NOTES ON DEPOT AND REPAIR SHIPS

by

H. E. SKINNER, O.B.E., B.SC., R.C.N.C.

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The Problem

The transactions of the various technical institutions reveal little reference to those important auxiliary vessels attached to fleets of warships. Knox, Harris, and Kimmell[1] have recently drawn attention to the disability attendant on a fleet having to depend for its maintenance on fixed bases and dockyards. This is a problem now well to the fore in the minds of the naval staffs of those powers whose fleets are required to operate at great distances from home waters, conscious as they are of the destructive power of the atomic bomb on fixed bases. The natural tendency is to move towards the adoption of a floating base to service the fleet units so that they are independent of shore facilities, except in the event of great damage which would, in any case, render them incapable of performing their duties for a period of several months. In a prophetic paper[2] before this Institution in 1924 Staples and Munro deduced the logical necessity of a mobile naval base.

At first sight it may be thought that it is only necessary to equip the ships with rudimentary appliances capable of dealing with a few minor repairs, and that perhaps at selected places temporary machine shops should be erected ashore to deal with repairs in a more economical manner.[3] But placing equipment ashore brings with it problems of lighting, water, fuel, accommodation and recreational facilities, which ultimately make the creation of such a temporary base a formidable task, and one which may quickly prove valueless as the tide of war moves to another area. The repair or depot ship has the great advantage of mobility and, of course, has her main services incorporated, so that there is a tendency to put into these ships as much equipment as they can work. The ship is then not only a floating workshop but is capable of being sent to any area to back up the existing supply services.

The necessity for a mobile base first arose in the Crimean war when a fleet repair ship was to be found operating in the Black Sea, whilst the advent of the torpedo-boat and later the destroyer and submarine in large numbers necessitated, in their turn, the provision of special units to deal with their peculiar requirements. During the recent war the great mobility of the fleet, and the necessity for it to operate at great distances from fixed bases, brought about the evolution of several additional types of vessel largely concerned with the maintenance of the fleet. Amongst these, four main types can be discerned ; they are :—

Repair ships
Submarine depot ships
Destroyer depot ships and
Maintenance ships.

It is the purpose of these remarks to deal only with the first three types.

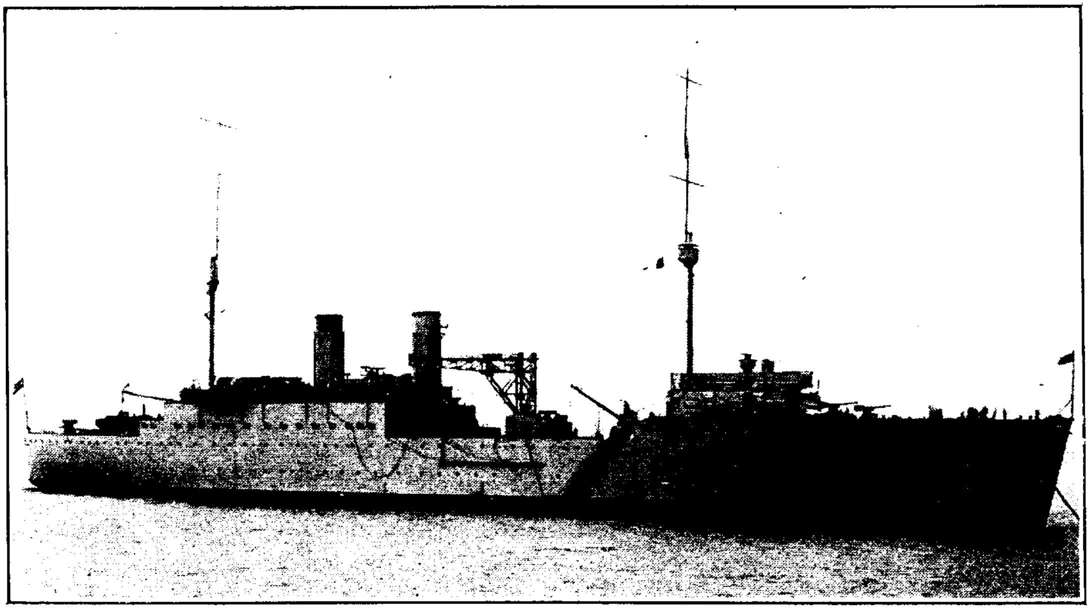

FIG. 1.—H.M.S. " RESOURCE " (1930)

Repair Ships

The function of a repair ship is to undertake only those repairs due to fair wear and tear, and stress of weather to fleet units ; also to carry out simultaneously on two battleships and two cruisers such after-action repairs as would obviate these vessels being sent to a main base. Such a ship was H.M.S. *Resource*, built by Messrs. Vickers-Armstrong, Barrow, in 1930. She remained the only vessel specially designed by the Admiralty to provide repair facilities afloat for the fleet. Consequently she was termed a " Fleet Repair Ship." In 1940 it became clear that additional afloat repair capacity was an urgent requirement and a merchant ship, the Cunard liner S.S. *Antonia*, was selected for conversion, being completed at Portsmouth in 1942 under difficult conditions. This vessel was renamed H.M.S. *Wayland.* A feature of this and all other conversions undertaken was the introduction of a large quantity of permanent ballast which was fitted for two reasons ; firstly, to reduce the windage, as it was expected that these ships would have to spend long periods at exposed anchorages and, secondly, to adjust the trim so that the vessel could achieve the maximum value from her sub-division, particularly when end compartments were damaged. It was also necessary to increase the electric power by fitting three additional 300 kw. turbo generators, and to augment the freshwater capacity by fitting distillers capable of producing 200 tons a day. Workshops of 37,000 sq. ft. deck area were provided together with considerable stowage space for naval and workshop stores. To provide the necessary deck heights for workshops involved some major structural work, and it was necessary to plate-in the ship's side over a length of 190 ft. between " B " and " C " decks. Storage tanks for 10,000 gallons of petrol were fitted in a hold compartment with direct flooding arrangements from the sea. In general, *Wayland's* layout and equipment followed that of *Resource*, and she had a complement of twenty-six officers and five hundred and seventy men of whom about two hundred were actually employed on repairs.

