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Design and Operating Experience of an Ore Carrier Built Abroad

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The problems facing different shipowners vary considerably in any design and therefore this paper should be interpreted in respect of the special problems dealing with the type of ship required. For the transport in bulk of bauxite or alumina† this is largely controlled by the following particular points:—

(a) Bauxite and alumina are relatively heavy materials so that a vessel loaded to its deadweight capacity still has considerable empty space for cargo.

(b) The vessel can be loaded to its deadweight capacity for each trip to the smelter.

(c) The return trip has to be made in ballast unless general cargo can be picked up on the return trip.

(d) The trade may be seasonal if the vessel discharges at ports closed in winter.

These conditions were met by designing a bulk carrier‡ that had the maximum possible deadweight for its type and size and which was sufficiently versatile to be used for general cargo. To achieve maximum deadweight, sizable quantities of aluminium were incorporated in many parts of the vessel, the most economical being the superstructure. The decision to use aluminium extensively was based on an economic analysis. The design and construction of this ship brought about a notable interchange of ideas and information between Canada and the United Kingdom, as well as the United States of America, especially in respect of aluminium, but also in respect of machinery and engine room practices.

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† Alumina is the raw material used for aluminium smelting. Stowage varies from 36-44 cu. ft. per ton, angle of repose 34 degrees, and shrinkage 6-17 per cent. This alleged shrinkage later turned out negligible in importance, but it created a problem akin to "special grain" at the time.

‡ S.S. *Sunrip*, built by Davie Shipbuilding Co., Ltd., Quebec, for Saguenay Terminals, Ltd., the shipping arm of the Aluminium Company of Canada.

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HULL

DESIGN CONSIDERATIONS

Generally, design considerations may be discussed with particular reference to the following:—

(a) General layout of the hull.
(b) Distribution of water ballast deep tanks, etc.
(c) Speed and type of machinery.
(d) Position of propelling machinery.
(e) General discussion on accommodation.

General Layout of Hull

(a) *With Machinery Aft*

A common type of bulk ship is the conventional ore carrier, which is similar in many respects to a tanker, usually a single deck vessel having twin longitudinal bulkheads positioned to provide capacity for a full deadweight cargo of ore in the space between. If required, this central compartment may be continuous fore and aft, the transverse bulkhead being omitted. The wing compartments, between the longitudinal bulkheads and the sides of the ship, may be utilized for the carriage of grain or oil cargo or perhaps only water ballast on the return trip. This type of subdivided internal arrangement is made necessary by the low storage rate of most ores. A ship big enough to absorb the deadweight required has far more capacity than is required to accommodate the cargo. Another common type is designed with grain as the principal cargo in mind; such vessels are invariably designed also for general cargo because of the seasonal nature of grain. The most common arrangement consists of a two-deck ship with four or five holds and no continuous longitudinal bulkheads. Such a vessel remains reasonably orthodox for general cargo and the 'tween decks make it comparatively easy to provide the feeders and bins required under regulations governing the carriage of heavy grain in bulk. One disadvantage of this type of hull is the necessity of fitting her up for grain with shifting boards, together with bins and/or feeders. The cost of fitting up is now quite high and the vessel loses three or four days during their construction.

(b) *With Machinery Amidships*

In this case the internal arrangement of the hull is as for any conventional cargo ship. In fact, any ship of this type can serve as a bulk carrier, but when building a new ship with bulk cargo in mind, a number of things can be done that will reduce the cost of repairs; also, the loading and discharging time. Cargoes such as iron ore, bauxite and coal are discharged by grabs and even under expert control these can wreak considerable damage to the ship. To minimize this, hatches are normally made as large as possible and a system of construction which avoids the use of pillaring in the holds and 'tween decks can, and should be, adopted. This is best done by designing the hatch end beams to support the loads transmitted from the main fore and aft girders. The hatch end beams are in turn supported by a partial centre line bulkhead in the centre and by web frames at the ship's sides.

Stiffness of the tank top is another vital feature. It is fairly common practice nowadays to frame longitudinally the bottom shell, tank top and decks. Solid plate floors are arranged on alternate frames in conjunction with this longitudinal framing when the tank top is adequately supported. Wood sheathing as a protection for the tank top plating is common and is costly to renew, but is liable to frequent damage by grabs. Perhaps the best solution is to leave the tank top bare and to increase the thickness by about 0·30in. above rule thickness. The increase in weight may be considerable, but probably compares favourably with the weight of wood sheathing and the accumulation of residual cargo generally found beneath. The conventional drainage arrangements in holds also warrants some modification for bulk cargoes. Normal bilges are apt to become choked, and if the cargo is of an abrasive nature, wear and tear on the bilge pumps may become excessive. An improved arrangement consists of carrying the tank top plating out to the ship's side horizontally, or following the line of the frame brackets. The former arrangement gives a slightly increased capacity and if, in addition, the double bottom happens to be of greater depth than the rules require, a case can sometimes be made out for omitting the frame brackets above the tank top altogether, and making an addition to the scantlings of the side framing. Drainage is effected by means of wells situated at the after end of each hold and fitted with portable filters to keep out the cargo.

Distribution of Water Ballast

The necessity for providing sufficient water ballast to make the ship seakindly almost invariably requires the inclusion of at least one deep tank. Whilst there are no rules governing the quantity of ballast required, a minimum of about 20 per cent of the deadweight forms a good guide. Depending upon a vessel's intended service, a greater or less margin over this figure should be provided. Normally, complete immersion of the propeller should be assured without having excessive stern trim.

In bulk cargo vessels with machinery aft, it is usually easy to provide adequate ballast capacity spread evenly over the vessel's length, either in the form of deep double bottom, wing tank, or hopper tanks under the sides of the deck, or by a combination of two or more of these alternatives. Deep tanks are usually required forward either for oil fuel or ballast in order to trim the ship evenly, and they should be kept to a minimum, to limit the stresses over the vessel's midship portion.

