equipped with sails for any purpose.

Successive types of machinery for propulsion have been approved for cutters, and significant dates are given below to demonstrate the continuing interest of the Coast Guard in engineering progress and confirm the fact that cutters are provided with improvements in machinery and auxiliaries as they become commercially available. The record shows, moreover, that in some cases the Coast Guard initiated the advances, and we feel justified in taking credit for real contributions to marine engineering development.

Machinery Progress. The chronology for engineering incidents in Service history is found below, with date, name of cutter, length, if available, and descriptive notes.

1842: Decision to introduce steam into Revenue Cutter Service; six steamers contracted for, two with Ericsson's propeller and four with a horizontal submerged wheel. *Legare* commissioned in 1844 as the first steam propelled vessel in the Service.

1856: *Harriet Lane*, 180 feet long. Steamer with side wheels; machinery very successful and influenced design of cutters for ensuing ten years.

1864: *Woodbury*, 146 feet long. First steamer with single cylinder vertical engine; cylinder 36 inches diameter by 36 inches stroke, single screw.

1865: *Johnson*, 175 feet long. Steamer with one engine; cylinder 48 inches diameter by 108 inches stroke, driving side wheels. From 1856 to 1871 the predominating type of machinery was a single engine driving side wheels. During this period the boiler pressure was generally about 45 pounds per square inch.

1871: *Colfax*, 185 feet long. Steamer with side wheels, the last used in the Service. *Hamilton*, 102 feet long. Steamer with two-cylinder compound engine; high-pressure cylinder, 23½ inches diameter; low-pressure cylinder, 37 inches diameter; stroke, 32 inches; single screw. Boiler pressure, 60 pounds per square inch. *Grant*, 163 feet long. Steamer, single-cylinder, vertical engine; cylinder 36 inches diameter by 36 inches stroke, driving a single screw; boiler pressure, 60 pounds per square inch. These three steamers were each a distinct type, embodying different principles of machinery design; it was an attempt to determine by comparative performance the type of machinery best suited to Service needs.

1873: *Boutwell*, 138 feet long. Steamer with high-pressure engine driving one propeller, and low-pressure engine driving the other propeller, twin screws being thus arranged. Records seem to indicate such compound-engine installations unsatisfactory.

1885: *Rush*, 175 feet long. Steamer, two-cylinder compound engine; high-pressure cylinder, $24^1/_2$ inches diameter; low-pressure cylinder, 37 inches diameter; stroke, 27 inches; driving a single screw. A novel feature was the Meyer valve, for the high-pressure cylinder, to obtain a sharper cut-off.

1891: *Galveston*, 190 feet long. Steamer, twin screw, with two two-cylinder compound engines, each driving a separate propeller.

1893: *Hudson*, 96 feet long. This first *Hudson* was a definite advance, being the initial installation of a three-cylinder, triple-expansion engine; high-pressure, 13 inches diameter; intermediate-pressure, 21 inches diameter; low-pressure, $32^1/_4$ inches diameter; stroke, 24 inches, driving a single screw. Boiler pressure, 160 pounds per square inch. The judgment of the designer, Constructor John Q. Walton, U.S.C.G., was fully justified.

1897: *Manning*, 205 feet long. Steamer, with pronounced increase in power and speed; triple-expansion engine on single screw, with four Scotch boilers. During a period of nearly twenty years many well-known cutters were built with generally similar propelling machinery, and they all made creditable records of reliability and efficient operation.

1899: Motor lifeboat, 34 feet long. Initial installation of a gasoline engine in Service craft.

1907: *Pamlico*, 158 feet long. First cruising cutter with watertube boilers of Babcock & Wilcox type; as early as 1893, however, watertube boilers of various designs were fitted in harbor craft of the smaller sizes.

1908: *Snohomish*, 152 feet long. Steamer, with one Scotch and one Babcock & Wilcox boiler; the Scotch boiler to be used for standby, and the watertube boiler as a reserve for raising steam quickly in an emergency.

1910: *Golden Gate*, 110 feet long. Steamer converted from coal to oil-burning; oil-burning so satisfactory that partial or complete conversion was later made on other cutters.

1915: *Tallapoosa*, 165 feet long. First cutter built to use fuel oil exclusively.

1921: *Tampa* class, 240 feet long. The four cutters of this class, including the *Modoc*, were the first with turbo-electric drive. Captain Q. B. Newman, U.S.C.G., Engineer-in-Chief, had for a number of years advocated electric drive and was convinced the synchronous motor could be adapted for marine propulsion. Working with the General Electric Company, propelling equipment was developed which proved entirely satisfactory, and was the first such installation applied to steam propulsion. The engineering judgment of Captain Newman has been confirmed by the use of synchronous motors in the commercial field where turbo-electric propulsion is adopted.

1924: 75-foot patrol boat class. There were 203 of these patrol boats built; gasoline engines, six-cylinder, rated at 200 horsepower; twin screws, with one engine direct-connected to each shaft. These engines satisfactorily fulfilled all requirements.

1926: *Active* class, 125 feet long. Diesel engines, 4-cycle type, air injection, six-cylinders, rated 150 horsepower; mechanical clutch and reverse gear; twin screws, with one engine direct-connected to each shaft. These patrol boats are now being reconditioned and re-engined, using either Diesel engines, 4-cycle, solid injection, six-cylinders, rated 175 to 200 horsepower, directly reversible; or Diesel engines, 4-cycle, solid injection, eight-cylinders, rated at 300 horsepower, directly reversible. The original 150-horsepower engines turned 450 and the new 300-horsepower engines turn 700 revolutions per minute, and are being installed on the same foundations without increase in weight or space. With higher revolutions, the original shafting has been utilized and the speed of the boats has been raised from about 10.8 knots to 13.3 knots.

1927: *Northland*, 216 feet long. Electric drive, with two Diesel engines, 4-cycle air injection, six-cylinders, rated 600 horsepower each, connected to two direct-current generating sets, driving a double-armature motor on a single screw.

1928: *Chelan* class, 250 feet long. The five cutters of this class, including the *Pontchartrain*, have turbo-electric propelling machinery and introduce the central power station aboard ship; this is accomplished by a three-unit auxiliary generator set comprising a steam turbine, an alternating-current generator and a direct-current generator. At low speeds of the vessel, this auxiliary set is driven by a turbine furnishing direct current for excitation and lighting and alternating current for auxiliary power. At speeds between two-thirds and full, the power for this auxiliary generator set is taken from the main propulsion turbo-generator set, which delivers alternating current through a transformer to drive the auxiliary alternating-current generator as a motor; at the same time, steam is automatically cut off from the auxiliary turbine, allowing it to rotate in a vacuum. The low water rate of the main turbine is therefore obtained for all purposes in connection with light and power.

1931: *Itasca* class, 250 feet long. These cutters have induction motors for driving the auxiliaries, and alternating current for lighting and other purposes, except a few specialized applications where direct current is provided by a small motor generator.

1931: *Thetis* class, 165 feet long. These patrol boats have 4-cycle Diesel engines, 6-cylinder, mechanical injection, rated 670 horsepower, directly reversible; twin-screw installation, with one engine direct-connected to each shaft.

1931: 78-foot patrol boat class. These patrol boats have eight-cylinder gasoline engines, rated at 565 horsepower; twin-screw installation, with one engine direct-connected to each shaft.

1932: *Algonquin* class, 165 feet long. First cutters designed for geared-turbine drive, as the type of propulsion best adapted to obtain the power in the machinery space available. Two differing installations have been made, and in both cases a double-reduction gear is fitted between the turbine and the shaft for the single screw. Ample backing power is provided for maneuvering purposes. Steam furnished by two watertube boilers at 310 pounds per square inch and 200 degrees superheat. Cutters suitable for ice-breaking and actively employed on this duty; no difficulty with geared-turbine propelling machinery in this service.

1934: *Hudson* class, 110 feet long. These harbor cutters have Diesel-electric drive, pilot-house control, with two 4-cycle Diesel engines, air injection, six-cylinders, rated 500 horsepower each. The propulsion motor on a single screw is of the direct-current double-commutator type.

1936: *Alexander Hamilton* class, 327 feet long. The seven cruising cutters of this class, commissioned during the last few months, have geared-turbine propelling machinery with twin screws. Each unit consists of a high-pressure and a low-pressure cross-compound turbine, each turbine connecting to the propeller shaft through a unit double-reduction gear housed in a single case. The boilers are oil-burning, of the Babcock & Wilcox design with tubes on an arc connecting the front and rear headers; pressure, 400 pounds per square inch; temperature, 200 degrees superheat.

1937: 80-foot and 72-foot patrol boat classes. These patrol boats have duplex gasoline engine units on each shaft of the twin-screw installation; the duplex unit consists of two 425-horsepower V-12 engines in line, one forward and one abaft a reduction gear with suitable ratio, and with mechanical clutch and reverse gear for each engine. The speed and power range is considerable; for instance, each duplex unit has available one engine at cruising speed, one engine at first intermediate speed, two engines at second intermediate speed and two engines at full speed. The propeller is the key to this speed range, since it has to utilize, with reasonable efficiency, extremes of engine power as the result of the step-up in revolutions from one engine at low speed to two engines at high speed. For a 72-foot patrol boat, the engine revolutions per minute and the corresponding statute miles on a trial run were as follows: 900 revolutions per minute, 16 statute miles; 1200 revolutions per minute, 22 statute miles; 1500 revolutions per minute, 28 statute miles; 1900 revolutions per minute, 34 statute miles, approximately. Experience will demonstrate if a duplex unit, or a modification thereof, deserves further development.

Auxiliaries. Engine-room and deck auxiliaries were improved along with the propelling machinery itself, and new devices were utilized as soon as they became available. Electric generating sets were installed at an early date to provide electric lighting, and since that time current consumption on the cutters has enormously increased for all the purposes found on any vessel. Direct and alternating current have been approved, as most advantageous for the various purposes, and at present all auxiliaries are electrically operated to the extent justified by the analysis of heat balance for the whole machinery installation.

Weight and Speed. During the progressive stages of machinery design for cutters and patrol boats, reliability has been a primary requirement, with economy nearly equal in importance; the latter because of its effect on cruising radius and fuel cost. For cruising cutters, no serious attempt is made to cut down weight excessively but advantage is taken of the weight-saving trend of all marine machinery. However, the policies indicated above are not applied so rigorously to patrol boats, where comparatively light-weight Diesel engines are approved, and extremely light-weight gasoline engines accepted, if high speed is imperative.