It became apparent, however, that *Resource* and *Wayland* were—although very well balanced as repair ships—larger and more lavishly equipped than was necessary for first-aid repairs, yet were inadequate to face the extensive structural repairs found necessary to enable a damaged ship to reach a distant base.

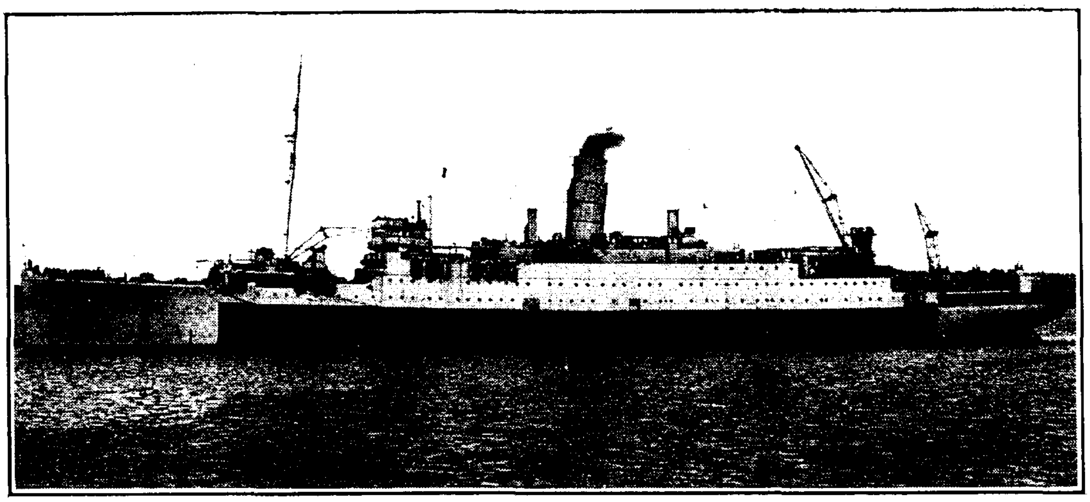

FIG. 2.—H.M.S. " ALAUNIA "

The principal difficulties lay in the lack of plant for producing oxygen and acetylene, insufficient stowage for the large quantities of plates and angles required and, in *Wayland*, the inefficiency of having to use winches and derricks for the rapid handling of stores, it being considered that cranes would be more effective. Both ships, moreover, suffered from the major disadvantage of not having sufficient accommodation to carry a large repair staff.

It was, therefore, arranged to convert four additional vessels into what were termed " Heavy Duty Repair Ships." These were : *Artifex* (ex-Cunard *Aurania*), completed at Devonport in July, 1944 ; *Ausonia* (ex-Cunard), completed at Portsmouth July, 1944 ; *Alaunia* (ex-Cunard), completed at Devonport September, 1945, and *Ranpura* (ex-P. & O.), completed at Portsmouth January, 1946.

In planning these ships it was necessary to adjust deck heights to suit workshops, consequently portions of " E," " C " and the promenade decks were completely removed and other flats built as necessary. Care had to be taken to maintain longitudinal strength by the fitting of additional girders and pillars. In particular, to obtain sufficient 'tween deck heights for the smithery and plate shops almost all the promenade deck together with its existing pillars had to be removed to allow the new shop to be traversed by the overhead travelling cranes. Heavy middle line pillars were now fitted whilst the deck beams were stiffened by reversed bars to take the increased span. Fore and aft lattice girders were introduced, and the side framing between the upper and promenade deck was reinforced to take the increased racking forces due to the removal of the intermediate deck, which was now reduced to a stringer plate heavily reinforced. The whole was further strengthened by plating-in the ship's side between the promenade and boat decks over a length of about 220-ft. It was found with the large spaces devoted to workshops and stores that the repair staff could not be increased beyond about two-hundred, which was no improvement on *Wayland*, whereas the workshop facilities were now estimated to be capable of maintaining a working force of at least seven hundred. Therefore, in 1943 the arrangements to accommodate the extra manpower were reviewed, and it was proposed that each repair ship should be accompanied by an accommodation ship which would carry the five-hundred additional staff required. Further, the fall of Singapore —a base whose necessity had been in question before this Institution by Staples and Munro in 1924[2]—had emphasized the necessity for these accommodation ships providing in their extensive holds repair materials of all kinds, and spare gear such as watertight doors, hatches, covers, sidelights, stanchions, fans,