With machinery amidships, however, the problem of water ballast becomes more acute. As previously indicated, the ship is usually of the conventional type, with normal depth of double bottom and no special wing compartments. Instead of distributing water ballast uniformly over the ship's girder, therefore, it is necessary to consider the placing of concentrations of water ballast forward, amidships and sometimes between, in order to maintain satisfactory trim and to prevent the ship's structure being overstressed. All this involves the introduction of a deep tank at one or both ends of the machinery space. This may be satisfactory in ballast, but the loaded condition may become quite critical. For example, the holds may be loaded with heavy density cargo, such as bauxite, so the deep tanks will normally remain empty. This, combined with the machinery space, constitutes a serious gap in the loading of the ship. Consequently, the combined bending and shearing stresses in way of this gap may be so high in normal service as to leave insufficient margins of strength to absorb the additional loads imposed by heavy weather conditions. A reasonable length of midship deep tank can be compensated for by additional stiffening as required by the Classification Societies, and the adoption of longitudinal framing of decks and bottom is a great help, but the length of the tank should be kept to the absolute minimum. A short amidship deep tank can be supplemented by the provision of tanks at the sides of the shaft and tunnel in the after holds, a slight increase in the depth of the double bottom throughout, and/or a deeper double bottom tank in No. 1 hold, where the loss of cargo capacity is not too important. Another alternative is the construction of a very short deep tank between two of the forward holds. The problem is one which warrants very careful consideration in any new ship.

Speed and Type of Machinery

This is a controversial subject, and in a general paper it is not possible to be too dogmatic regarding service speed required. Several data, however, are normally available; for example, it may be assumed that an owner contracting for a new bulk cargo vessel has a particular trade in mind which will occupy the vessel for the whole or a large part of its year's trading. The service speed, therefore, is closely interrelated with the conditions existing on the run for which the ship is intended, as, for example, the loading and discharging facilities, and therefore, time in port, type and cost of fuel available, freight rate offered, average weather conditions, wage scales, etc., and this can form the subject of a detailed economic analysis. It is important, therefore, that the owner should obtain the results of such an investigation in the cost per ton of cargo based on average speeds with different types of machinery, before making a decision regarding economic speed. In this he is normally fortunate in being able to estimate for one type of cargo only, which simplifies the problem.

The type of machinery to be adopted also requires careful consideration depending on the intended service. An excellent case can usually be made out for both steam turbine and Diesel engines for a bulk vessel, there being strong arguments in favour of both. The Diesel ship will usually show reduction in first cost compared with the turbine, and if the engine burns heavy oil a forecast of the economics over a period of years will almost undoubtedly favour Diesel. So much depends upon the variation and quality of fuel available for the Diesel, however, that maintenance costs are difficult to estimate. An owner might still choose a steam turbine on the grounds that it is a simpler machine, well suited to a long, steady haul, and usually free from actual breakdown as well as being less liable to vibration. The final choice must be made after a study of all the factors involved, not the least of these being the experience and capabilities of the operating personnel available.

In the end, however, it is usual for one particular reason, which may be a simple preference, to be paramount in the mind of the owner.

Position of Propelling Machinery

As regards the position of the propelling machinery, this is usually resolved into a question of whether it should be placed in the conventional position amidships, with cargo fore and aft, or at the after end.

Various intermediate positions have in the past been adopted but these represent a side issue which do not affect the fundamental question. Until recent years, vessels with machinery aft were generally confined to tankers, a few bulk ships and ore carriers, and small type ships such as coasters, colliers, trawlers and small tramps. Whilst many have favoured the adoption of machinery aft (for reasons which are given later), the eternal stumbling block appears to have been the difficulty of achieving a suitable loaded trim. The machinery space aft results in the centre of gravity of the cargo spaces being well forward of amidships, so when the ship is loaded to full cubic capacity with homogeneous cargo, she is more than likely to be "down by the head".

In the smaller type of dry cargo vessel up to about 300ft. length between perpendiculars, this phenomenon has for many years been overcome by stepping the upper deck, thus raising the after part about three feet or more above the fore part. This resulted in the afterholds having greater capacity than those forward, which was tantamount to shifting the cargo centre of gravity bodily aft. This type of vessel is known as the "raised quarter decker".

In larger vessels, however, the solution is not such a happy one. The longitudinal bending moments being of a much higher order than in small ships, the upper deck assumes relatively heavy duties as a strength member and it becomes difficult to provide adequate compensation in way of the step. In oil tankers and other vessels carrying liquids and bulk, the problems of trim is not acute. Liquids carried are normally of relatively heavy density, so it is not necessary to make use of the maximum cubic capacity available. Consequently, it is usual to provide a small dry cargo hold forward which remains empty when loaded and this serves to keep the centre of gravity as far aft as possible. By careful design, it is possible to achieve the necessary incidence of the longitudinal centres of gravity and buoyancy with the ship on even keel. Fortunately, a similar situation exists in vessels designed for the carriage of dry cargoes and bulk. Most commodities in this category have a stowage rate of something less than 50 cu. ft. per ton, and on this assumption it is usually possible to limit the forward extent of the cargo space to achieve a satisfactory state of trim. It may be argued that light grain stows at a higher rate than 50 cu. ft. and that the space lost forward would constitute a penalty with such a cargo. Whilst this is quite true, it is also true that it is seldom, if ever, possible to load a full scantling ship down to her marks with grain, due to the limitations on capacity, and in this respect a ship with machinery aft is superior to her sister with machinery amidships, because of the extra cubic space.

To sum up, the adoption of machinery aft in a vessel designed exclusively for bulk cargoes presents no major difficulties, particularly when a single deck vessel is contemplated, and, indeed, offers certain real advantages as follows:—

(i) The availability of a large rectangular space amidships for cargo.
(ii) Increase in the cargo capacity due to the elimination of the shaft tunnel.
(iii) Reduction in shaft transmission losses, due to the short length of shafting.
(iv) Elimination of stress concentrations resulting from abrupt variations in the loading curve.

It might be added that, in the case of bulk carriers, the reduced distance between the fore and aft cargo hatches facilitates the use of shore loading and discharging equipment, particularly when the intervening deck space is clear of obstructions such as masts, deck houses, etc. On the other hand, some shipowners are more interested in owning vessels which are equally suitable for general cargo as well as bulk, and in such cases they prefer to retain the machinery amidships, particularly if the vessel is to be time chartered.