As regards the speeds of Coast Guard craft, trials with too light a load to simulate conditions found in service are not reported; the latest specifications for the trial loading cover the completed

TABLE 1.—TECHNICAL DATA ON COAST GUARD CUTTERS

Name	*Alexander Hamilton*	*316-Foot	*Itasca*	*Tampa*	*Northland*	*Manning*	*Algonquin*	*Tallapoosa*	*Hudson*
Class	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	C.C.	H.C.
Built	1936	Proposed	1930	1921	1927	1898	1934	1915	1934
Length, overall	327'0"	316'0"	250'0"	240'0"	216'7"	205'6"	165'0"	165'6"	110'6"
Length, waterline	308'0"	295'0"	239'0"	220'0"	200'0"	188'0"	150'0"	150'0"	101'6"
Beam, waterline	41'0"	46'6"	42'0"	39'0"	39'0"	32'10"	36'0"	32'0"	24'0"
Draft, mean (trial)	12'8"	16'0"	12'10 1/2"	13'2"	13'8"	12'3"	12'3"	11'9"	8'8"
Block coefficient	0.510	0.379	0.490	0.477	0.611	0.477	0.538	0.585	0.456
Midship coefficient	0.885	0.686	0.900	0.887	0.963	...	0.852	0.932	0.738
Prismatic coefficient	0.579	0.547	0.540	0.539	0.635	...	0.632	0.627	0.618
Displacement (trial)	2350	2350	1662	1506	1785	1000	1000	912	269
Speed (trial)	20 K	20 K	17 K	16.2 K	11.7 K	16 K	12.8 K	12 K	12.9 K
Propelling machinery	Geared-turbine	Geared-turbine	Turbo-electric	Turbo-electric	Diesel-electric	Triple-expansion	Geared-turbine	Triple-expansion	Diesel-electric
Shaft horsepower (total-trial)	5250	5650	3350	2600	1025	2181	1500	1000	800
Propeller	3-blade twin	4-blade single	4-blade single	4-blade single	4-blade single	4-blade single	4-blade single	4-blade single	3-blade single
Diameter	9'0"	13'9"	11'9"	13'0"	10'0"	11'0"	10'8"	9'6"	7'6"
Pitch	10'1 3/4"	11'9"	11'6"	14'0"	13'3 1/2"	12'4"	10'4"	12'0"	6'5"
R.P.M. (trial)	241	173	163	130	132	152	140	115	250
Weights—Hull (tons)	1178	1528	952	842	1121	...	560	418	157
Machinery	414	340	323	275	316	...	162	223	82
Fuel	561	450	300	293	220	205†	156	172	12
Water	251	138	149	114	39	66	49	46	3
Equipment and supplies	156	108	153	114	192	52	74	54	15
Cost	$2,468,460	$1,500,000	$893,570	$775,000	$865,730	$175,960	$525,550	$225,000	$260,000

TABLE 1. (*Continued*).— TECHNICAL DATA ON COAST GUARD CUTTERS

Name	*110-Foot	*Thetis*	*Active*	80-Foot	75-Foot	72-Foot	38-Foot	52-Foot	36-Foot
Class	H.C.	P.B.	P.B.	P.B.	P.B.	P.B.	PKT.	M.L.B.	M.L.B.
Built	Proposed	1931	1927	1937	1925	1937	1936	1935	1936
Length, overall	110'3"	165'0"	125'0"	80'9"	74'11"	72'0"	38'0"	52'0"	36'8"
Length, waterline	105'10"	160'9"	120'0"	78'0"	74'2"	70'0"	37'0"	50'0"	35'0"
Beam, waterline	25'0"	23'9 1/4"	23'4"	14'7"	12'7 3/4"	12'9"	8'6 3/4"	12'8 1/4"	9'5 1/4"
Draft, mean (trial)	9'6"	7'8 1/2"	7' 1/2"	4'0"	3'7 1/2"	3'7"	3'0"	6'6 1/2"	3'3"
Block coefficient	0.437	0.378	0.334	0.458	0.428	0.449	0.483	0.419	0.524
Midship coefficient	0.759	0.660	0.734	0.722	0.710	0.613	0.708	0.675	0.763
Prismatic coefficient	0.576	0.573	0.537	0.635	0.603	0.733	0.682	0.621	0.687
Displacement (trial)	310	334	232	51.7	34	31	7	31	11
Speed (trial)	12 K	16 K	13.3 K	30 SM	18 SM	35 SM	26 SM	11 SM	9.5 SM
Propelling machinery	Diesel-electric	Diesel	Diesel	Gasoline	Gasoline	Gasoline	Gasoline	Diesel	Gasoline
Shaft horsepower (total-trial)	1000	1340	600	1680	400	1680	325	150	100
Propeller	3-blade single	3-blade twin	3-blade twin	3-blade twin	3-blade twin	3-blade twin	3-blade single	3-blade single	3-blade single
Diameter	8'0"	62"	42"	33"	28"	33"	23"	30"	28"
Pitch	5'6"	53"	30"	34"	21"	30"	22"	28"	16"
R.P.M. (trial)	260	450	700	1200	1200	1489	1630	673	1000
Weights—Hull (tons)	167	170	156	34.4	21.3	20.1	3.44	21.2	8.16
Machinery	91	88	33	9.3	5.7	7.0	1.47	4.9	1.21
Fuel	20	28	22	7.1	2.6	5.3	0.67	2.0	0.45
Water	5	17	6	1.1	0.8	..	..	..	..
Equipment and supplies	27	31	32	4.7	3.6	1.3	1.34	2.2	0.89
Cost	$375,000	$208,850	$63,173	$51,975	$35,000	$43,965	$10,000	$70,000	$20,000

* Estimated. K—knots. SM—statute miles. † Coal, others oil or gasoline.

vessel, with equipment, fuel, water and stores comparable to an average load condition.

TECHNICAL DATA ON TYPICAL COAST GUARD CUTTERS

Items of information relating to certain cutters, patrol boats and small boats built in recent years are shown in Table 1, which is a table of technical data on Coast Guard cutters. The table may prove to be a useful page for comparative purposes, if it is necessary to meet the problems presented to the technical staff of the Coast Guard and to attempt the reconciliation of many contradictory elements in a creditable compromise, with cost one of the factors. Comment on the table is as follows:

(a) Names identify the units as similarly referred to elsewhere in the paper.

(b) Classes indicate cruising cutters (C.C.), harbor cutters (H.C.), patrol boats (P.B.), picket boats (PKT.) and motor lifeboats (M.L.B.).

(c) Length overall is the length from the foreside of the stem to the after end of the overhang.

(d) Length on waterline; beam at waterline; draft, mean; block coefficient; midship coefficient; prismatic coefficient; and displacement in long tons, are all consistent with loading when the recorded speed was attained.

(e) Speed is knots (K) or statute miles (SM), and the trial approximates the average service condition; in any case, the speed corresponds to the displacement.

(f) Propelling machinery gives the type of propulsion; fuel is oil or gasoline, except coal for *Manning*.

(g) Shaft horsepower is total power on a single screw or total power on twin screws, as the case may be, and corresponds to the speed recorded.

(h) Propeller data apply to propellers actually installed; R.P.M. is the revolutions of the propeller consistent with the trial.

(i) Weights are approximate; they are for general information only, and do not necessarily agree with the trial displacement. They are grouped as hull proper and deck auxiliaries; machinery, including engines, boilers and auxiliaries; fuel, to capacity of bunkers; fresh water for reserve feed, washing and drinking purposes; and equipment, supplies, boats, radio, ordnance, ammunition, stores and miscellaneous material.

(j) Cost is only an approximation to the total cost of the hull, machinery, equipment and outfits furnished by both the contractor and the Government, with the cutter complete for service, except for consumable supplies and stores. The cost figure is affected by the date when built, locality and building yard, and by the fact that where units of a class were built by more than one contractor the cost reported is about an average cost. It is emphasized that the cost figure is not accurate and is included for whatever value it may have as an item of general information only.

The headings of the columns identify the cutters, patrol boats and other units by name and length, to correspond to other references in the paper. There follow some remarks explanatory of similarities, differences or peculiarities applying to classes or to individual units, which it seems desirable to discuss.

Hamilton Class and 316-Foot Cutters. For the latest cruising cutters a speed of 20 knots was desired. Based on gratifying reports on the *Itasca* class of 250-foot cutters, a design was studied of a generally similar type, but longer, with the speed increased from 17 knots to 20 knots. As it was also desired to carry airplanes on deck in an enclosed hangar, the beam was increased to a feasible maximum for added deck area. This design was practically complete and the result of the Model Basin tests on a set of lines is summarized in Table 1, even though this cutter was not built. The power increase at 20 knots, as compared with the 327-foot cutters, was to be accepted, since at cruising speeds a modest increase only would be involved.

A design of a Navy gunboat to make 20 knots was underway at the same time, and it is interesting to note the two solutions for 20 knots on 2000 tons Treaty displacement, even though other important elements were quite diverse. The Coast Guard design conformed to previous practice, with a single screw, whereas the Navy design embodied structural innovations, as far as the Coast Guard was concerned, and propulsion was by twin screws. The Commandant finally directed the technical staff to use the gunboat as the basis of a new design, with a definite proviso that typical Coast Guard features be incorporated wherever possible to reduce the cost of construction and repair.

Since the gunboat lines, as shown in Fig. 8, had been through the Model Basin tests, these lines were approved, except for alterations in sheer, stem, stern and skeg, which were justified for Coast Guard purposes. The longitudinal framing and the watertight subdivision of the gunboat were approved, but the scantlings were appreciably heavier throughout and the machinery space bulkheads were adjusted to suit the Coast Guard requirements for the propulsion layout. The typical Coast Guard scheme of quarters was applied, and deck erections were reduced and rearranged for the definite purpose of obtaining a long and clear afterdeck for space to handle and transport airplanes and allow the mounting of a heavy towing bitt in the usual location, well forward of the rudder and propellers. These changes brought about a general agreement of the profile with the typical Coast Guard cutter, so that, except for the underwater body, the cutter designed by the Coast Guard is distinctly different from the gunboat designed by the Navy.

The incorporation of Coast Guard practice extended also to the propelling machinery, and the specifications for the boilers, turbines, reduction gears and propellers were prepared and issued to suit the requirements of a Coast Guard cutter.

While the technical staff of the Coast Guard

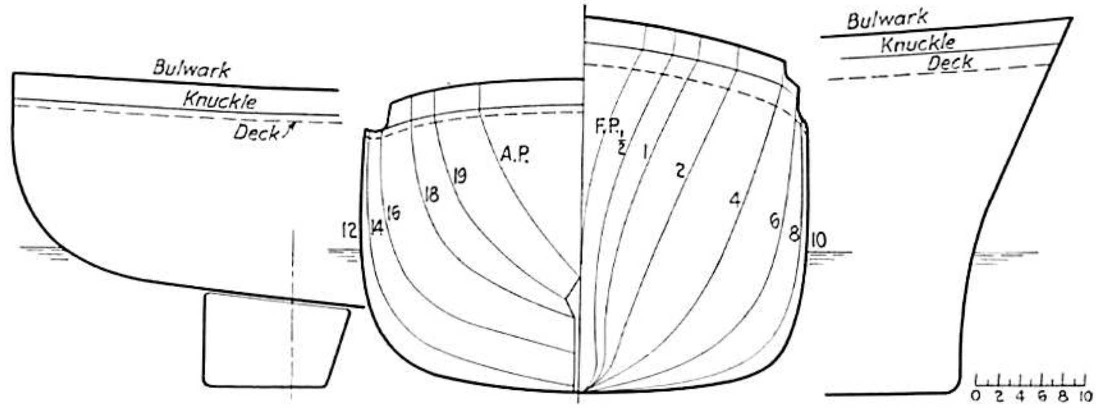


FIG. 8.—LINES OF CUTTER "ALEXANDER HAMILTON"