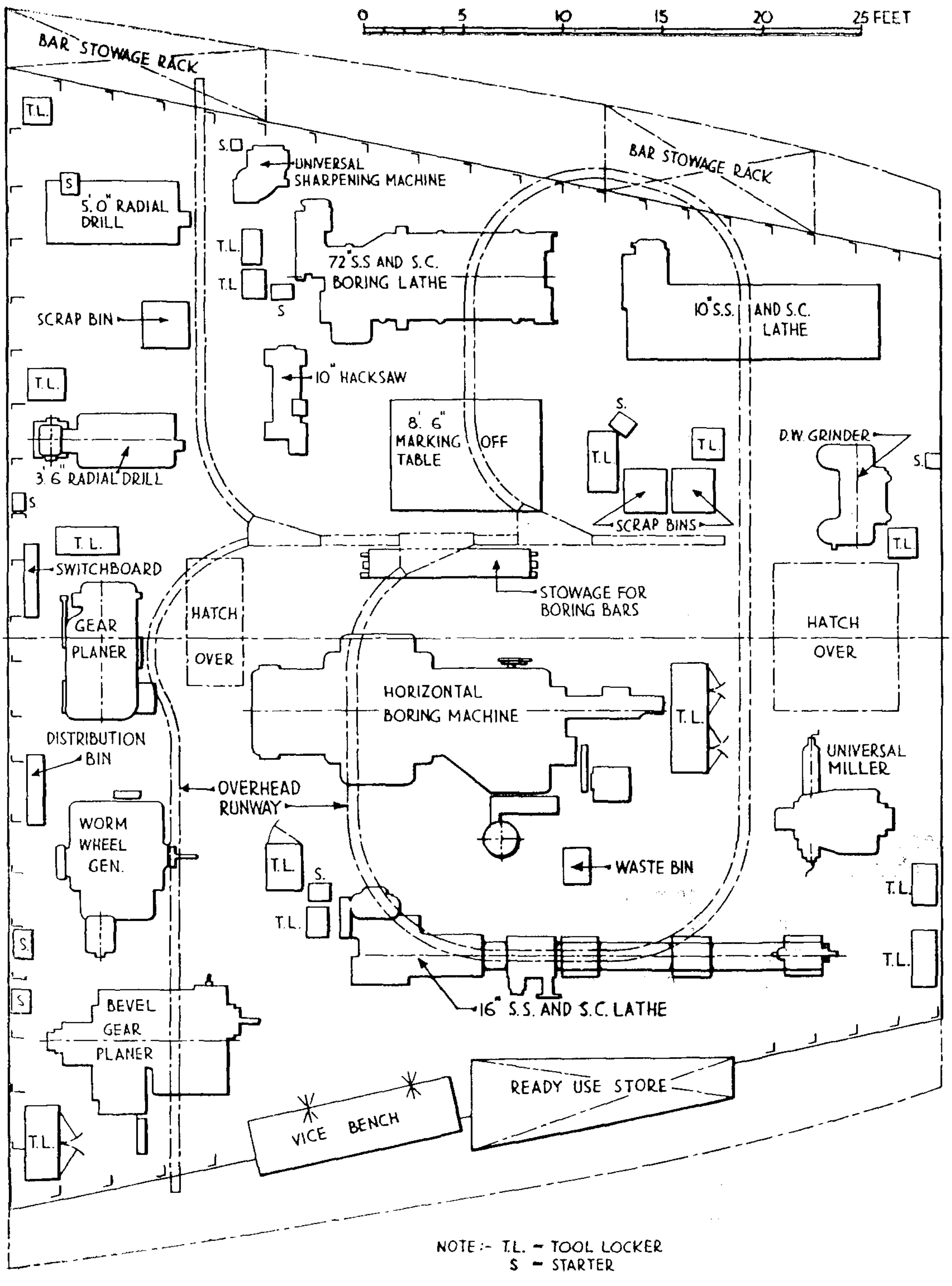

FIG. 3.—REPAIR SHIP H.M.S. "RANPURA." ARRANGEMENT OF HEAVY MACHINE SHOP.

valves, and gearing. The heavy demand for oxygen also necessitated arrangements being made for its manufacture in all accommodation vessels. Owing to the shortage of merchant tonnage it was possible only to allocate four accommodation ships to the six repair ships : of these S.S. *Lancashire* was on station in 1945 and S.S. *Southern Prince* arrived later, whilst the remainder never materialized.

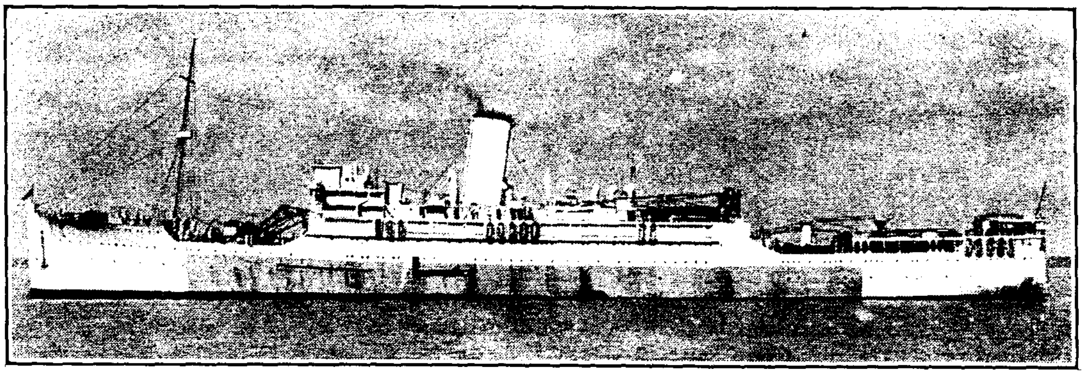

FIG. 4.—H.M.S. " RANPURA "

In 1943 it was also thought necessary to back up *Resource* and *Wayland* with additional capacity for the undertaking of hull damage repairs, and it was intended that each ship should have another vessel in company equipped with a minimum of heavy shipyard machines, together with as much space as practicable for the laying out and working of plates and angles necessary for the repair of hull damage. It was not until 1944, however, that two standard P.F.C. types of hull could be fitted out, and in the summer of 1945 these became the hull repair ships H.M.S. *Mullion Cove* and *Dullisk Cove* respectively.

In 1916 Thompson[4] had noted that the placing of power-driven tools in ships involves much thought, especially in arranging for suitable working space to enable the various operations to be performed. It is to be remembered that in a ship the sequence of operations cannot be planned as at shore establishments, for the work to be carried out is of an uncertain nature. The numerous machines in repair ships, therefore, had to be examined on their merits, particularly such bulky items as bending rolls, and if for example, space for both bending rolls and hydraulic press could not be found, the rolls had to go. On the other hand, it was necessary to include both shearing machines as well as oxy-acetylene cutting gear in case the supplies of gas were to fail.

The fundamental workshops required in all repair and depot ships were found to be :—

(i) A pattern shop and foundry, capable of dealing with brass and iron castings up to 1,000 lb.
(ii) A coppersmiths and plumbers shop, suitable for dealing with all pipe work up to 4 in.
(iii) A smithery and plate shop, preferably fitted with pneumatic hammers, forging press, bending slab, anvils, quench tank, plate shearing and drilling machines, bending rolls and acetylene burning facilities, also a light plate section capable of dealing with plates up to $\frac{1}{4}$ in. thick.
(iv) An electric welding shop, with equipment for about ten welders.
(v) A heavy machine shop, with borers, planers, heavy lathes, gear cutters and milling machines.
(vi) A light machine and engineers fitting shop, with radial drills, light lathes, universal millers, slotting machines, grinding machines, hacksaws, vices and benches.
(vii) An internal combustion engine shop, capable of giving complete overhauls to the engines of boats attached to the repair ships.