General Discussion on Accommodation

In bulk carriers with machinery amidships, the accommodation position is the same as for any cargo vessel, either all amidships, or, more commonly, officers amidships and ratings aft. When the machinery is aft, there are three variations available:—

(i) The first is the arrangement traditional in oil tankers, where deck officers are in a short deck house just forward of amidships, and everyone else aft.
(ii) Everyone aft, except the radio operator, who is accommodated in the midship house.
(iii) Probably the most modern arrangement where everyone is aft and the forward house is omitted, the navigating bridge being incorporated in the after superstructure. This arrangement is gaining popularity in new vessels and has been adopted in a number of small carriers and in at least several tankers. The idea is most suitable for bulk cargo vessels which are to be loaded and discharged by shore equipment; the absence of the amidships structure gives clear fore

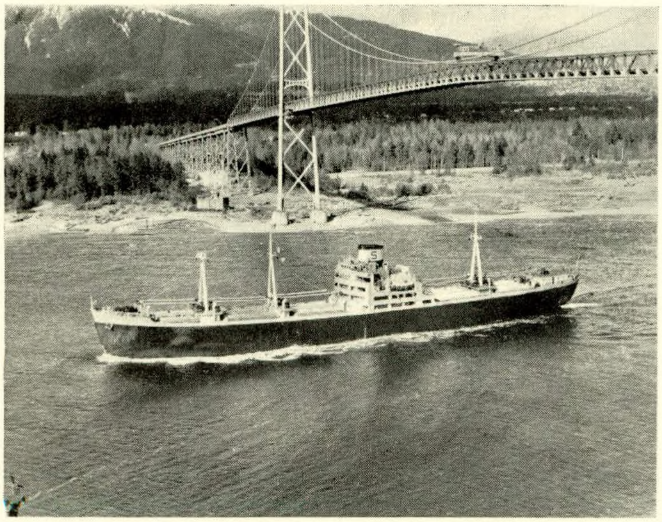


FIG. 1—*T.S.S.* Sunrip

and aft room for travelling conveyors, pipes, etc. Provided that the navigating platform aft is arranged at a suitable height, there seems to be no valid reason why it should not serve as efficiently as in the midship position once the personnel become accustomed to the arrangement.

THE FINAL DESIGN
(See Figs. 1 and 2)

Principal Characteristics

Length, b.p.	450ft. 0in.
Breadth moulded	62ft. 6in.
Depth to upper deck	40ft. 8in.
Height of midship deckhouses... ...	39ft. 6in.
Draught	29ft. 2¾in.
Deadweight, tons	12,825
Lightweight, tons	4,320
Displacement, tons	17,165
Capacity of holds and 'tween decks, cu. ft.	621,115
Capacity of holds, cu. ft.	390,570
Capacity of feeders, cu. ft.	102,716
Capacity available for heavy bulk cargoes, cu. ft.	493,286
S.H.P.	5,000

The service horsepower of 5,000 s.h.p. was estimated to give an average service speed of 13½ knots. (In three years' service 13¾ knots had been averaged.) A resistance and propulsion test was run on a model at the Washington Model Basin.

The vessel as finally designed looked rather like a conventional cargo liner. Although designed to transport, in order of expected importance, alumina in bulk, heavy grains in bulk, other bulk cargo and general cargo, examination of the general arrangement will reveal a versatile ship, easily converted from one type of cargo to another (Fig. 2).

The ship is almost completely welded, the only exception being the upper deck stringer angle and three plate seams on each side of the hull, as well as the join between the steel upper deck coamings and aluminium deck houses. The aluminium midship structure and after deck house were completely welded. Final choice placed the machinery amidships and the machinery selected was a geared steam turbine driving a single screw. The ship is of the closed shelter deck type, with short forecastle. The stem is raked, of soft nose form, and the stern is of the cruiser type. The superstructure consists of mast houses, midship houses and after deckhouses.