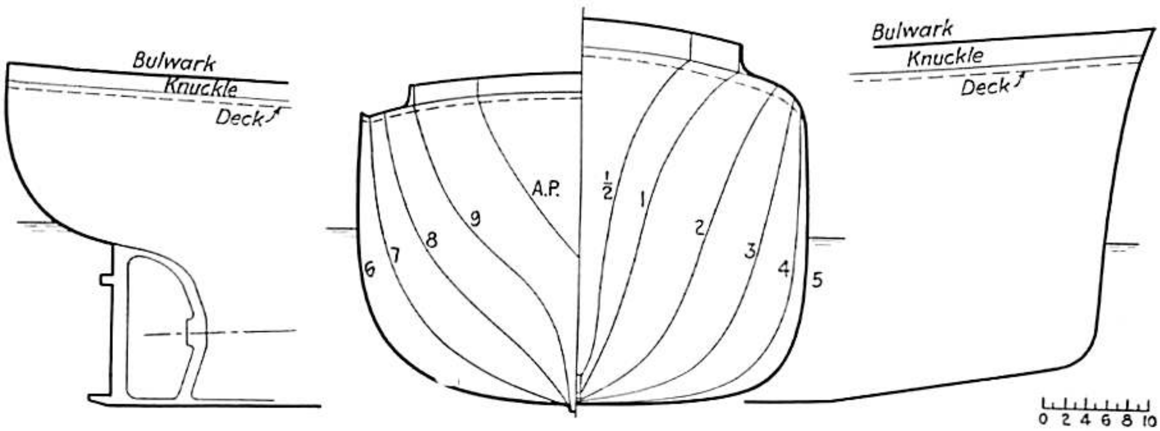


FIG. 9.—LINES OF CUTTER "ITASCA"

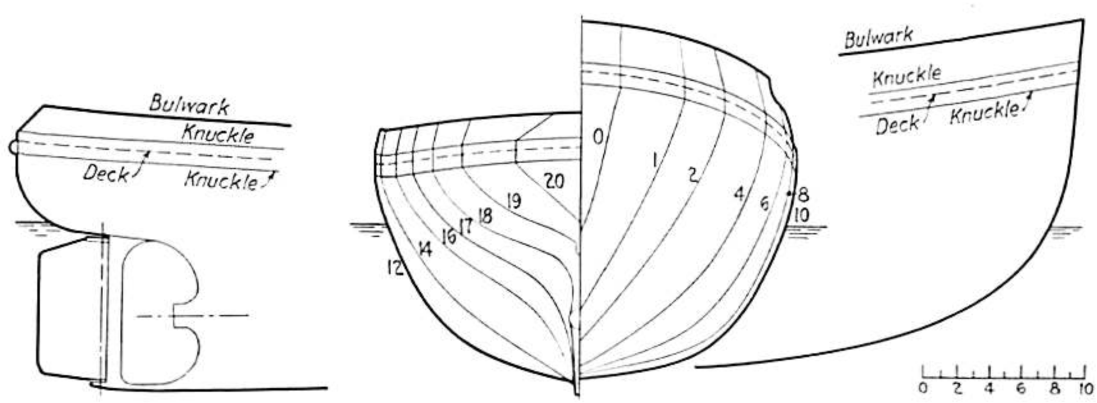


FIG. 10.—LINES OF 110-FOOT HARBOR CUTTER

is responsible for the *Hamilton* class of cutters we are indebted to the Navy Department for the lines approved for the underwater body, and are indebted also to the Navy Yards at Philadelphia, New York and Charleston, for their assignment of Coast Guard officers to responsible positions concerned with the building of the cutters, during the period the yards were functioning as contractors. It is fully expected that these new 20-knot cutters will be a credit to all who had a part in their production.

Itasca and Tampa Classes. The *Tampa* class

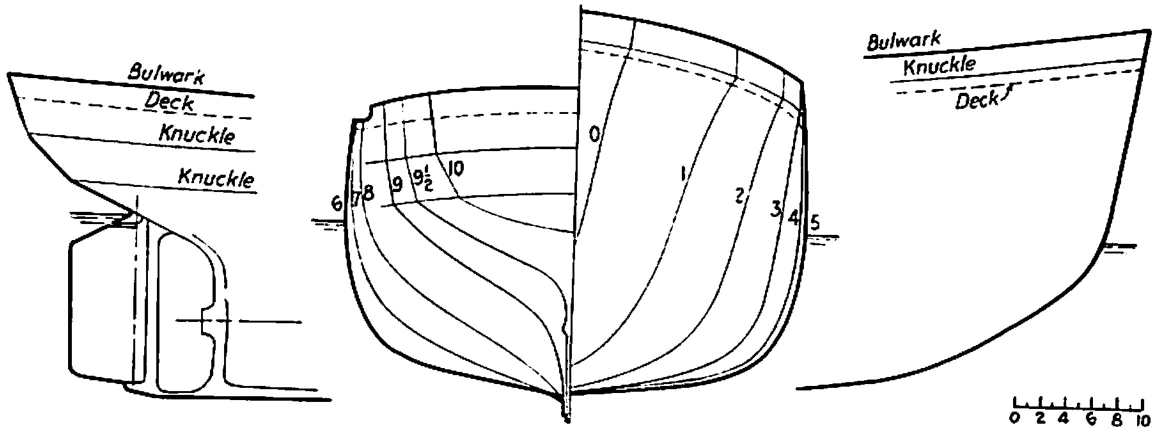


FIG. 11.—LINES OF CUTTER "ALGONQUIN"

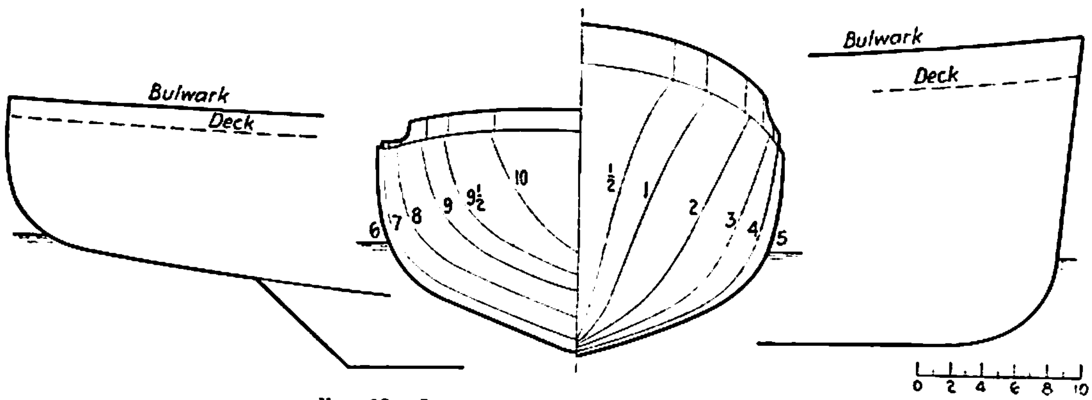


FIG. 12.—LINES OF PATROL BOAT "THETIS"

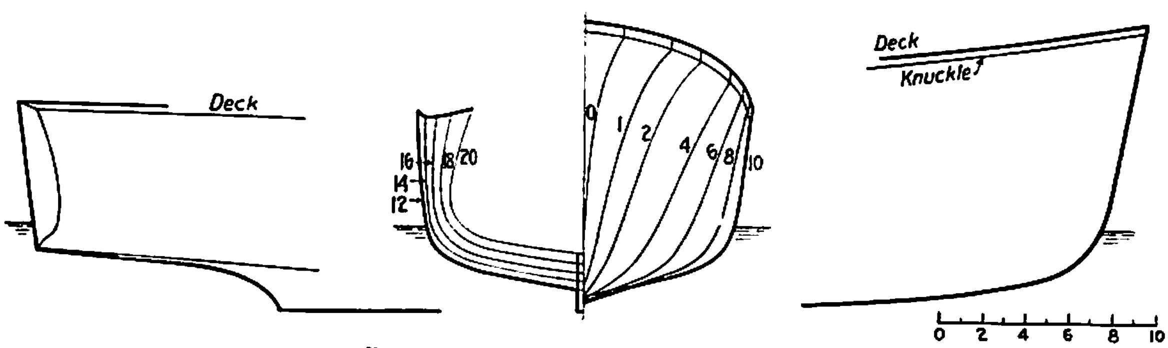


FIG. 13.—LINES OF 80-FOOT PATROL BOAT

design of 16-knot cutters was begun in 1916, with the plumb bow and overhanging stern of previous vessels perpetuated. Ice patrol in stormy weather on the North Atlantic later showed the undesirability of repeating the overhanging stern, as heavy seas coming up under the counter gave the hull severe shocks.

In the design which followed, of the *Itasca* class, a raking stem and a cruiser stern were adopted and a slight increase in the power of propelling machinery was provided for some increased speed. From many points of view, the *Itasca* class turns out to be an ideal cutter for all-round service, present and prospective, and with reasonable increases in length and power and with savings in weight, a desired speed of 20 knots can be obtained in a generally similar design.

Northland. This cutter is the successor to the venerable cutter *Bear,* which did duty in Arctic waters for more than fifty years. Officers with service in the Arctic attended a conference to determine the characteristics of the *Northland,* and opinions were expressed on wood, steel, sails, steam, Diesel, coal and oil, not to mention length, draft strength, speed, cruising radius, accommodations, hospital facilities, small boats, cargo capacity and other items of debate. The final outcome is a steel vessel with full lines and cutaway bow, of very strong construction and close watertight subdivision, and with Diesel-electric propelling machinery on a single screw.

On account of ice, no bilge keels are fitted and the *Northland* rolls heavily under some conditions. Bilge keels have been schemed out, composed of single-plate sections, 18 inches deep and 6 feet long, rather lightly fastened to the outside plating at the bilges. It is expected that any or all of these sections may be torn adrift without damage to the hull, but the idea is of doubtful practicality and such bilge keels have not yet been fitted.

For many years the *Northland* has withstood severe punishment in the ice, and is now fulfilling its mission in Arctic and Alaskan waters.

Manning. This cutter was typical of a group with fine lines, triple-expansion engine, and four Scotch boilers, strictly up-to-date when built. On account of the comparatively high power, the cruising radius was limited, and deck auxiliaries and accommodations were rather also meager. In due course, these cutters came up for a deserved reconditioning and the *Gresham,* for instance, was changed from coal to oil-burning and from Scotch to watertube boilers, furnishing steam at higher pressure. Liners and new pistons were fitted in the high and intermediate cylinders to make the cylinder ratios suitable for the higher boiler pressure. Every one of the five essential elements for a cutter was improved and the extensive alterations were fully justified.

Algonquin and Tallapoosa Classes. When the old "tugboat" type of low-freeboard cutter became obsolete, replacement cutters retained, as far as possible, the handiness of a tugboat but gained in other elements. The *Tallapoosa* was the first of the smaller cutters with flush deck and good freeboard, and her behavior was so satisfactory that the design was further developed in the recent *Algonquin* class, which is required to meet severe ice conditions. Heavier scantlings and higher powered machinery were adopted, but, with the limited draft, the beam was increased to obtain the additional displacement. Six successful cutters of the *Algonquin* class are now in commission.

To meet ice conditions, the alterations to the *Kickapoo* are an interesting example of reconditioning work for a particular purpose. This vessel was originally a deep-draft sea-going tugboat, built by the Shipping Board, and the problem was to cut away the stem, reinforce the frames and plating, increase the displacement by a considerable amount, and simultaneously reduce the draft about four feet. This was accomplished by sponsons on each side, built out beyond the original frames, increasing the beam 7 feet 6 inches, from 27 feet 6 inches to 35 feet. The final result was even more satisfactory than hoped for, and the *Kickapoo* has given a good account of itself for years, being laid up in reserve only last summer.