Fig. facing page 38.—H.M.S. *Ranpura*, Arrangement of Smithery and Plate Shop.

(viii) An electrical workshop, fitted with a hydraulic press, impregnator, armature taping machine, coil winders, baking ovens, test switchboard, benches, etc.

(ix) A woodworking shop, fitted with a woodworking machine, bandsaw, planer and jointer, drills and work benches.

(x) A tool room, fitted with lathes, drills, grinding, hardening, tempering and annealing equipment.

(xi) An optical and instrument shop, containing watchmakers' lathes and benches.

(xii) A radar maintenance shop.

(xiii) To these may be added—when space is available—the following shops : Ordnance workshop, asdic workshop, boat repair shop, canvas shop, painters' shop, electrical test shop, hydraulic test shop and a small drawing office.

The main machine shops and smithery should be provided with travellers of capacity up to 4-ton lifts and a plentiful supply of power-operated hoists travelling on girders and having 1-ton lifts.

The problem of siting the smithery and plate shop generally proves to be a major problem in converted repair ships. In *Ranpura* the difficulty was accentuated because she had one superstructure deck less than the earlier ships ; therefore, to get the required 'tween deck height it was necessary to cut away the long bridge deck, which, of course, was a strength deck leaving only a reinforced stringer. The effect of this modification was to lower the top of the strength girder from the bridge deck to the upper deck amidships ; consequently the upper deck had to be reinforced by doubling plates so that not only was it strong enough to take the load now thrown upon it, but that the movement of the boat deck above, which was fitted with expansion joints, should be so small that the girders carrying the travellers which were secured to the boat deck would be unaffected. The ventilation problems which are associated with the foundry situated below decks need only be mentioned to be appreciated.

It is believed that these heavy repair ships are the foundation of the mobile repair organization. Their major disadvantage, shown by experience, was the inefficiency caused by the necessity of a daily transfer of hundreds of men to and fro between the heavy repair ship, her accompanying accommodation ship, and the vessel under repair. Therefore, the tendency was to keep the repair ship well back from the main scene of operations where they then found themselves in the company of floating docks. This created the demand for a smaller type of self-contained repair ship which was capable of operating close up to the fleet. Two such vessels were received under lease-lend from the United States : they were known as H.M.S. *Assistance* and H.M.S. *Diligence*. Each of these vessels carried a repair force of two hundred, with the workshop area geared down to the labour force so that its total area was about 16,000 sq. ft.

A typical example of the work which can be undertaken by repair ships was that carried out by H.M.S. *Artifex* on the aircraft carrier H.M.S. *Indefatigable*, extensively damaged following a suicide attack by a Japanese bomber in March, 1945. The ship was hit at the junction of the island structure with the flight deck, blowing in the inboard side of the island, and extensively damaging the operational equipment and structure in the vicinity. The work of repair was carried out in shifts. As a result of this work being undertaken, H.M.S. *Indefatigable* was able to remain with the fleet, and to operate her aircraft at full efficiency, after one week in hand for repairs, which one would concede is a very creditable performance and justifies the work put into the production of the fleet repair ship.

Table I gives particulars of typical repair ships.

TABLE I

REPAIR SHIPS

Name	*Resource*	*Wayland* (ex-*Antonia*)	*Alaunia*	*Assistance*
Builder	Vickers-Armstrong	Vickers-Armstrong	John Brown	Maryland Dry Dock Co., Ltd., U.S.A.
Date	1930	Converted 1942	Converted 1945	1945
Length	500 ft. 0 in.	520 ft. 0 in.	520 ft. 0 in.	441 ft. 6 in.
Breadth	83 ft. 3 in.	65 ft. 0 in.	65 ft. 0 in.	56 ft. 11 in.
Depth	49 ft. 0 in.	43 ft. 0 in.	43 ft. 0 in.	37 ft. 4 in.
Deep draught	22 ft. $10\frac{1}{2}$ in.	26 ft. 11 in.	27 ft. 4 in.	19 ft. 5 in.
Deep displacement, tons	15,580	18,750	19,000	9,470
Machinery	Twin-screw turbines	Twin-screw turbines	Twin-screw turbines	Twin-screw turbines
Horse-power	7,500	8,500	8,500	2,500
Speed, knots	15	15	$14\frac{1}{2}$	11
Oil fuel, tons	1,500	1,430	1,560	1,200
Workshop area, sq. ft.	40,000	37,000	44,000	16,000
Electric power, kw.	1,800	1,200	1,500	2,000
Distilling capacity, tons/day	300	200	300	80
Complement:				
Officers	25	26	32	26
Men	556	570	560	463
Ballast, tons	—	3,200	3,500	1,638
Armament	Four 4 in.	Four 4 in.	—	—
Lifting appliances	One 25-ton crane Two 3-ton cranes One 20-ton derrick	One 10-ton derrick Four 3-ton derricks	One 10-ton crane Three 4-ton cranes Two 5-ton derricks	Four 10-ton derricks

Submarine and Destroyer Depot Ships

The submarine and destroyer depot ships lie more in the region of maintenance vessels than repair ships. Their function is to enable their attached craft to keep the seas, to carry an administrative staff and to be able to take up a position from which their attached vessels can perform their duties. One would, therefore, expect that these vessels would have smaller areas for workshops than repair ships although they include the same kinds of workshops.

There are two important differences between a submarine depot ship and a destroyer depot ship. Firstly, the submarine depot ship is a rehabilitation centre, that is, she must provide the necessary amenities for the comfort and welfare of submarine crews during their period off patrol. Secondly, since the operation of submarines is largely independent of the fleet, the submarine depot ship must be capable of operating as an independent unit at considerable distances from the main fleet. Destroyers, on the other hand, are part of the fleet organization, and, therefore, the destroyer depot ship moves with the fleet and takes her part in the running repairs of the fleet.