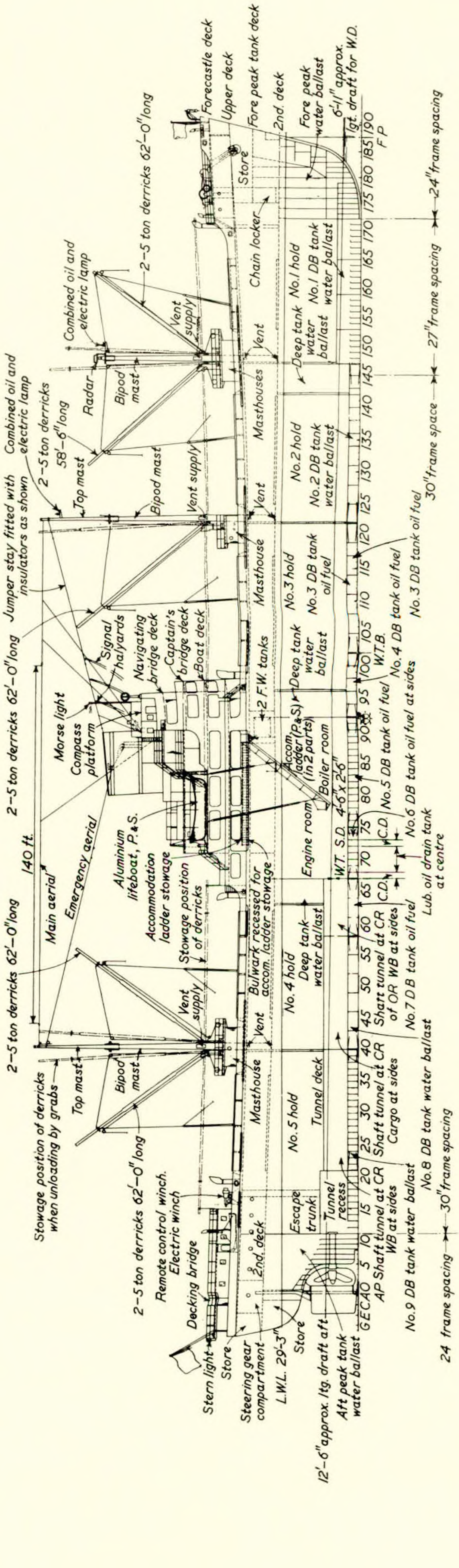
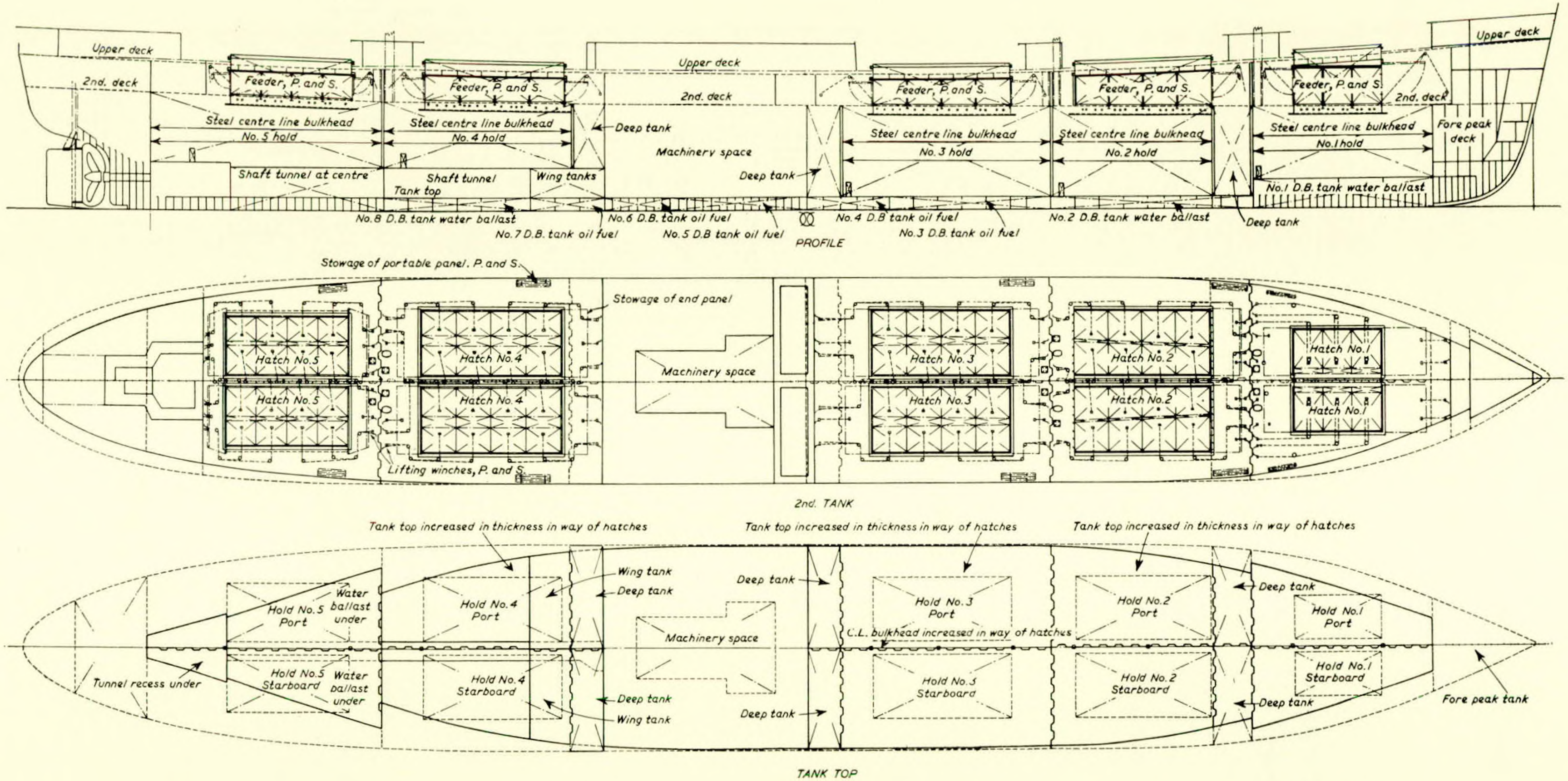


FIG. 2—*Profile and decks*



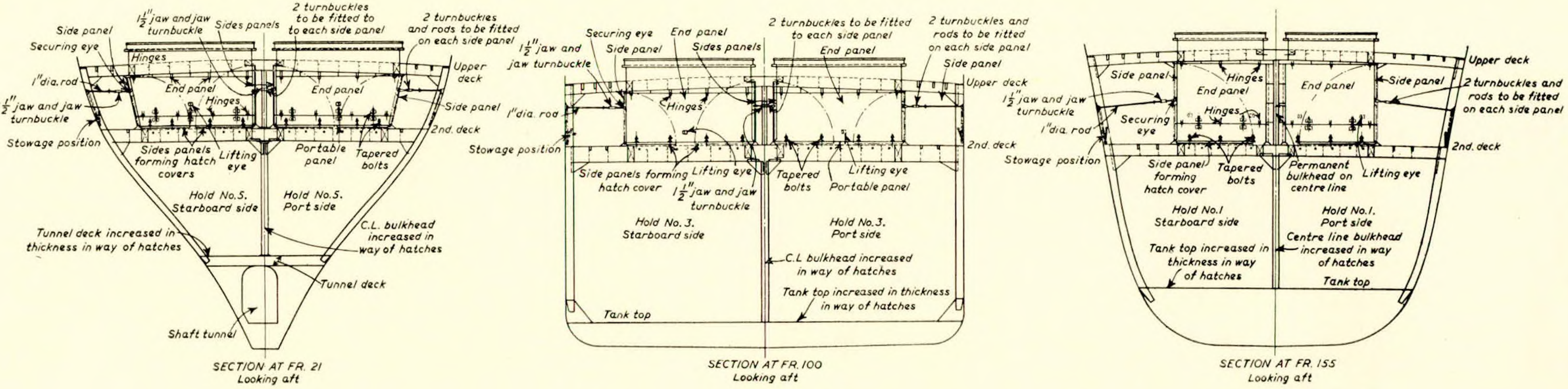
No. 1 Hold
Grain capacity: Starboard, 25,110 cu. ft.
Port, 25,069 cu. ft.
Feeder, port and starboard
Hatch: 27 × 13·5 × 2·64 = 962 cu. ft.
Trunk: 27 × 15·5 × 15·5 = 6,487 cu. ft.
Gross = 7,449 cu. ft.
Net = 7,410 cu. ft.