Hudson Class and 110-Foot Harbor Cutters. For general harbor service, as much speed as is practicable in a typical harbor tugboat is desired, and the combination of this and many other minor features brought about the *Hudson* class. These hulls suffered some damage when breaking ice, and the design is now being modified to reduce the speed somewhat, and add to the displacement to carry heavier framing and plating and increased engine power, so as to improve the ability to work in ice. A draft limitation being accepted, the beam and the lines have been altered for the new displacement, and Fig. 10 shows the lines as now approved with sloping sections at the waterline throughout. The design now laid down will probably be used for building the next replacement of a harbor cutter.

Thetis Class. It was imperative that the 165-foot patrol boats should excel in every element; that is, seaworthiness, speed, maneuverability, cruising radius, accommodations, searchlights, radio, ordnance and other items. It was equally important that the increments should be equalized inasmuch as over-emphasis on one would adversely affect others; for instance, over-emphasis on speed would sacrifice seaworthiness, cruising radius, accommodations, and other features, or else compel a larger boat with more cost attendant on every item in the completed vessel. The 165-foot patrol boats are an outstanding instance where judgment was demanded to balance the advantages of conflicting elements.

Active Class. The 125-foot patrol boats were built with emphasis on seaworthiness and cruising radius, and they have the reputation in the Fleet of fulfilling these requirements to an unusual degree. Their original robust construction for deep-sea service has kept them available for many important assignments.

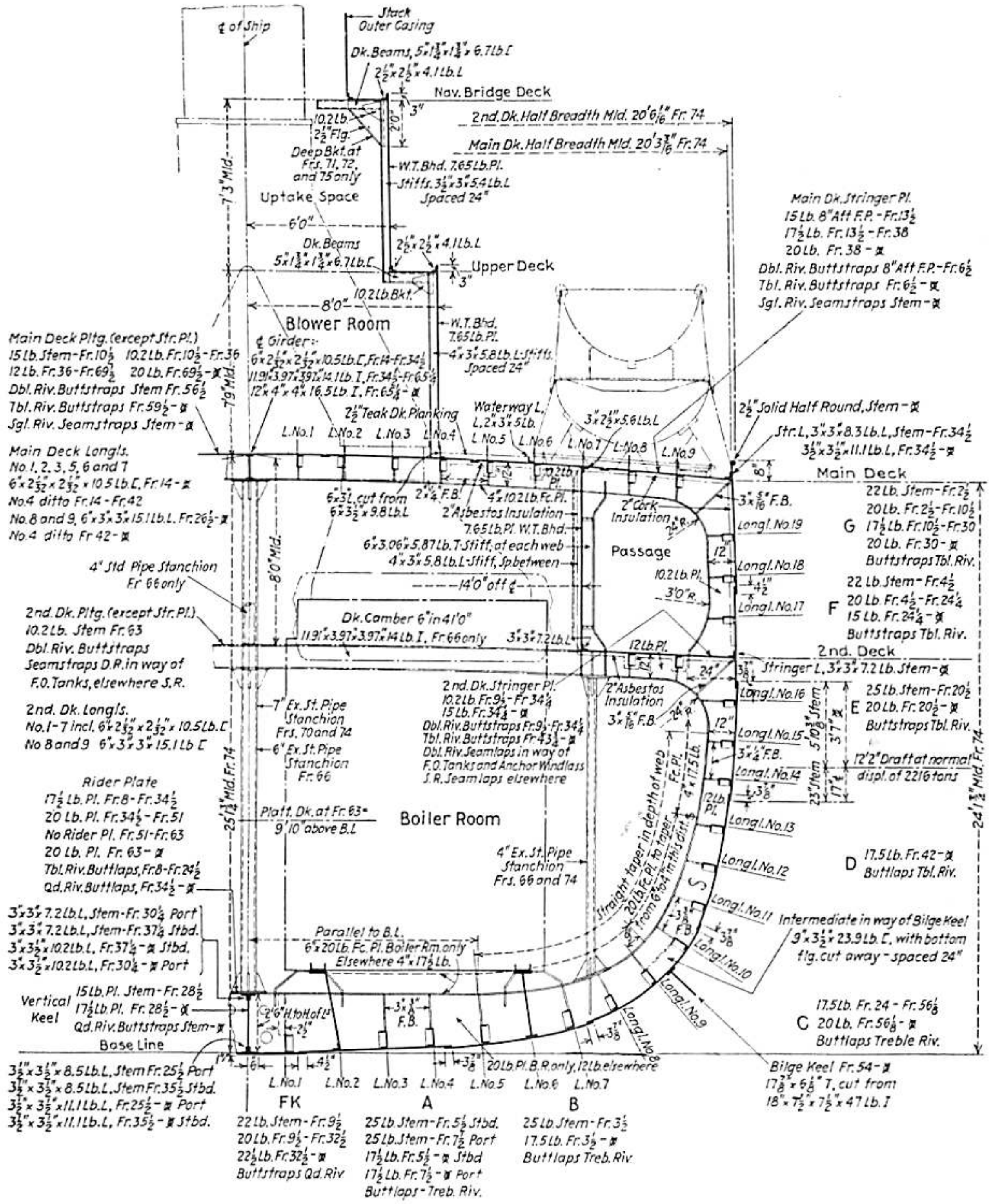


FIG. 14.—MIDSHIP SECTION OF CUTTER "ALEXANDER HAMILTON"

80-Foot, 75-Foot and 72-Foot Patrol Boats. The 75-foot patrol boats were designed as the smallest boats which could be seaworthy; to have a speed of about 18 statute miles, and at the same time were to be self-sustaining at sea for a period of several days. Service history has clearly shown that they fulfill these requirements, and patrol boats of this class remain an important group in the Fleet for local assignments. Technical developments in hull and machinery indicated that more speed

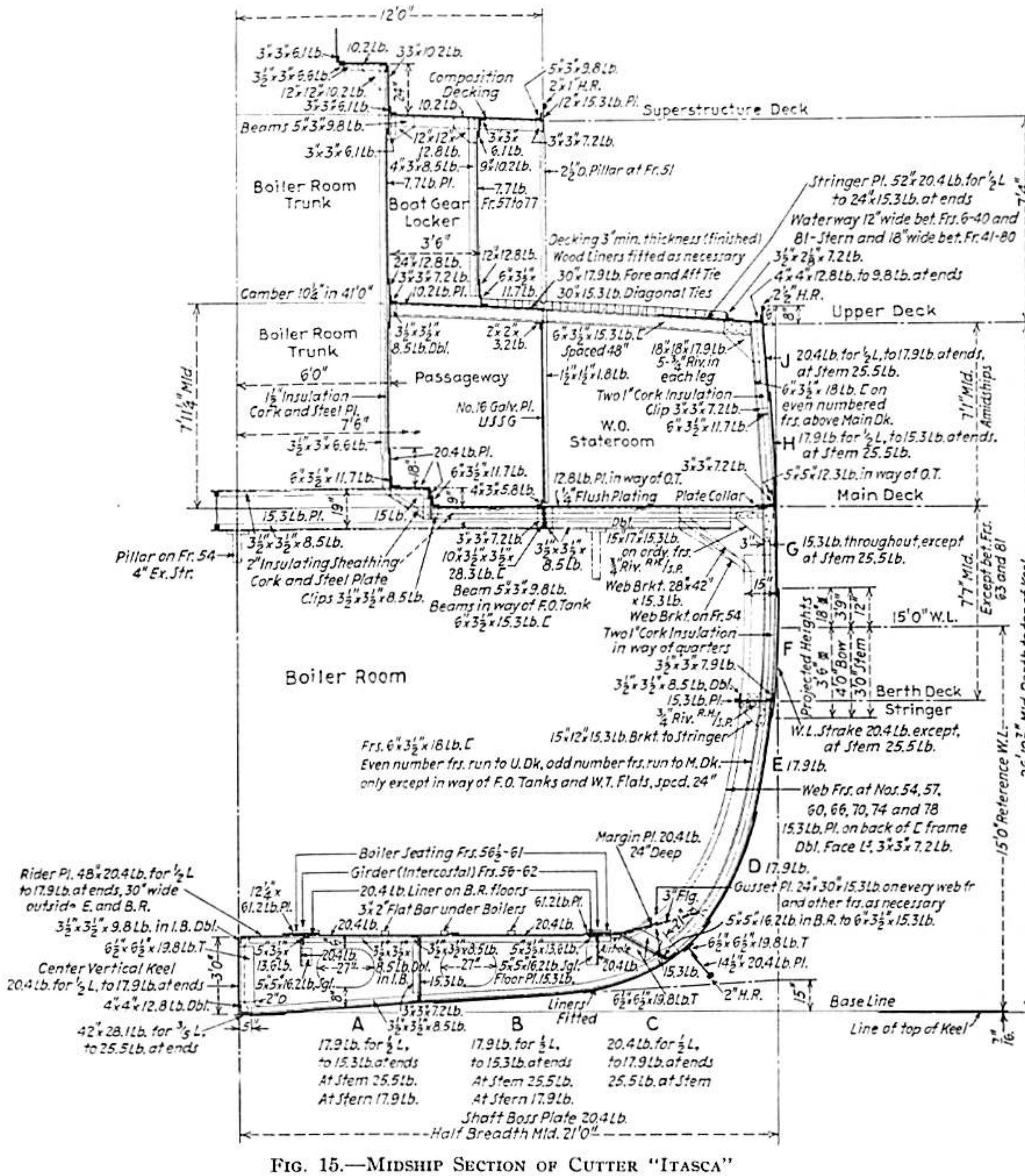


FIG. 15.—MIDSHIP SECTION OF CUTTER "ITASCA"

could be obtained without the loss of other features, and accordingly the initial 80-foot patrol boats have just been built, in the confidence that they will prove an important advance. To gain still further speed, but with a lighter hull and the sacrifice of accommodations, two 72-foot patrol boats have recently been constructed for experimental purposes. There is no doubt but that the Coast Guard, as a law enforcement agency, should always have available a few high-speed patrol boats to be used as circumstances may determine. It is contemplated that replacements for the 75-foot patrol boats will be made by boats of these two classes.

Small Boats. The picket boats and motor lifeboats comprise some of the classes of small boats which the Coast Guard has designed and built chiefly for Coast Guard station use. These boats are recent models, following a long series of construction programs, and several of the classes are

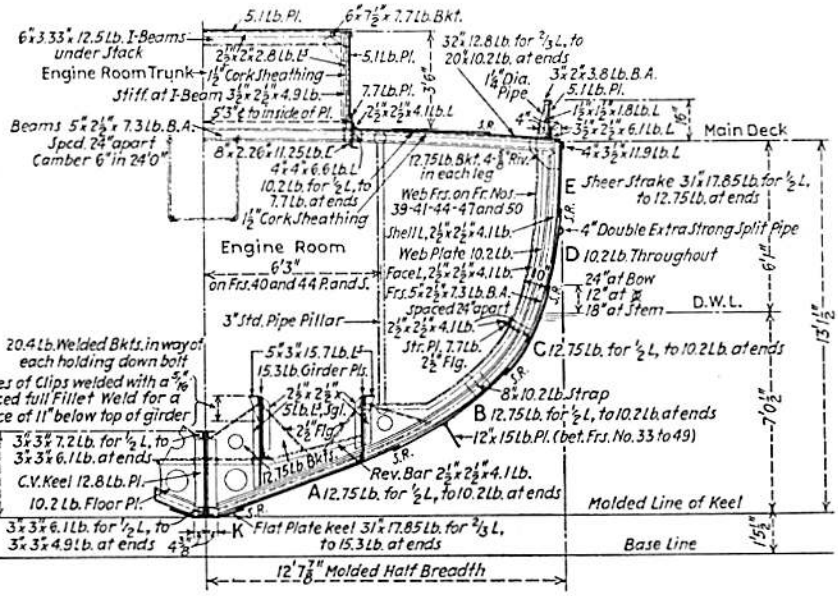


FIG. 16.—MIDSHIP SECTION OF PATROL BOAT "THETIS"

in production as standard boats of the Service.