Despite a constant barrage of criticism, based mainly on the peacetime cost of performing work in shore establishments compared with the extra cost afloat, the Admiralty, bearing in mind the all-important advantage of mobility, pushed ahead prior to the war with the construction of special vessels of the depot ship type.

Submarine Depot Ships

The earlier submarine depot ships were distinguished mainly by their small size. In 1916 Davis[5] gave particulars of U.S.S. *Bushnell*, a submarine tender, and in 1922 the Diesel-electric Dutch ship *Pelikaan*[6] made her appearance. Both these ships were small vessels fitted with overhanging bows and lifting appliances, stated to be desirable in the case of *Bushnell* for the somewhat dubious operation of lifting the stern of a submarine for the examination of propellers. Nowadays the submarine depot ship is generally designed to provide accommodation, provisions, torpedoes, stores and fuel on a scale necessary for at least a dozen submarines and their crews. She must carry a repair staff to deal with the maintenance items, and an administrative staff to control the operations of the submarines. She thus requires space for a complement of roughly twelve hundred. To this must be added space for workshops, stores, recreation, training, torpedo stowage and refrigeration which makes it clear that a ship of large cubic capacity and plenty of freeboard is necessary for this purpose. In addition, a good turn of speed is required as the ship may have to operate for long periods out of dock and will be expected to move to new positions at a fair speed. The rapid supply of stores, provisions, and fuel to submarines is important, requiring special consideration to be given to the accessibility of the storage spaces and fuel discharging arrangements. The submarine depot ship has also to undertake the maintenance and storage of torpedoes and a considerable quantity of submarine ammunition. She must have ample distilling plant and proper electrical facilities for the battery charging of submarines.

Table II gives particulars of some submarine depot ships.

TABLE II

SUBMARINE DEPOT SHIPS

Name	*Maidstone*	*Adamant*	*Wolfe* (ex-*Montcalm*)
Builder	John Brown	Harland & Wolff	John Brown
Date	1938	1942	Converted 1943
Length	497 ft. 0 in.	620 ft. 0 in.	546 ft. 0 in.
Breadth	73 ft. 0 in.	70 ft. 0 in.	70 ft. 0 in.
Depth	44 ft. 0 in.	45 ft. 0 in.	43 ft. 3 in.
Deep draught	19 ft. 9 in.	21 ft. 3 in.	27 ft. 8 in.
Deep displacement, tons ...	11,500	16,500	21,550
Machinery	Twin-screw turbines	Twin-screw turbines	Twin-screw turbines
Horse-power	7,400	8,000	13,500
Speed, knots	18	17	16
Oil fuel, tons	2,300	2,600	1,760
Workshop areas, sq. ft. ...	18,000	17,000	18,000
Electric power, kw. ...	1,200	3,000	1,825
Distilling capacity, tons/day	280	360	280
Complement :			
Officers	87	93	102
Men	1,080	1,180	1,200
Ballast, tons	—	—	2,600
Armament	Eight 4·5 in.	Eight 4·5 in.	Four 4 in.
Lifting appliances	One 10-ton crane One 6-ton crane One 2-ton crane Four 2-ton derricks Two 1-ton derricks	One 10-ton crane One 6-ton crane One 2-ton crane Four 2-ton derricks Two 1-ton derricks	One 10-ton derrick Four 5-ton derricks Four 2-ton derricks

Before the war H.M.S. *Medway*[7], a Diesel-driven vessel, was completed by Messrs. Vickers, Barrow, in July 1929. She was sunk in the late war. H.M.S. *Maidstone*[8], with geared turbines, was completed by John Brown & Co. in May 1938. With the growth of the Submarine Branch it became necessary

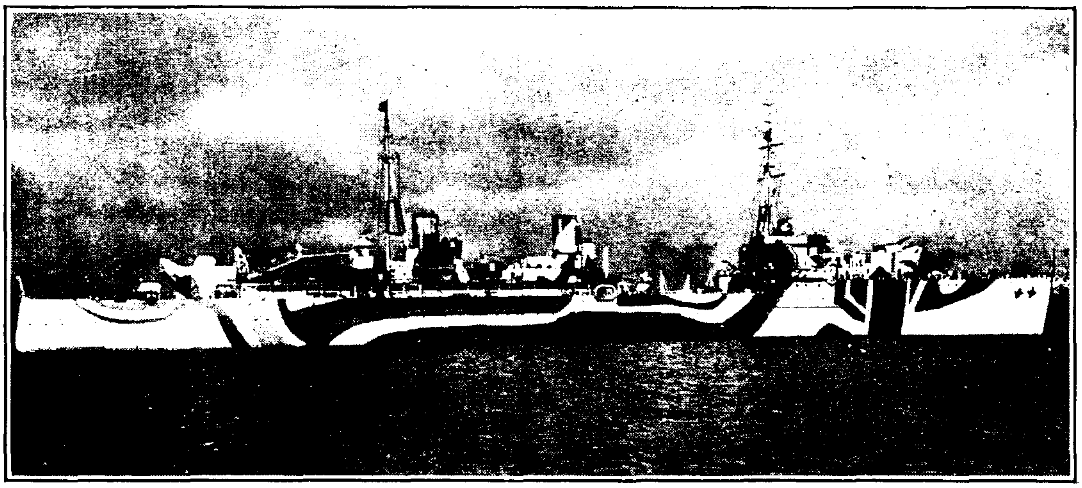

FIG. 5.—H.M.S. " ADAMANT "

to add a sister ship, H.M.S. *Forth*, completed by John Brown & Co. in May 1939, and H.M.S. *Adamant*, completed by Messrs. Harland & Wolff in February 1942. These vessels were specially designed and constructed as submarine depot ships.