No. 2 Hold
Grain capacity: Starboard, 41,570 cu. ft.
Port, 40,690 cu. ft.
Feeder, port and starboard
Hatch: 42·5 × 19·5 × 2·64 = 2,188 cu. ft.
Trunk: 42·5 × 19·5 × 12·56 = 10,409 cu. ft.
Total net = 12,597 cu. ft.

No. 3 Hold
Grain capacity: Starboard, 54,690 cu. ft.
Port, 55,860 cu. ft.
Feeder, port and starboard
Hatch: 42·5 × 19·5 × 2·64 = 2,188 cu. ft.
Trunk: 42·5 × 19·5 × 10·69 = 8,859 cu. ft.
Total net = 11,047 cu. ft.

No. 4 Hold
Grain capacity: Starboard, 43,110 cu. ft.
Port, 43,005 cu. ft.
Feeder, port and starboard
Hatch: 42·5 × 19·5 × 2·64 = 2,188 cu. ft.
Trunk: 42·5 × 19·5 × 10·49 = 8,692 cu. ft.
Total net = 10,880 cu. ft.

No. 5 Hold
Grain capacity: Starboard, 29,725 cu. ft.
Port, 30,765 cu. ft.
Feeder, port and starboard
Hatch: 37·5 × 19·5 × 2·64 = 1,951 cu. ft.
Trunk: (37·5 × 18·64 × 8·02) + (37·5 × 19·5 × 2·56) = 7,493 cu. ft.
Total net = 9,424 cu. ft.



SECTION AT FR. 21
Looking aft

SECTION AT FR. 100
Looking aft

SECTION AT FR. 155
Looking aft

Summary of capacities of holds in cu. ft.

Compartment	*Frames*	*Capacities*	*Feeder*	*Feeder as per cent of hold*	*Total*
No. 1 hold, starboard ...	147-172	25,170	7,410	29·44	32,580
No. 1 hold, port ...	147-172	25,985	7,410	28·52	33,395
No. 2 hold, starboard ...	122-142	41,570	12,597	30·30	54,167
No. 2 hold, port ...	122-142	40,690	12,597	30·96	53,287
No. 3 hold, starboard ...	90-122	54,690	11,047	20·20	65,737
No. 3 hold, port ...	90-122	55,860	11,047	19·78	66,907
No. 4 hold, starboard ...	40-63	4,300	10,880	25·30	53,885
No. 4 hold, port ...	40-63	43,110	10,880	26·24	53,990
No. 5 hold, starboard ...	11-40	29,725	9,424	31·70	39,149
No. 5 hold, port ...	11-40	30,765	9,424	30·63	40,189

The capacities of the holds are net capacities of the spaces measured out to the skin plating and to the top of beams after deducting the space occupied by frames, beams, etc. The feeder capacities are their actual capacities after deductions have been made of all obstructions.

Total hold capacity ...	390,570 cu. ft.
Total feeder capacity ...	102,716 cu. ft.
Total grain capacity ...	493,286 cu. ft.

FIG. 3—*Loading plan*

The midship houses consist of five decks, namely the upper deck, bridge deck, boat deck, captain's bridge and navigating bridge, providing accommodation for officers, owners and passengers. The arrangement of accommodation is petty officers and ratings aft, all other midships. The standard is very high and includes well-fitted recreation rooms and, indeed, all conveniences normally associated with modern living. Except for the saloon, all eating facilities are on the cafeteria system with separate arrangements for crew, petty officers, stewards, and engineers in port, or duty engineers at sea. These cafeteria arrangements are adjacent to the main galley. The galley and bakery are equipped with an electric range, baker's oven, dressers of stainless steel finish, coffee urn, daily use refrigerator, etc. The after mast house is fitted out as laundry rooms.

The mechanical ventilation and air conditioning is thermostatically controlled with secondary systems for galley, store rooms, refrigeration space, etc. Separate exhaust systems were used for public rooms, sleeping accommodation, and toilets, etc.

A special feature is the cargo arrangements. The three mast houses support three bipod masts with electric winches on platforms serving five holds on the port side and five on the starboard side. The twin hatch arrangement was made to provide maximum free digging area for bulk cargoes. To obviate the time and cost of fitting shifting boards and feeders, the ship was built with a permanent steel centre line division bulkhead between tanktop and second deck. This subdivided the lower holds to form ten compartments served by ten hatchways. Semi-permanent feeders were fitted between second and upper deck as follows. The steel hatch covers of the second deck were arranged to hinge up each side of the hatch in the 'tween deck, thus forming the sides of the feeders. End panels hinge down from the deck above to form the feeder. Each