Supplemental Data. To supplement the information in Table 1 there have been included in the paper sets of lines, midship sections, general arrangement plans and pictures, which also indicate similarities and differences in the various present classes of cutters and patrol boats. As regards the lines, it is apparent from Figs. 8 to 13, inclusive, that no abnormal features are found in the underwater body of any vessel. The midship sections, Figs. 14, 15 and 16, indicate scantlings and construction details which conservative practice will approve. Two typical accommodation plans are shown of the layout which is proving satisfactory; Fig. 6 for cutters and Fig. 7 for patrol boats. For the *Itasca* class of cutters, the only variation at present would probably locate the quarters for the commanding officer in the deckhouse just below the bridge, departing from the sentimental association of the commanding officer and the quarterdeck. The pictures reproduced in Figs. 1 to 5 and 17 to 19, inclusive, are inserted with apologies, as it is doubtful if they do credit to the appearance of the Coast Guard Fleet; it seems to be almost impossible to obtain satisfactory pictures of cutters and patrol boats at sea carrying out the normal Service duties.

COAST GUARD ANTI-SMUGGLING CRAFT

It may be interesting to insert in the record at this time a narrative account of the design and building programs, during recent years, for the Coast Guard anti-smuggling craft; the facts have not before been reported to a technical group which might gain from the information thus available. There is no confidential matter to release, since regular Government procedure was followed for the procurement of the new patrol boats, with full disclosure of the necessity in printed hearings; legislative authorizations and appropriations; advertising and awards of contracts; and construction, trials, commissioning and operation, and with publicity at every stage. As might be assumed, the Coast Guard technical staff was well informed as to prospective developments in the smuggling boats, and sometimes envied the quick action which cash in hand was able to secure from conception to completion of the boats, incidentally known as "Blacks" or "Rummies," depending on the dignity of the occasion and discussion, and therefore here described as "Blacks."

In 1920, the Prohibition Amendment was declared in effect, and for a year or two there seemed to be general obedience to the law. It was not long, however, before "Rum Row" became in evidence and in 1923 the situation was so flagrant a defiance of the law, and "Rum Row" so notorious that government action was imperative. During this time the Coast Guard, with insufficient vessels, had coped with conditions, but with only fair success, and in 1924 the duty of enforcing the law afloat was definitely assigned the Coast Guard. Operating officers were at once called into conference, and the technical staff submitted alternate designs for new and effective enforcement units of the Fleet. Immediate action was expected, and contracts for fast 36-foot picket boats were awarded, as this type could be built most expeditiously. The Act of April, 1924, turned over twenty-five decommissioned destroyers for operation by Coast Guard officers and men, and these high-speed craft were soon reconditioned with torpedo tubes removed, and put on law enforcement duty. It was fully realized that these few law enforcement craft, at the extremes of size, would be inadequate in number to terminate the smuggling; but they did, in conjunction with the regular Coast Guard units in commission, practically wipe out "Rum Row" as it then existed, with nondescript foreign cargo-carriers outside the legal limit and miscellaneous American motor boats transporting cargoes to the shore. This spectacular phase of the business soon drew to a close, but the traffic was by no means ended, for by this time it had taken on international proportions, with untold resources in money, men and up-to-date facilities consequent on the profits when fortune favored.

75-Foot Patrol Boats. In 1924, to augment further the law enforcement groups, the building of more than 200 of the 75-foot patrol boats was initiated. This was by far the most ambitious boatbuilding program since the War, and it was handled with gratifying celerity and to the satisfaction of all concerned.

A conference of intending bidders was called and the program outlined for their information. It had been decided that machinery, radio and ordnance would be furnished by the Government, and boat-builders would construct the hulls and install machinery. It was explained that bids must name the price per boat in groups of 10, 15, 25, 35 or 50 boats, up to the maximum number a contractor could build within the time allowed; that completion of the boats was desired as soon as possible; and that the contracts would require the first boat to be delivered in 120 calendar days and the last boat in 360 calendar days. As stated above, regular Government procurement procedure was followed, and tenders were received from 59 concerns; bids were scheduled and considered, and awards were made on the basis of lowest responsible bid, seventeen contractors qualifying, with boat yards on the Atlantic and Pacific coasts and the Great Lakes.

In the meantime, the Engineer-in-Chief undertook procurement of 200-horsepower gasoline engines and other items of machinery, following similar steps of conference, advertising, awards, tests and deliveries to the boat yards. Contract prices for the hulls and the installation of machinery varied widely, but it is probable actual cost to the contractors likewise varied, depending on the boat yard management and the production methods used. At all events, the 75-foot patrol boat program was successful from every point of view, and this class of patrol boats contained to an unusual degree the seaworthiness, speed, cruising radius and accommodations, so essential for a self-sustaining unit in the Service. The boats have held up well under severe operating conditions and continue to be valuable units in the Fleet for local service.

Speed Boats. Early in the campaign the probability of a trend toward speed was realized, and in 1925 Coast Guard speed boats were built, 42 feet long, with marine-conversion Liberty engines on twin screws, which made trial speeds of 42 statute miles per hour. They were open boats, however, lacking features which service demonstrated later to be necessary and these speed boats were not duplicated.

In the meantime, the smugglers were actually building "Blacks" with speeds well beyond normal limits. They were naturally intended to make a profit, and, facing the hazards of capture, the boats were as cheaply built as possible to minimize loss. High-powered gasoline engines of various types were installed on two screws, three screws and four screws, and extraordinary speeds were obtained although reports of inspired propaganda were commonly exaggerated.

On the West Coast a different type of "Black" was evolved, generally with a Diesel engine on a center screw and high-powered gasoline engines on two wing screws. In view of the dubious engineering aspects of this combination, the Coast Guard did not attempt to outbuild the "Blacks" with a similar propelling machinery layout.

In 1930, Coast Guard picket boats were built, with a Liberty-conversion engine on a single screw making 30 statute miles per hour and proving valuable law enforcement units for some local areas. In spite of various handicaps, the Coast Guard was successful in combating every sort of smuggling craft and thus compelled the building of faster and more expensive "Blacks" to take the contraband ashore, but even then Coast Guard boats made many seizures.

125-Foot Patrol Boats. The foreign cargo-carriers outside the 3-mile limit, or whatever limit legal and international developments decreed, became a serious problem, and trailing of these boats to prevent a cargo transfer became imperative. In 1927, the 125-foot patrol boats were built, with

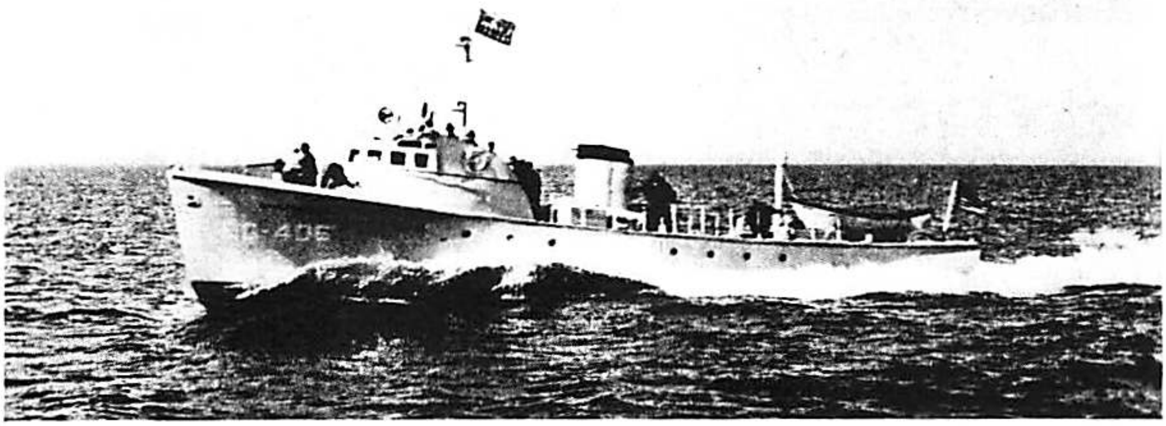


FIG. 17.—UNITED STATES COAST GUARD 80-FOOT PATROL BOAT

Diesel engines on twin screws, the engines being of the highest power then available with mechanical clutches and reverse gear; direct-reversing engines seemed to be precluded by the maneuvering air which would be necessary. It is not surprising that the "Blacks" imposed such trailing speeds as might wear out the engine clutches by excessive use in trailing; judicious handling of the engines, however, avoided serious trouble. In this, as in other respects, the "Blacks" had an advantage, since the initiative lay with them and a patrol boat had to be ready for any shift of action.

The effective trailing by the 125-foot patrol boats brought about the building of new cargo "Blacks" of increased size and speed to more than hold their own with the patrol boats. The new "Blacks" discovered an ability to outwit destroyers occasionally by abruptly reversing their course, escaping searchlights, and disappearing in fog and darkness before the destroyers could pick up the trail again. The destroyers were unquestionably the correct recourse when put in service, but the cost of maintenance and operation, and the changing tactics of the "Blacks," led to their decommissioning as the years passed. The Coast Guard destroyers fulfilled an instant need and their temporary use along the Atlantic seaboard obtained immediate results which could not otherwise have been secured.