In May 1939 H.M.S. *Adamant* was laid down at Belfast ; she was launched in November 1940, but the delivery due to have taken place in March 1941 was delayed by wartime circumstances, namely, delay in the delivery of auxiliaries, damage by enemy action, and the diversion of shipyard labour to more urgent repair work : she was not completed until February 1942. The vessel was built to Lloyd's rules, and the overseeing—except for special Admiralty equipment—was carried out by Lloyd's surveyors. The Director of Naval Construction wishes to pay a special tribute to the grand way in which the surveyors of Lloyd's Register and of the British Corporation helped the Naval Construction Department to carry on its extensive activities throughout the whole war. *Adamant* followed the general lines of the earlier ships, *Maidstone* and *Forth*, except that increased provision was made against air and underwater attack resulting in an increased displacement compared with *Maidstone* of about 5,000 tons. She was designed to act as a depot ship for twelve submarines with accommodation for eleven submarine crews. Ample provision for spare torpedo stowage and maintenance was a feature of the deisgn. The distillers are capable of providing 360 tons a day, and a total electrical supply of 3,000 kw. divided between steam and Diesel generators, was fitted. Approximately 1,000 tons of oil are carried in the ship for the attached submarines. A periscope examination and repair shop, in addition to the usual maintenance facilities, are provided. Ample refrigerated and stowage space for dry provisions is fitted. The lifting appliances consist of one 2-ton and one 6-ton crane for workshop and torpedo handling, and one 10-ton crane for boats, all of which are electrically operated. It may be of interest to note that air-raid damage at Belfast in May 1941 caused considerable dislocation of the shipyard facilities, and *Adamant* was able to help build herself by using her own cranes and workshop machinery. The workshop area is roughly 17,000 sq. ft., and she carries a total complement, including submarine crews, of twelve hundred and seventy-three.

Adamant was the only specially built submarine depot ship constructed during the war. The strength of the depot service was augmented by means of conversions ; these were H.M.S. *Bonaventure* (converted whilst building by

Fig. facing page 42.—H.M.S. *Adamant*, Submarine Depot Ship.

Greenock Dockyard Company and Messrs. Alexander Stephen), H.M.S. *Wolfe* (ex C.P.R. liner *Montcalm*), S.S. *City of London* and S.S. *Wu Chang*. Of these, H.M.S. *Wolfe* represents a typical conversion. From her original role as a C.P.R. liner she became an armed merchant cruiser and was finally converted to a submarine depot ship at Baltimore, U.S.A., in 1943, returning to the U.K. in 1944. She then proceeded East and after one year on station she had serviced forty-eight submarines of five different classes, and gave assistance to seventeen escort vessels of all types. The engineering work handled consisted of two thousand eight hundred jobs for submarines. Approximately 25,000 tons of stores, ammunition, torpedo and fuel were handled, whilst the ship's bakery produced 300,000 lb. of bread. Whilst lying at moorings H.M.S. *Wolfe* burnt 9,500 tons of boiler oil and 1,200 tons of Diesel oil, thus bringing her consumption well above that of her attached submarines which, between them, steamed nearly a quarter of a million miles. She has a workshop area of 18,000 sq. ft. and a total complement of thirteen hundred. The main disability from which she suffered during her tropical service was the lack of adequate ventilation, rather to be expected when a vessel, designed primarily for passenger service under largely temperate conditions, is required to spend the greater part of her time moored in tropical harbours. After the usual removal of the portions of the lower main and superstructure decks to adjust the deck heights for workshops, it was found in converting this vessel that 2,600 tons of ballast was necessary. This in itself constituted a minor problem, for it began to be found in such submarine depot ships—where the provision of adequate space is all important—that the ballast was encroaching on the valuable space required for stores.

Destroyer Depot Ships

Prior to 1935 the function of destroyer depot ships was not fully appreciated, and those built and converted were generally on the small side. In June 1935, H.M.S. *Woolwich* was completed by Messrs Fairfield ; she was followed by H.M.S. *Hecla* (completed in January 1941 by Messrs. John Brown & Co.) and H.M.S. *Tyne* (completed February 1941 by Messrs. Scotts). *Tyne* and *Hecla* were practically sister ships. *Hecla* cost one million one hundred thousand pounds and was built to Lloyd's rules. She had a workshop area of 20,000 sq. ft., and a total complement of eight hundred.

As a depot ship, H.M.S. *Hecla* was expected to mother one *Tribal* flotilla and two normal flotillas of destroyers, that is, about twenty-four vessels in all. She was required to be steady so that destroyers could lie alongside in safety. Her dynamo power had to be sufficient to supply four destroyers and totalled 1,200 kw., supplied by steam and Diesel generators. Her distillers provided 360 tons of water per day. She differed from the submarine depot ship in that she carried boiler oil fuel for herself only and not for the attached vessels. On the other hand her large bakery was required to supply three flotillas with bread amounting to about 6,000 lb. a day. This was put to use very early in her career to supply bread to bomb-damaged Greenock. She was also equipped to do the laundry work for her attached craft, which necessitated handling seven hundred pieces a day. Large spaces were devoted to provisions and cold storage, while her naval stores were said to contain forty thousand items. Special facilities were also fitted for the repair of boats. The handling equipment consisted of two 4-ton and one 10-ton electric cranes. The complement of the ship, in addition to the normal crew, provided for a repair staff, a boiler cleaning party, spare ratings for the crew of the flotilla, and staff to deal with destroyers' accounts. It was also found in H.M.S. *Tyne* that when the Rear-Admiral (Destroyers) hoisted his flag in the ship, the extra administrative staff which then had to be carried brought the complement to approximately one thousand, and made conditions distinctly cramped. Large spaces for the carriage and maintenance of torpedoes were fitted out in a similar manner to a submarine depot ship, and additional capacity was required for carrying depth charges for the attached destroyers.

H.M.S. *Hecla* was fitted with protection against underwater attack, which proved useful in May, 1942, when she was mined and yet managed to proceed to Simonstown at 10 knots. Unfortunately, in November of the same year in the Mediterranean she was struck at intervals by five torpedoes, but managed to remain afloat for two hours thereby enabling the greater part of the crew to be saved. The manner in which this auxiliary warship stood up to repeated torpedo hits shows the value of the work put into her design.