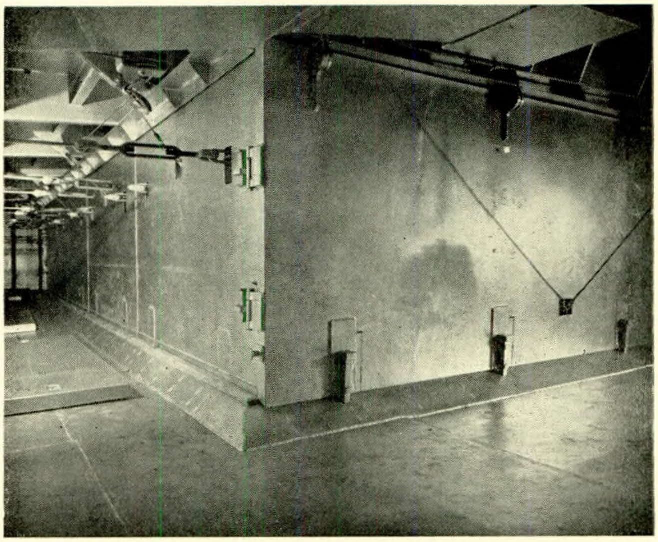


FIG. 5—*A hatch feeder closed and viewed from the 'tween decks*

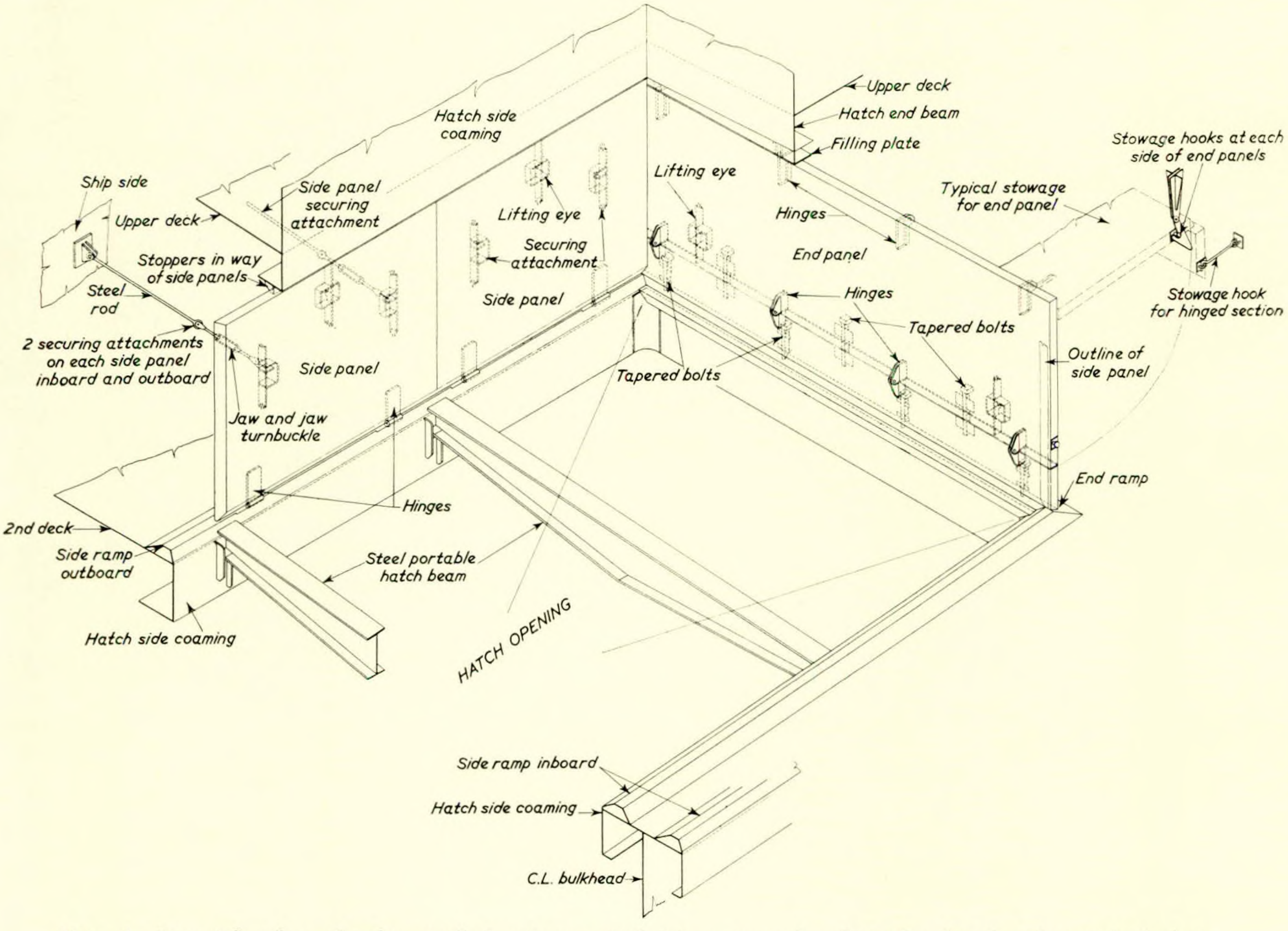


FIG. 4—*Isometric view showing typical scheme of hatch covers and end panels when forming grain feeders*

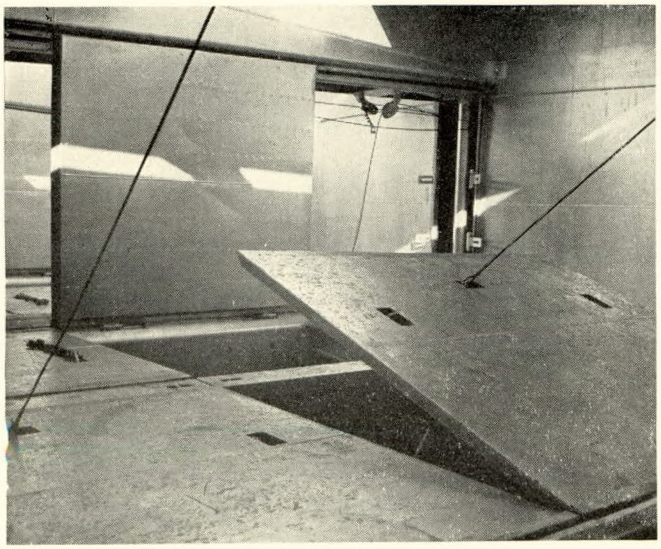


FIG. 6—*A feeder being prepared*

cover was provided with rubber packing to ensure grain tight joints between each panel. These were secured in place by wedges or stayrods to the ship's side. Turnbuckles only were used to secure the two inboard rows of panels near the centre line. The feeder panels were handled by small one-ton hand winches. The complete erection of the feeder for a twin set of hatchways takes just less than one hour. This alone presents a great labour and cost economy compared with the usual portable wood division. The feeders are outstanding also in respect of capacity, the normal limit of 8 per cent being exceeded and the average capacity being 26 per cent of the grain capacity of the holds fed. When the lower holds are full of grain or alumina, the hatch feeders are filled to the level required to bring the ship to her marks. The trunks serve to keep the cargo up in the ship and thus excessive stability is obviated (Figs. 3 to 7).

Regarding bipod masts, the basic advantage is the elimination of mast shrouds and stays which are normally an obstruction for free operation of derricks. These masts were also adapted for cargo hold ventilation; each leg was arranged with a suitable opening fitted with louvres and a hinged closing cover.