165-Foot Patrol Boats. Success in trailing had been demonstrated, but as time elapsed the problem was again presented by the new fleet of cargo-

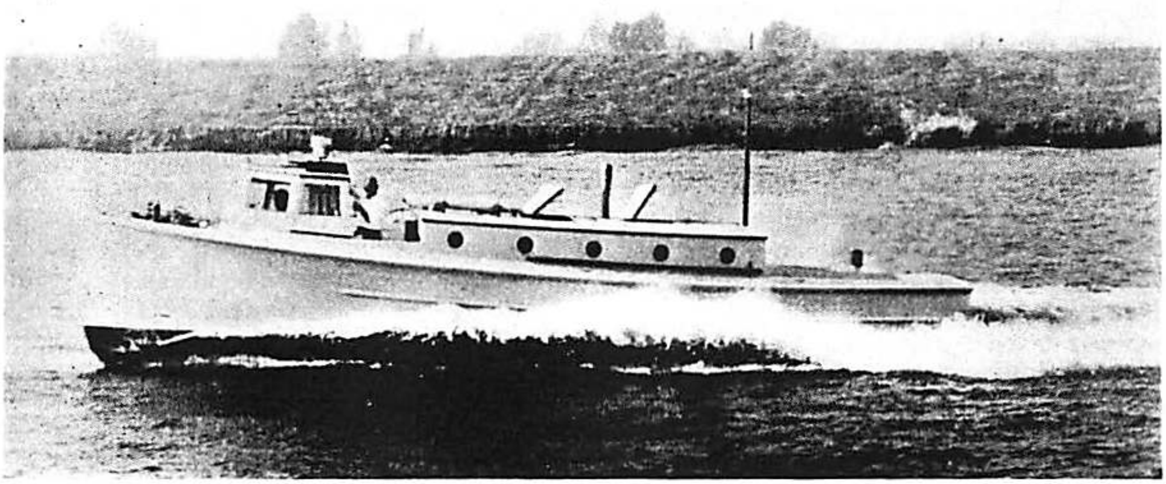


FIG. 18.—UNITED STATES COAST GUARD 38-FOOT PICKET BOAT

carriers which appeared off the coast. The Coast Guard now decided to terminate this kind of competition, and, accordingly, in 1931 the 165-foot patrol boats were built to outclass the "Blacks" in every way. As these new Coast Guard patrol boats went into commission, trailing became increasingly effective. With the "Blacks" under constant surveillance, the transfer of cargo to the contact boats could be made only occasionally and the long uncertainty and delay in disposing of a cargo cut deeply into profits. The seaworthiness, speed and maneuverability incorporated in the 165-foot patrol boats, and the efficient searchlights, made it comparatively easy to hold the "Blacks," except when an unusual combination of fog, rain, snow or adverse weather gave an opportunity to shake the trail for short periods. From the date of their commissioning until now, the 165-foot patrol boats have an unsurpassed record for efficient operation.

Fast Patrol Boats. In 1931, the 78-foot patrol boats were built, with a 565-horsepower medium-speed gasoline engine, direct-connected to each of the twin screws. These boats were heavily constructed for hard service under all conditions. They proved to be reliable and effective units with captures to their credit and they continue as active units.

The displacement necessitated by the robust hull and machinery set the top speed around 25 statute miles per hour, but this class of patrol boats drove the speed of the "Blacks" still higher. The expansion in size, power and speed of the foreign "Blacks" engaged in carrying cargo, and the American "Blacks" employed as contact boats, was even more than originally expected, and the new boats were a real credit to the designers and builders, but in due time many of them were seized, although replacements were forthcoming from the profits of the smuggling enterprise. One of the latest of the "Blacks" was awaited with especial interest, as it was a 72-foot twin-screw boat, with high-power duplex engine units which had recently been designed. The steady pressure toward high speed had thus compelled the building of a boat, with experimental hull and engines, possessing possibilities of development into fast Coast Guard patrols able to dominate a local situation.

After seizure in the normal course, this "Black" was used for regular duty and incidental service tests. It was now decided to terminate the speed boat competition, and in 1935 the designs were drawn of 80-foot and 72-foot patrol boats to make about 30 and 35 statute miles per hour, respectively. These new boats have been commissioned only recently, but an adequate number of patrol boats of these two classes will be a potent factor in solving any smuggling problem should there be a renewal of activity. The arrangements and details of the hull and machinery are now being studied in Service use and perfected designs will therefore be available when appropriations are made for Coast Guard boat replacements. The various patrol boats surpass, at present, the "Blacks" with which they can be compared, but it is the purpose to be ready to outbuild whatever other craft can reasonably be anticipated in the future.

It ought not to be gathered from the above that law enforcement work was undertaken only by a portion of the Coast Guard Fleet; on the contrary, all the floating units, large and small, bore their part in the extensive operations. Furthermore no effort was made to obtain boats solely for law enforcement purposes, and future use on the various duties of the service was always carefully considered. The record of assistance was favorably affected by the anti-smuggling operations, as Coast Guard boats were very much in evidence and were always diverted to assistance whenever need arose.

The technical features embodied in patrol and picket boats are important, but still more vital are the personal characteristics of the officers and men. A tribute is due all the personnel who used to the full elements the technical staff put into the boats, and with the equipment which was provided accomplished creditable results in spite of unprecedented handicaps.

Alternate Designs for Boats. During the time when decisions were in order regarding anti-smuggling craft to be added to the Fleet, officers responsible for operations balanced the opposing policies which would finally determine the primary elements of boat designs. In retrospect, the conservative policy actually adopted is confirmed, as calculated to attain the objective within a reasonable time and cost. This policy involved a conservative increase in the number of officers and men and a consistent expansion of the Fleet as regards number, size and speed of units. This policy compelled the smuggling interests continually to increase the cost of all the "Blacks" and still face seizure of the contact boats and cargoes; attrition of the "Blacks" and drain on profits was an overhead becoming heavier as Coast Guard co-ordination of its facilities was improved. Repeal was not a factor in decisions, and time was working with the Coast Guard as its building programs for the anti-smuggling craft came up for action.

The radical policy as an alternate, would have meant the training and absorption of an excessive

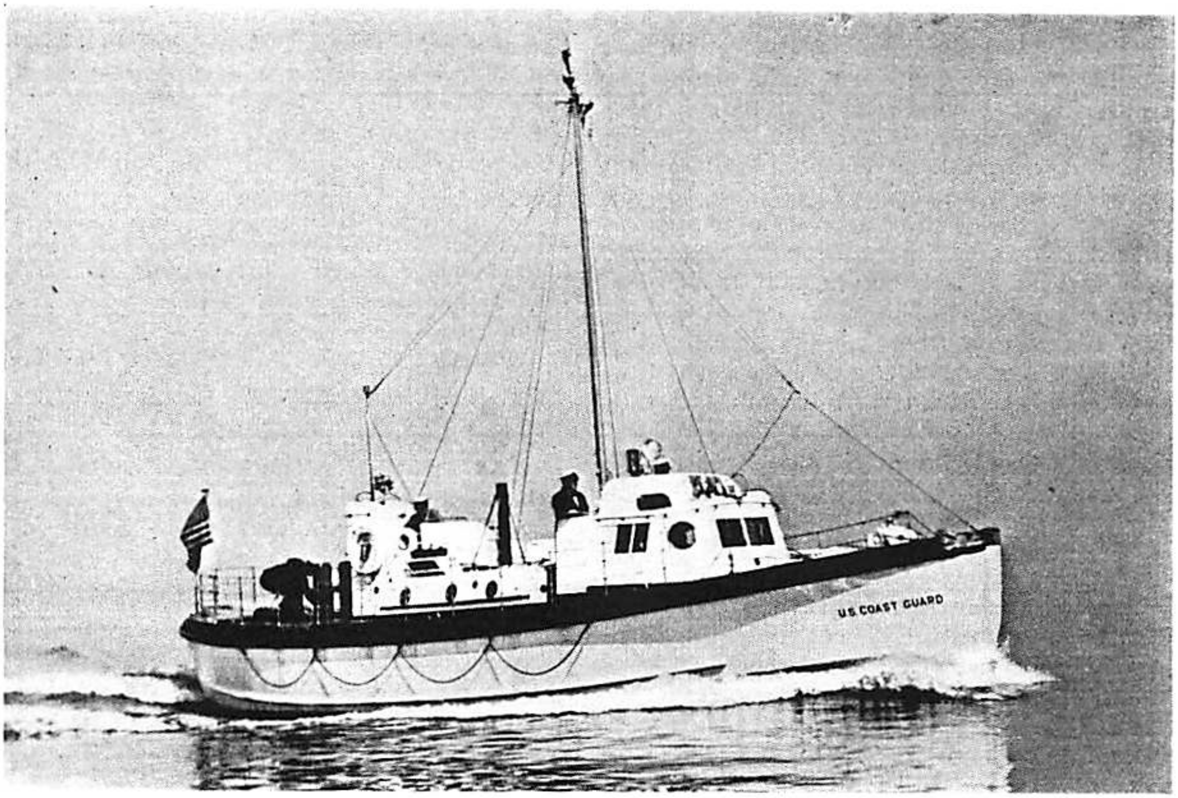


FIG. 19.—UNITED STATES COAST GUARD 52-FOOT MOTOR LIFEBOAT

untried personnel, and the acquisition of many expensive and experimental high-speed boats, which would have been produced in advance of assured progress in hull and machinery and of unknown value in prospective operations. It took several years of intensive effort by those whose profits were at stake to arrive at the "Blacks" which finally were built, and such costly speculation was not attempted by the Coast Guard. In the future, if uncertainty again exists as to the means by which a situation can best be met, a conservative policy for personnel and boats undoubtedly should prevail. If, on the contrary, the course an illicit enterprise will follow is assured, then a radical policy will be justified to overwhelm it at the start. For smuggling, it is doubtful if developments can possibly be as rapid in the future as in the past, and it will be easier to determine, at an early stage, the priority of elements which should be found in the units which must augment the Fleet.

TRENDS FOR A COAST GUARD FLEET

To supplement the observations relating to the Fleet already built, it may not be out of place to outline, in a general way, what seem to be the trends for a future Fleet to undertake prospective missions on a basis of efficiency and economy. It has come to pass that many different countries use "Coast Guard" as the name for the agency at sea to protect the revenue, share in law enforcement, and assist in saving life and property, and for like duties a similarity in equipment will be expected. If other functions are added to the primary duties, then differences in the cutters and boats will be called for according to the emphasis placed on special services. However, a multiplicity of types ought certainly to be avoided, and there is an attempt below to indicate a Coast Guard Fleet from which selections may be made, depending on national needs and policies. Future Coast Guard cutters can well continue to stress simplicity and economy in original construction and in expense of operation.

Speed, Size and Machinery. Rated speeds of 35 knots, 25 knots, 20 knots and a range of 15 to 10 knots, are proposed as the nominal speeds to be found in units of the Fleet; these speeds are not figures to be met exactly, but are purposely set apart from one another because of the wide steps in power which are involved. The high cost of high speed cannot be ignored, and no Coast Guard will be justified in using it except for units where speed is imperative. The speed of 35 knots stands for what is necessary in a local patrol boat intended to dominate certain waters; this speed to exceed that of any "Black" by all that can be paid for. A speed of 25 knots is found in a coastal patrol boat to dominate larger offshore areas. A speed of 20 knots is standard for the Service, and is assigned to cruising cutters, patrol boats and small boats, being feasible for them all. A range of 15 to 10 knots is the moderate speed for many cutters and launches engaged in normal coastal services.

As far as length is concerned, limits of 300 feet for a cruising cutter and 20 feet for a motor launch allow a range within which every element for a Coast Guard unit can be incorporated. As regards displacement, limits of about 2400 tons for a cruising cutter and about 6 tons or less, for a motor launch cover every class likely to be of use in operations. As in the case of speeds, figures for length are not exact; in general, length ought to be the least and displacement the greatest that the required speed will tolerate. The balance to be struck between knots, feet and tons falls back once more on the conservative or radical policies controlling operations.

For propulsion, steam, Diesel and gasoline machinery are available, with the selection indicated by the class of cutter or patrol boat to be built. A single-screw installation is preferred, if efficient propulsion can be obtained thereby, and twin screws are not compelled by a limit in draft, for instance. A single screw promotes simplicity and economy, and is less subject to damage from lines, wreckage, ice and other hazards. With modern machinery and radio, and with planes and other cutters for search and towing service, the breakdown of a single-screw equipment is remote and ought not to be a serious difficulty, if it occurs.