Again, in addition to H.M.S. *Tyne* and *Hecla*, the number of destroyer depot ships had to be augmented by conversions. The vessels chosen were the Holt ships *Philoctetes* and *Achilles* (renamed *Blenheim*). These were fitted out to mother two flotillas of destroyers, being officially described as "Auxiliary Destroyer Depot Ships." They are not being retained in the post-war fleet. Later, in 1944, to meet a very urgent need for an additional destroyer depot ship and flagship for the fleet train—a fleet of supply and other vessels for the support of fighting ships at sea—*Montclare*, an ex C.P.R. liner, was selected. At the time, she was nearing the completion of her conversion to a submarine depot ship at Southampton. Modifications and additions were carried out to enable her to combine her two new functions ; the work being carried out by Messrs. Harland & Wolff, Govan. It may be of interest to note that *Montclare* has now returned to home waters, and has just completed her fourth conversion which will return her once again into a submarine depot ship.

Table III gives particulars of some destroyer depot ships.

TABLE III

DESTROYER DEPOT SHIPS

Name	*Woolwich*	*Hecla*	*Philoctetes*
Builder	Fairfield	John Brown	Scotts
Date	1935	1941	Converted 1941
Length	575 ft. 0 in.	585 ft. 0 in.	503 ft. 0 in.
Breadth	64 ft. 0 in.	66 ft. 0 in.	63 ft. 4 in.
Depth	44 ft. 3 in.	43 ft. 0 in.	44 ft. 6 in.
Deep draught	16 ft. 6 in.	20 ft. 6 in.	25 ft. 4 in.
Deep displacement, tons ...	10,200	14,000	16,600
Machinery	Twin-screw turbines	Twin-screw turbines	Twin-screw turbines
Horse-power	6,500	7,500	7,000
Speed, knots	15	17	$14\frac{3}{4}$
Oil fuel, tons	1,170	1,400	1,570
Workshop areas, sq. ft. ...	12,000	20,000	14,500
Electric power, kw. ...	1,200	1,200	1,200
Distilling capacity tons/day	360	360	200
Complement :			
Officers	35	48	44
Men	631	770	630
Ballast, tons	—	—	1,500
Armament	Four 4 in.	Eight 4·5 in.	Four 4 in.
Lifting appliances	Two 2-ton cranes One 20-ton derrick One 6-ton derrick	Two 4-ton cranes One 10-ton crane Four 2-ton derricks	Four 10-ton derrick Two 4-ton derricks Six 2-ton derricks

Conversions

In the course of these remarks the author has tried to indicate that, for each of the types of ship mentioned, it has been found necessary, in emergency,

Fig. facing page 44.—H.M.S. *Hecla*, Destroyer Depot Ship.

to back up the specially designed ships by numbers of vessels converted from merchant ship types. Generally, the merchant ship type which suits best is the so-called " mixed " type of vessel in the region of 500 ft. length.

It is always difficult for ship owners to see the necessity for converting their perfectly good ships, on the outbreak of war, into mysterious auxiliaries for the Royal Navy, but it must be remembered that in peace-time it is notoriously difficult to find money for war purposes. Consequently, in order to meet the needs of war the nation is faced with the necessity of producing numbers of auxiliary naval vessels in the shortest time. This can only be done by converting such existing merchant vessels as can be obtained. If suitable types are building—as were *Bonaventure*, *Mullion Cove*, and *Dullisk Cove*—so much the better, but at any given moment the likelihood of sufficient numbers of such ships being on the stocks is remote. Further, it must be mentioned that, unless circumstances change, the requirements of the Navy may make even greater inroads on mercantile types in any future emergency than in the past, due to the growing complexity of maintaining operating forces at sea.

The examination of the characteristics of those merchant ships taken for conversion naturally gives food for thought. Table IV shows a comparison between three typical Admiralty-designed vessels and their corresponding converted counterparts.

It will be seen that even after the addition of considerable quantities of ballast, the excess of initial metacentric height of the Admiralty design over the conversion is appreciable. In the converted vessels the standard aimed at for ballasting was that in a bilged condition, with any two adjacent compartments flooded, the vessel should have a slightly positive GM. The condition chosen prior to damage is one approximating to the spent condition with 10 per cent. of the consumable stores, water, and fuel on board, and allowing for a maximum free surface in all tanks. Hovgaard[9] also found that, in conversions to troop transports, the assumption of damage in the light condition necessitated the addition of solid ballast.

As previously stated, the addition of some ballast is not undesirable, as it

TABLE IV.

	Admiralty Design			Admiralty Conversion		
	Submarine Depot Ship *Adamant*	Fleet Repair Ship *Resource*	Destroyer Depot Ship *Tyne*	Submarine Depot Ship *Wolfe*	Fleet Repair Ship *Wayland*	Destroyer Depot Ship *Philoctetes*
Dimensions	620 ft. × 70 ft. × 45 ft.	500 ft. × 83 ft. 3 in. × 49 ft.	585 ft. × 66 ft. × 43 ft.	546 ft. × 70 ft. × 43 ft. 3 in.	520 ft. × 65 ft. × 43 ft.	503 ft. × 63 ft. 4 in. × 44 ft. 6 in
Deep displacement ...	16,500	15,580	14,000	21,550	18,750	16,600
Deep draught mean ...	21 ft. 3 in.	22 ft. 10½ in.	20 ft. 6 in.	27 ft. 8 in.	26 ft. 11 in.	25ft. 4 in.
Deep GM corrected for free surface	6·2	8·4	3·8	3·1	2·2	1·8
Light displacement ...	12,124	11,067	10,873	19,557	16,286	13,980
Light draught mean ...	16 ft. 7 in.	17 ft. 2 in.	16 ft. 7 in.	25 ft. 6 in.	23 ft. 10 in.	21 ft. 0 in.
Light GM corrected for free surface	4·5	7·5	2·6	2·9	2·2	1·6
Ballast (tons)	—	—	—	2,600	3,200	1,500 +980 water ballast

affords an opportunity of ensuring propeller immersion and reducing windage in vessels which have to anchor in exposed waters. But the scarcity of heavy ballast in war leads to the use of more bulky forms of ballast, which encroaches on the valuable internal space of the ship required for other purposes. It will not be assumed, of course, from the figures given, that the converted ships illustrated were in their normal state deficient in stability, for it will be remembered that any conversion leads to the addition of considerable topweight, and it is well known that for every ton of weight added above the centre of gravity roughly about twice as much weight of ballast is required to compensate for the loss of BM with the increased displacement. This is a pointer to the generally undesirable nature of attempting to improve stability by the addition of ballast. One is tempted, therefore, to speculate on the trend of " mixed " type development in the direction of improving the stability in the ballast condition when damaged. Montgomerie[10] in his able paper recalled that safety at sea was discussed at the opening meeting of this Institution in 1860. A resolution was carried in 1866 which led to the Council formulating *inter alia* the following statement in its general report for 1867 :—

> " In proportioning the compartments of a ship (and especially of ships devoted to passengers) it is very desirable so to arrange them that if any *two* adjacent compartments be filled or placed in free communication with the sea, the remaining compartments will float the ship."