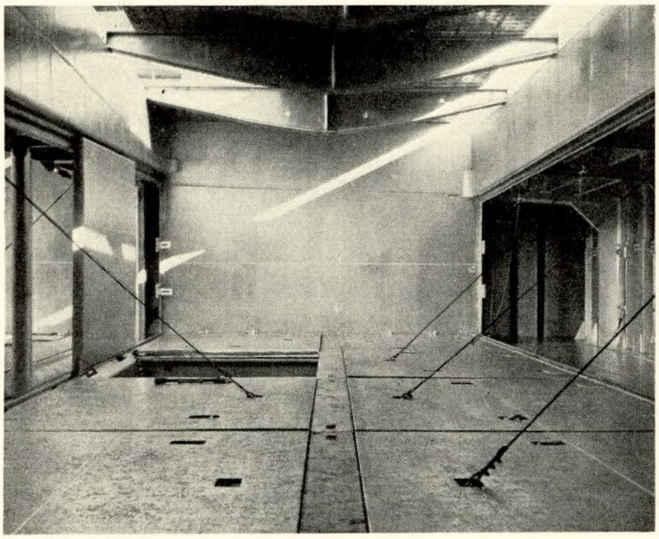


FIG. 7—*A feeder being disconnected*

In calculating the cross section area of material in way of the strength deck, no value could be given to the small portion of deck between the twin hatches nor to the centre line bulkhead, as these were not continuous members within the meaning of the term. The effective width of deck plating at each side is 117in., and this indicated a plating thickness of 1¾in., or the necessity for doubling. Both these features were avoided by increasing the scantlings of the deck longitudinals from the rule size—7in. × 3½in. × 0·44in. B.A. riveted to 12in. × 4in. × 0·70/0·83in. channels welded—and distributing the required sectional area over the sheer strake, the stringer angle, the deck plating and the longitudinals. Every possible measure was taken to ensure the maximum deadweight on the dimensions and the following figures will demonstrate how successful was the attempt. The deadweight came out at 12,825 tons, which gives a deadweight displacement ratio of almost 0·755, which figure is claimed to be quite high for this class of ship*. Altogether about 121 tons of aluminium were used in the construction (weight saving 195 tons).

The machinery chosen was a Pametrada two-stage turbine, transmitting through double reduction articulated gearing, to the propeller turning at 115 r.p.m.

The design has two objectives, one to minimize the amount of time and money required to convert the ship from one type of cargo to another, and the other to obtain the highest possible deadweight for a given size. There is ample cubic space (see principal characteristics, p. 265, the limiting factor for heavy bulk cargoes being the deadweight. When the designer, using the more conventional materials of ship construction, reaches the maximum possible ratio of deadweight to displacement, he can turn to lightweight materials such as aluminium to obtain the extra ton of capacity which means adding earning power over the life of the ship.

ALUMINIUM

(See Appendix 6 for weights and alloys actually used)

Technical and Economic Synopsis

It was clear at the outset that the greatest and most rapid reward from capital expenditure would be in respect of superstructures. The initial proposal was to use alloy 65 ST for a wholly riveted structure (see Appendix 1) the weight ratios for aluminium/steel being 0·417 : 1. The author felt that riveted construction did not represent the practice whereby maximum saving in weight and cost would be obtained and therefore consideration was given to welding. Tests on welded 65 ST at Laval University (Appendix 7) failed to produce the elongation required by Lloyd's Register of Shipping (Appendix 8) and whilst these tests may be considered disappointing to the extent of coincidence, it nevertheless indicated that Lloyd's Register's approved material, the B54 S softer material, was the choice for welding. Some authorities in both Canada and America referred to the use of 61 ST in the s.s. *United States* and they held the view that 65 ST (the Canadian equivalent) was suitable for welding, ships of the Royal Canadian Navy being cited as examples. It should be appreciated that since riveted 61 ST was decided for the s.s. *United States,* aluminium welding technique has developed considerably, with consequent effect upon the shipbuilding industry and the material to be used. Heat treated material is not the best for welding (see note on test results, Appendix 7). The material B54 S

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* Original calculations	12,400 tons on 29ft. 0in.
Final deadweight	12,670 tons on 29ft. 0in.
Difference, tons	270.
Aluminium (228·4 short tons), tons ... =	205.
Balance of 65 tons ... ... =	Safety margin not included in original calculations but nevertheless realized.
Maximum draught ratio agreed by Lloyd's Register on basis of structural scantlings as fixed ... ... =	29ft. 2¾in.

Increment of 2¾in. allows the loading of 155 tons more cargo (TPI 56·8).
Total increase in deadweight, 155 + 270 = 425 tons.

used with A56 S extrusions is excellent for welding. To illustrate this paragraph further, a welded aluminium structure as compared with the riveted aluminium structure is cheaper by about 36·5 per cent of the first cost of an equivalent steel structure (see Appendix 1). This is not abnormal, estimates as high as 43 per cent being existent.

One very important consideration, if not the criterion, in the selection of material for marine use is the resistance to corrosion. The non-heat treated magnesium type alloy has very high corrosion resistance provided bi-metallic separation is maintained. Research development has shown that alloys suitable for marine use are of the magnesium, or the magnesium silicide, family and a minimum of 3 per cent magnesium is set as giving suitable structural strength, but on the other hand, a magnesium content of 5-7 per cent may, and has, led to disastrous corrosion vulnerability. For non-heat treatable alloy, Lloyd's Register has settled on 5·5 per cent magnesium as nominal. Tests have revealed that magnesium alloys weld 90 per cent efficient and elongation is almost as good as the metal itself.

The heat treated alloys of the magnesium silicide class are not suitable for welding, as was established at Laval University, subsequent heat treatment after welding to restore properties being impossible when dealing with ships' structures. The cost and weight differential leaves no doubt in favour of welding. It was clear, therefore, that B54 S was the material most suitable. An A56 extrusion has greater proof stress and if used in conjunction with B54 S, utilizes this property because the weld is near the neutral axis of the combination and is not so highly stressed as a section flange remote from the weld.