Composition of a Fleet. By transposing and summarizing comments given above, a suggested Coast Guard Fleet will contain the units indicated below; the assembly is on a basis for this country but from the list selections can be made to suit prospective duties of any other Service. The presentation may be over-simplified, but no figure is exact and expediency may blur distinctions and merge the classes here and there, although the the separate classes are clearly outlined.

Cruising Cutters

300-foot, 20 knots: Assistance; North Atlantic ice patrol; North Pacific cruises; emergency service to ocean airlines; general all-round seagoing duties.

200-foot, 12 knots: Assistance and humanitarian work in Alaska, Bering Sea and Arctic cruises; strong construction to withstand ice pressure.

175-foot, 15 knots: Assistance; emergency salvage; derelict destruction; all-round coastwise service; adapted for ice-breaking.

Harbor Cutters and Launches

100-foot, 12 knots: Customs and navigation work in harbors, bays and sounds; adapted for ice-breaking.

75 to 60-foot, 12 knots: Launches for utility service in protected waters.

Coastal Patrol Boats

250 to 200-foot, 25 knots: Law enforcement; fast trailing in coastwise waters.

175-foot, 20 knots: Law enforcement; trailing; assistance work along the coast.

100-foot, 12 knots: Assistance; law enforcement; limited draft for river patrol.

Local Patrol Boats

80 to 60-foot, 35 knots: Law enforcement; maximum speed well above the "Blacks," which will be determined by the profits a smuggling enterprise can spend.

80-foot, 25 knots: Assistance; law enforcement; smallest self-sustaining unit for normal cruising at all seasons.

Special Craft

Varying lengths, 10 knots: Cable laying; freight carriers; cadet practice vessel; miscellaneous special services.

Small Boats

50 to 40-foot, 10 knots: Assistance; motor lifeboats at stations.

40 to 30-foot, 20 knots: Assistance; law enforcement; rescue boats at stations.

30 to 20-foot, 10 knots: Utility launches and special boats of various types for cutters and stations.

The notations as to duties, like the size and speed are not intended to be literal, but the mention of law enforcement, assistance and general service gives a fair idea of the field of operations. The number of units in the classes is obviously dependent on the policy set up for the duties to be carried on. The Fleet now actually in commission in this country contains many units in accord with the categories and it is probable replacements in the future will recognize still more distinctions now proposed, especially if the element of speed becomes increasingly important in distinguishing the classes.

As may be gathered from this review of the past, present and future Coast Guard, the technical staff keeps current the many construction and repair activities relating to the Fleet, and has continually under way the alternate designs for cutters and patrol boats which may be authorized in building programs. It is always a satisfaction to interchange with other agencies the information accumulated relating to the floating units, and it is hoped this reciprocity, so happily exhibited by the International Lifeboat Conferences, will expand and apply to the cutters and patrol boats of the Fleet. The staff at Washington will be ready to respond to officially transmitted overtures along this line, to the end that the Coast Guards, by whatever name they may be known, may serve still better the countries which maintain them.

Bibliography and Acknowledgments

This paper has been prepared by permission of the Commandant, U. S. Coast Guard, and with the co-operation of the Engineer-in-Chief and members of the technical staff at Coast Guard Headquarters. The comments and conclusions, however, are not, in any sense, official pronouncements on behalf of the Coast Guard, but are simply the present personal opinions of the author on the subject. Certain cutters have been more fully treated in the *Transactions* of the Society; for instance, *Manning*, 1899, *Modoc*, 1923; *Pontchartrain*, 1928; and early sailing cutters are described in the "History of American Sailing Ships," by Mr. Howard I. Chapelle. It is regretted that the records of Coast Guard cutters contain only meager information regarding some very interesting vessels.

In closing, it is proper to express the appreciation of the Coast Guard for the interest of naval architects and marine engineers in our problems of design; and for the co-operation of shipyards and boat yards in our building programs. With their support we have built up the Coast Guard Fleet which is now in commission all along the coasts of the United States, contributing to the welfare and commercial interests of our citizens.

DISCUSSION

Professor H. L. Seward, *Council Member:* This paper is a valuable contribution to the *Transactions* of the Society, not only as a reference file of information, but also in giving a picture of the methods used in an organization which has many technical problems to solve while carrying on a very complicated job of vessel operation. It leaves little to be said by commentators, but a few personal observations may be in order.

The Coast Guard is often seen making a gallant exit from a safe harbor when the rest of us, due to conditions, are thankful to get in out of the weather. Because of its position under the Treasury Department in time of peace, automatically alined with the Navy in times of emergency, secures that combination of superior seamanship and effective discipline in carrying out its duties which rates it quite properly as the big brother of the merchant marine.

"The Priority of Technical Elements," page 84, together with the consideration of the elements of cost and economy of operation, are clear and obvious, the further discussion of the policy for selecting technical features, especially the emphasis on the principle of simplicity, are all commendable. The experience of this Service in arriving at 300 feet as a rough dividing point in length of hull between transverse and longitudinal framing is interesting, but more emphasis might have been placed on the fact that recent gradual changes in operations now require many more contacts with docks, working in ice or coming alongside for boarding purposes than formerly, so that, in the absence of guards, the transverse system is necessary to prevent repeated outside plating damage. In this Service a healthy discussion is always possible on the subject of twin-screw *versus* single-screw vessels (witness the discussion of this question in two places in the paper). My own observation is that when, during certain dark and busy days, it fell to the lot of the Coast Guard to operate ex-Navy destroyers, the younger officers and men assigned to these destroyers handled the ships in an excellent manner. For long cruises and some close operations in rescue work, the single-screw vessel has its advantages and finds loyal proponents among the officers, both old and young. The work of the Service has become more and more varied and the long off-shore cruises are a smaller proportion of the load than formerly.

The basic policy and primary purpose underlying the design of Coast Guard cutters is reliability and simplicity. Anyone who has worked with the Service or cruised on the cutters could observe that these objectives have been successfully obtained. This policy assures a reasonable first cost and the resulting economy in maintenance and repairs. Few other vessels outside of the Navy are so fully and adequately equipped for every possible emergency or service.

The Coast Guard never has had proper credit for the pioneer work it has done in engineering, particularly in developing the electric drive and applications of the Diesel engine. Every mechanical device has an appropriate area of usefulness and the problem usually consists in finding that appropriate area of application. In the Diesel vessels, the next problem to be taken up should be the elimination of noise. The oppressiveness of this condition of noise on personnel is serious on some vessels. As some of it is due to the presence of the direct reversing gear, one wonders when a practical and successful reversing propeller may be developed.

The transformation of a gunboat design into a large cruising cutter was no easy task, but the result is a rather large unit of assistance which can travel at a very desirable speed in almost any weather.

Under the subject of training personnel, not elaborated in the paper, one finds here a service which is able to designate its newest, best and most instructive vessels for use on cadet cruises. The United States Coast Guard Academy at New London, Conn., is rated as one of the best all-round technical schools in the country. In addition to an excellent curriculum, the cadets make valuable cruises on vessels described in the paper. The caliber of the young men selected as cadets equals that found in any of our technical institutions. The recent developments leading to the possibility of Coast Guard participation in the training of men for the merchant marine serve to illustrate the resourcefulness of this service. In the merchant marine we can work out the answers to our problems in materials and design, but we need help in solving the complicated problem of personnel under present conditions. It is fully to be expected that the Coast Guard will be as effective in making contributions to leadership in personnel matters as it has been in technical and engineering matters.

MR. E. H. RIGG, *Honorary Vice-President:* This paper has decided interest for us both historically and professionally; by going back to the commencement and bringing his review down to date, Commander Hunnewell has placed us in his debt for a most comprehensive picture of the Service and their ships. As for its big brother, the Navy, the various duties of the Coast Guard Service have resulted in many types, from "pulling" boats to junior cruisers; from boats suitable for tropical waters to boats for service within the Arctic Circle; the summary of the 1936 services rendered given on page 82, speaks for itself, supporting our general knowledge of the varied activities of the Coast Guard with statistics. While this paper naturally deals primarily with the sea-borne ships of the Service, the airplane patrols should not be lost sight of, nor the modern developments of wireless and other communication systems; likewise the special craft referred to on page 83.

The review of the design conditions is comprehensive (page 84). The problems of the ship designer are not always given the consideration they deserve; some of the many people involved in the construction of ships are very apt to view their own problems with the small end of the telescope at their eye and the designer's problems with the large end. Speaking very broadly, Navy ships get the serious attention that is desirable in the design stage; there are now definite evidences that general commercial ship designs are beginning to receive the attention that they should; that is, in addition to outstanding ships, such as Atlantic liners and other special types. Under modern conditions, the time taken to work out a design carefully, with regard both to the good points of earlier ships of the same type and to available betterments, will pay handsomely.

Commander Hunnewell's comment (page 87) as to minimization of deck houses may well be taken to heart by the designers of Atlantic and other passenger liners; with modern ventilation, we can well learn a lesson from this section of his paper.

The account of the design and building of the *Alexander Hamilton* class is interesting; the adoption of twin screws (notwithstanding their obvious disadvantage in close rescue work), increased speed, longitudinal framing and airplane handling facilities are points well worth noting. We hope to hear good accounts of their utility in service; they are not yet old enough for a record of any extent.

One would not normally look for an experience in fitting "blisters" on a Coast Guard Cutter, a war-time method of providing effective torpedo protection to older battleships; the account of that experience, applied for other reasons, to the *Kickapoo* (page 100) is interesting.

The recent improvements in single-screw drive, due to streamline, contra-rudders, etc., has an application that should save real money in new single-screw cutters.

The Coast Guard Service, when the "Rum Row" activities of the prohibition era came to the end of their extreme strenuosity, must have been considerably relieved; the account given of these activities takes up several pages of this paper. Whatever else it did, this era very definitely contributed to the improvement of high-speed, seagoing, patrol boats; doubtless with lessons learned from the coastal motorboats of the earlier (1914 to 1918) war period.

Viewed as a whole, this paper furnishes us with a comprehensive account of the ships of a Service that has a vital place in our maritime picture.

Captain Henry Williams, (CC), U.S.N., *Council Member:* As stated by Commander Hunnewell, the *Hamilton*-class of cutters were built in the Navy Yards, four at Philadelphia, two at New York, and one at Charleston. Working plans and material orders were prepared at Philadelphia for all ships, under the direct supervision of Coast Guard Headquarters. Technical officers of the Coast Guard having been ordered to duty in the Philadelphia Navy Yard, were assigned to positions in the regular organization. A Coast Guard engineer officer and a Coast Guard constructor were assistants to the design superintendent of the Navy Yard and had responsible duties in the preparation of the working plans and in ordering the materials for all of the seven cutters. A Coast Guard engineer officer and a Coast Guard constructor similarly were assigned in connection with the actual work of construction as ship superintendents for the vessels, assistants to the regular machinery and hull superintendents of the Navy Yard organization. Several Coast Guard warrant officers also were similarly assigned as assistants to ship superintendents. All of these officers took active part in the work and contributed greatly to the successful outcome.

This arrangement was of value to the Philadelphia Navy Yard management in providing highly expert technical assistants having knowledge of Coast Guard methods and requirements. It was of value also to the individual officers in providing practical experience in the design and supervision of Navy Yard ship construction. I might add that all of us who had contact with these excellent officers had nothing but praise for their technical abilities, as well as the highly cooperative manner in which they performed their duties as part of the Navy Yard organization.

The characteristics and performance during trials and in service of these fine vessels were a matter of great pride to the Navy Yard personnel concerned with their construction. They are handsome, seaworthy ships, well-found, and perform splendidly under service conditions.