Since passenger ships to-day are largely of the intermediate type, legislation[11] has not yet brought us to the stage of achieving the Council's recommendation, as this has been found to interfere unduly with commercial operation. Indeed, the position shows that, although earlier legislation was in favour of something approaching a two-compartment standard for medium-sized passenger-carrying vessels, the whole trend of recent development has been in the opposite direction, commencing with the easing of regulations in 1920. The computing of the Criterion of Service Numeral—introduced in 1928—on a basis by which it grows and involves extra sub-division with increased size of machinery spaces, has been defeated by progressive developments in design, for ever greater machinery power is being concentrated in smaller and smaller spaces. This tends to place the upper numeral value of 123, controlling the sub-division for a full " passenger " ship, outside the range of practical design. Thus, all passenger ships are tending to gravitate towards the " mixed " type, and for vessels in the region of 500 ft. long, virtually a one-compartment standard for flooding is the best that can be attained. It is thought, however, that it may not be inconsistent with commercial success to aim at a two-compartment standard for stability : that is, if a ship in the ballast condition receives flooding in two compartments she will retain a positive GM. It is evident that an important factor in determining the stability when so flooded is the beam-draught ratio. Flamm[12] in his investigation on a block-shaped figure, and Brimblecombe[17] and Macmillan and Comstock[13] for ship forms, have indicated that the greater this ratio the greater loss of GM due to flooding.

If flooding is assumed over about one-quarter of the ship's length in the mid-ship part, there are indications that stability will be reduced on flooding if the beam-draught ratio exceeds a value of approximately $2\frac{1}{2}$. Naturally, the actual value in any particular ship is affected by permeability and form. In most ships it is clearly impracticable to obtain a ratio of $2\frac{1}{2}$ or under at ballast draughts, therefore a reserve of intact stability is necessary from which the loss can take place. Increase in beam is a powerful factor in providing that extra intact stability and, in general, unit increases in GM may be obtained with fractional loss due to flooding. It will be seen, too, from Table III of Anderson and Steel's paper[14], that an increased ratio of beam-draught, giving improved stability in the intact light condition of a proposed ship over a type ship, need not necessarily adversely affect commercial characteristics. The problem of ship's stability after damage has been dealt with exhaustively by Niedermair[16], on the basis of existing regulations, and the effect of two-compartment flooding as compared with one-compartment indicates that provision of the order of an additional 1 ft. of intact metacentric height is required for a satisfactory two-compartment stability in a vessel 500 ft. long when in the ballast condition. Both Niedermair[16] and Bates and Wanless[15] have drawn attention to the increased GM's required in the intact conditions, and express fears regarding the comfort of such ships at sea, but there is reason to believe that we may have been unduly squeamish in deciding the best metacentric height to be given to ships in their service conditions. Although it is the fashion to express metacentric heights in terms of beam, the author is of the opinion that in general up to 1/100th of the ship's length may be accepted in most cases for the maximum value of the intact metacentric height without undue discomfort.

The factor of unsymmetrical flooding, and the extra loss of GM which is likely to take place in a flooded compartment where the cargo does not extend as high as the waterline, show that some margin of stability is necessary even in one-compartment flooding. It, therefore, appears clear that it is not unreasonable to suggest that a two-compartment standard for stability in the ballast condition should be aimed at in the larger " mixed " type ship of one-compartment standard. It will be all to the good if some advance can be effected in the direction of the original resolution carried by our Council by improving the damaged stability in " mixed " type ships, and rules to include such considerations might usefully be embodied in the orders on the subject.

Another modification, which is found necessary in nearly every merchant ship taken over, is to increase the electric power supply. This is naturally due to the excessive electric load added by Admiralty requirements, but it is a load which is likely to increase in any event with future commercial requirements. It is reaching such proportions as to cause strong consideration to be given to the desirability of having electricity as the main source of power for all purposes.

Main machinery running at constant speed coupled to a variable pitch propeller appears to offer scope for the solution of the electrical difficulty. In U.S.S. *Fulton*, a submarine tender, 529 ft. 6 in. O.A. × 73 ft. 4 in. × 20 ft. 6 in. mean draught, for the main propulsion a Diesel-electric drive of 11,200 h.p. is employed, thus ample power is available for ship use, repairs, and the supply to submarines alongside. It tends to give in depot ships, which are not tied by tonnage measurements, a compact machinery space. It is refreshing to observe that the somewhat similar development with a turbo-electric drive in the Canadian Pacific *Beaver* class has recently taken place, thus showing that such progress is in step with the latest commercial ideas.

The provision of increased fire-fighting equipment is a feature which should commend itself to ship operators. The supply of water at suitable pressures at high levels in a ship does not yet appear to have had the attention it deserves, whilst recent developments in small diameter hoses, improved branchpipes, together with powerful and compact lightweight pumps is one which might well be followed in standard ship practice. It is believed that some consideration is being given to this question by the appropriate authorities.

Enough has been written to show that in dealing with these humble auxiliaries of the Royal Navy, one finds room for developments of a most interesting nature. The tendency is towards improved stability, extra electric power, better galleys, crew's high-class accommodation, ventilation with air conditioning, and increased endurance, all of which are reflected in the present trends of high-class merchant ship construction.

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