Mr. James L. Bates, *Member:* It has been a pleasure to read Commander Hunnewell's paper because of his frank statement of some of the problems facing a designer and of the detail which he furnishes relative to the solutions reached.

His discussion of the duties to be performed and of the technical elements with his suggested priority, viz: Seaworthiness, speed, cruising radius, deck equipment and accommodations, is not only of interest but of importance. It is an expression of his experience with the Coast Guard, extending over a long period of years and based on the performance of many types of vessels under a variety of conditions.

There will be little, if any, tendency to disagree with the placing of seaworthiness first in importance. It would not have been surprising had accommodations been placed second and speed been made of lesser importance.

It is interesting to note that the Coast Guard has been able to secure highly satisfactory maneuvering with single-screw vessels.

Commander Hunnewell's comment upon the importance of ample beam, in order to provide reserve stability against any reasonable loss of waterline area, is noted. It is assumed that he goes further and spaces his bulkheads so as to control this loss.

Commander Hunnewell strongly favors the flush-deck type of hull with pronounced sheer. He also favors a minimum of deck houses. The two go together. In certain naval types it has been found that a shorter hull carrying a forecastle with several deck houses is lighter for a required enclosed volume than a longer hull with a minimum of deck houses. Undoubtedly, the flush-deck type simplifies the design and construction of the strength girder when minimum weight is not decisive.

The body plans and coefficients of form are of especial value to the designer. It is noted that for the larger vessels the values of the prismatic coefficient lie in two zones, either between 0.54 and 0.58 or about 0.62 to 0.635. The lower values have usually gone with the higher speeds. It would be of interest to know the reasons for these differing values. In the writer's experience it has been much more difficult to beat Taylor's standard series with a model having a prismatic of say 0.56 than with one having 0.63. It would be of interest to know what Commander Hunnewell's experience has been.

Further, the writer has heard adverse comment as to the seagoing qualities of vessels having very fine underbodies. Commander Hunnewell's comment upon this subject would have particular weight for obvious reasons.

Each of the six body plans shows a pronounced flare in the vicinity of the waterline of about 20 to 25 degrees at about 10 to 15 per cent of ship's length aft the forward perpendicular. This rather pronounced flare has been given to aid the vessel in lifting to a sea and in throwing water aside. Its necessity is recognized, particularly for smaller vessels for which the water is nearly always rough. However, it is worth-while to note that these flared sections usually increase the effective horsepowers by from 3 to as much as 10 per cent above that for the same vessel with vertical sections in the vicinity of the waterline.

Presumably, the speeds given in Commander Hunnewell's tabulation are trial speeds made under favorable conditions. Taking *Thetis* with 16 statute miles and the 80-foot patrol boat with 30 statute miles (trial) as examples, it would be of value to know what speeds each can maintain under adverse conditions of wind and weather for considerable periods of time without damage to material or excessive discomfort for personnel.

It would also be of interest if Commander Hunnewell would state the approximate values of metacentric height (ship being light or fully loaded) which he considers desirable for his 250 to 300-foot types as well as for such vessels as *Thetis*.

Constructor E. M. Kent, U.S.C.G., *Member:* As Commander Hunnewell has intended, this paper differs from those previously presented on the subject of Coast Guard vessels because of its more general character. The Service and its floating units are to a degree familiar to those having maritime interests. The construction projects under which these craft have come into being have been sufficiently widespread to involve the participation of many shipbuilders, each of whom thereby has gleaned a certain insight into Coast Guard technical requirements and practices. Yet it is doubtful if there are many readers outside of the Service who will not be greatly interested in learning for the first time some of the reasons prompting the adoption of the various features which make Coast Guard vessels distinctive as a class.

The types of constructed vessels and boats for which the technical data are offered form, with the exception of the oldest listed, the essential part of the present-day Coast Guard fleet. The design and building of these have taken place in the period of nearly twenty-five years during which Commander Hunnewell has borne the heavy responsibility of carrying the various designs to successful conclusions. He is, therefore, admirably qualified to make this contribution to the proceedings of the Society. It is felt that the foresight shown in meeting the changing needs of the Service and the attention to details and to special features of design which make the vessels suited to the multiplicity of duties which they are required to perform have well established the confidence of the operating personnel, and the nation at large, in the ability of the vessels to fulfill their mission.

Lieutenant Commander T. P. Wynkoop, (CC), U.S.N., *Visitor:* I have read Commander Hunnewell's paper through several times and feel that it is one primarily concerned, as the title indicates, with Coast Guard cutters as a whole. I was associated with Commander Hunnewell during the preliminary design stage of the *Alexander Hamilton* class of cutter, but between the time of the preliminary design and the construction period a great many changes were made in the cutter, both as to scantlings and general arrangements.

On page 97 the author states that the design of a Navy gunboat, to make 20 knots, was under way at the same time that the 327-foot cutters were being designed. Apparently my name was given to the Society because I was in charge of the Navy gunboat design. Naturally, the problems differ on the two vessels, especially as to armament, cruising radius, complement, etc. The gunboats have a great deal more top hamper than the Coast Guard cutters, and since the lines in general were the same, I understand the lack of this top hamper on the Coast Guard cutters has made them rather stiff.

I have had the pleasure of seeing two of the *Alexander Hamilton* class cutters in the last month. The officers of these vessels state that, except for this stiffness, they are comfortable and satisfactory vessels and, I presume, well qualified to perform the duties for which they were designed.

Mr. Charles F. Bailey, *Honorary Vice-President:* I would like to ask if the author of this interesting paper could give us the cost of the *Alexander Hamilton* as built in a Navy Yard as compared with the proposals of other parties.

Commander E. L. Cochrane, U.S.N., *Member:* The Navy Department appreciates very heartily the work that the Coast Guard does, particularly in the smaller ships, and wishes to give due acknowledgment to the Coast Guard for one of the most successful small boats that the Navy has adopted in recent years, which is an adaptation of their

26-foot motor whaleboat. I think we call it a motor lifeboat. We made a few changes, chiefly to switch from clinker to carvel planking, and to abandon the self-bailing feature, but that little boat is continuously used in the fleet, and when a ship is to go out, unless large numbers of men are to be transferred or heavy weights, this is the one that is invariably lowered for transferring mail, orders and so forth.

Mr. D. S. Carmbnt, *Member:* This paper is one of great interest to the naval architect and the author is to be congratulated on his very excellent and straightforward paper. The United States Government is also to be congratulated for allowing the great amount of information contained in Table 1 to be published.

The question of speed is a vital one in these vessels, and saving of weight becomes a matter of prime importance. In a patrol vessel at present building in Australia, we are using aluminium alloy for the deck erections. This, if corrosion is not excessive, appears to be a logical development.

With regard to machinery, the Diesel-electric installation seems to meet the requirements of economical cruising speeds and high top speeds.

We have here an example of this in the case of a Diesel-electric ferry. This boat, with a length of 200 feet, has to have a high top speed for the business trips, and a lower speed during the rest of the day. The speed range is from 13 to 16 knots. These conditions are met by using four Diesel-electric generating sets, three being used for the slower and four for the faster trips.

The use of twin rudders in twin-screw jobs seems to have some advantages. I presume they are used on the American boats.

Commander Hunnewell's paper will be of lasting assistance not only to designers of patrol boats, but also to those engaged in the design of seagoing yachts.

The President: Is there further discussion of this paper? If not, we will ask Commander Hunnewell to reply to the discussion. I should like to ask him whether that 26-foot whaleboat is the same one in which the International Lifeboat race is rowed, and also why he didn't put in this paper the same kind of plans for the *Hamilton* that he did for some of the earlier boats; namely, the general deck arrangements that are shown for the *Itasca?*

Commander Hunnewell: As regards the plans for the *Hamilton*, it may be well to state that the arrangements on that cutter are simply a development of our standard type layout exhibited by the plans of the *Itasca* and the cost of reproduction seemed hardly justified.

The motor self-bailing surfboat is the outcome of Service experience extending over many years but clinker-built construction, instead of smooth carvel planking, is being perpetuated as the surfmen seem to feel the slight "bilge keel" effect of the planking edges improves buoyancy and behavior in broken water. This is not the class of boat in which the International Lifeboat Race is rowed; the latter is a Monomoy surfboat, originally coming from the Cape Cod area but now adopted as one of our standard pulling boats for cutter use. An interesting adaptation of a larger Coast Guard unit is the selection by the President of one of the 165-foot patrol boats as a modest yacht available for recreation purposes.

It is a satisfaction to furnish Mr. Bates the items of additional information desired. Reserve stability gained by generous beam and waterline area undoubtedly can be lost by hull damage unless transverse bulkheads are spaced to control it, and such spacing has been given attention. Deck erections amidships, above the weather deck, undoubtedly enclose a considerable volume of usable space, but freeboard adequate for the cutters, together with the flush deck, provide good accommodations with only limited expenditure of weight and cost for deckhouses. Certain naval vessels may require deckhouses in addition to the cubic space available below the continuous weather deck, but, generally speaking, we avoid deckhouse appendages as far as practicable to gain clear deck space.

It has to be admitted that prismatic coefficients for Coast Guard craft are partially controlled by other reasons than an optimum figure for speed alone. For instance, length, draft, beam and displacement may be affected by operating service, protection for a single screw, stability or machinery layout, scantlings for all-round service or special duty and the like, and we are thus handicapped in adopting an ideal coefficient which might otherwise be preferred. This same comment applies to the flare in the vicinity of the waterline forward, and the increase in horsepower apparently has to be accepted. As a matter of fact, the waterline of a cutter at sea in rough weather is a decidedly indefinite line and the tendency to lift to a sea encouraged by the flare in body plan sections and in buttock lines is vitally important. The cutters do not pitch excessively and reports show that the cutters and patrol boats have been driven at full power, even if not at trial speeds, on emergency missions under very adverse conditions of wind and weather. I am not able to furnish the actual speeds attained on such occasions, but can only report that the material has stood up without damage and the discomfort to personnel no more than would naturally be expected. The 80-foot patrol boats, however, have not been in commission for a sufficient period to cover such service and a statement regarding them must be reserved.

An average figure for the metacentric heights of certain classes of cutters and patrol boats is as follows:

	Light condition, feet	Load condition, feet
Alexander Hamilton	3.75	4.29
Itasca	1.34	2.83
Thetis	4.1	4.29

Taking account of a definite intent to err on the side of excess metacentric height in the original design, the *Alexander Hamilton* and the *Thetis* might have a little less stability, whereas the *Itasca* could have more, without adverse results. Considerations of safety under Service hazards are more potent than the comfort of prospective passengers.

The understanding remarks by the various commentators and the generally approving nature of their observations, are appreciated and it is hoped the paper and the discussions now completed contain useful information for inclusion in the *Transactions* of the Society.

THE PRESIDENT: I feel that the Society is very much indebted to Commander Hunnewell for presenting a very fine paper. I think that it would be extremely appreciated if he could add to this paper the same plans for the *Alexander Hamilton*. With reference to the remarks on the cost of these vessels, I am sure that the Society would be interested if it is possible at a later date to add something along those lines. That is always a matter of keen importance to those of us engaged in private shipbuilding, because, when we come into competition with the navy yards, we like to know what their results are compared with what we thought we might be able to build these ships for if they were contracted for in private yards.