The design as first proposed by the shipyard was based on W. Muckle's design(3) and an aluminium/steel weight of 0·417 : 1 resulted for this welded structure. Later, Corlett had established a weight ratio of 0·36 : 1 as possible(1), using welded structure again. It followed therefore that with improved design it was possible to satisfy strength requirements and make a further saving of about 4 tons of aluminium. At the time of this ship being built it was the first ship of its type to have all welded superstructure, and indeed, the largest all-welded superstructure ever built, and there was, therefore, not a great deal of past experience available.

Corlett's subsequent comments and redesign exceeded the best estimates and saved 6 tons of aluminium (i.e. about £4,280). Because of lack of information about creep and resistance to fatigue, it was felt that the mast houses, derricks, mast, etc., should not be of aluminium, although it is understood that there is no reason why aluminium should not be used. There was little or no previous experience available, however, and it was thought that when working cargo the reversal of the stresses, being rapid, could lead to early fatigue.

The midship superstructure was not a bridge erection within the meaning of the term, and was not, therefore, a strength member although greater than 15 per cent of its length. Nevertheless, it has some influence and if the general arrangement is inspected there is the possibility of notching due to the discontinuity caused by the bridge front being in way of the deep tank extremity. An aluminium superstructure does much to neutralize this possibility in the following way. Young's modulus of elasticity for aluminium is about one-third of that for steel; consequently the stress in aluminium will be about one-third of that for steel. In this particular ship this is especially useful because distribution of stress will cause a much smaller change between steel hull and aluminium superstructure than it would if both were of steel, thus tending to neutralize a notching effect. This was considered important. Whilst it is not proposed to enter into a discussion on the working of aluminium in shipyards, because recognized methods have now been promulgated by the Aluminium Development Association(2), the opportunity is taken to record the extent to which correct procedures are considered vital for corrosion prevention, especially where bimetallic contacts are being worked. In passing, it may be remarked that the methods appear tentative, if not primitive. It seems unavoidably necessary to place very great reliance on substances such as cotton fabric, "Duralac", marine glue, "Holdtight", aluminium spraying, etc., and any one of these small jobs, not well done, can lead to endless trouble.

A serious hindrance to the use of aluminium is in providing against fire protection. Whilst there are no definite rules applicable to cargo ships, the Ministry of Transport has in the past considered it its duty to thoroughly safeguard the crew, whether passenger or cargo. In a ship of the type being discussed, the fact that the ship is oil fired with lifeboats above the midship house (in which personnel are housed), is more than likely to cause the Ministry of Transport to call for complete lining of this house with marinite or a substitute. The Ministry of Transport assesses by fire factor, which is their estimate of the percentage likelihood of fire. The fire factor depends upon the position of the accommodation with respect to the boilers and the inflammability of its contents.

Regarding maintenance, it is claimed that aluminium has the advantage, and is cheaper, but convincing arguments are not readily available. For example, in the case of bimetallic contacts, electrolysis is always ready to begin when moisture is present and it is always present in a ship. Resistance to corrosion, therefore, depends upon the jointing and upon its ability to sustain itself over the ship's lifetime. It is wise, therefore, to make a very thorough specification in respect of such connexions and to ensure their observation. Again, painting of aluminium surfaces requires very careful cleaning with etch primer or spirits. This extra preparation represents extra outlay and frequent painting is necessary in way of bimetallic joints. Similarly, aluminium deck coverings require special properties and it will be necessary to use latex or some such rubber base composition, which is also additional outlay. Repair also needs consideration. As yet, there is no shipbuilding standard aluminium plate or section alloy, and if repair abroad were necessary there is no guarantee that either the material or the means to weld would be available.

The list of applications considered is recorded in Appendix 5.

In engineering, special difficulties arise. Aluminium and copper as well as other non-ferrous metals lend themselves to electrolysis and this has special significance in machinery space where there is invariably a great deal of copper pipe bends, bronze pumps, condenser tubes, etc. In addition, the fluid is usually warm and dense, and offers good prospects of electrolysis. There is a further difficulty of accessibility of pipes and insulation for inspection. This in itself may cause difficulty as, for example, in pipe clips and insulation and joints under floors, in manifolds and in tanks, which are seldom opened. Consideration was given to the use of aluminium in the main feed system but was rejected on the grounds of electrolytic possibilities in what may be termed the very heart of the ship. Regarding boiler casings, this possibility was also examined and rejected on the grounds of high cost. It should also be said that nearly half the cost was due to the necessity of new design, and, furthermore, there was a definite nervousness and unwillingness on the part of the manufacturer to delve into the unknown. The author still believes there are possibilities here. The application to electrical engineering, of course, is not new.

The quantity of aluminium incorporated in this ship is what appeared practical in the light of the then present costs and experience, and which could be justified economically. The interpretation of "economically justifiable" means that the shipowner will receive financial reward as a return for the increased capital cost. The most obvious way of justifying added expense and indeed the most convincing, because of the ease with which it can be expressed in sterling, is the increased earning power due to greater deadweight. It was agreed that any item which paid for itself in ten to twelve years, thereafter adding substantially to income, would be acceptable.

Since increase in deadweight by increasing the size of the ship causes a rise in operating costs, and whereas increasing deadweight through weight saving brings no increase in the operating costs*, then it is possible to pay more per ton gained in this fashion than would be paid for new tonnage. The ship itself cost very approximately £118 sterling per deadweight ton, whereas aluminium was considered attractive in items where tonnage was gained considerably in excess of that figure. Perhaps less obvious is the advantage gained due to maintenance, less replacement during the life of the ship, this, of course, being best estimated and cannot be proved until there is an accumulation of experience. At the time of writing the experience is quite satisfactory, but longer will be required to assess the value of, say, the bilge and ballast piping which will be best done at special survey.

In the economic analysis which preceded decision, an expression was built up to indicate the total cost as follows:—

Total cost $= m + (l + p)$, where

m = cost of the fireproofing material and its associated labour and is a selected constant.

l = cost of shipyard labour and is a constant.

p = cost of aluminium and was made a variable.

Interest was allowed at 4$\frac{3}{4}$ per cent, there being no allowance for tax or depreciation (see Appendix 3).

Aluminium Applications (to be read in conjunction with Appendices 1-10 inclusive)

(a) *Superstructure*

Investigation revealed that the midship house and after deck house, being non-strength deck, could be designed to give very favourable weight saving, but not so the mast houses, and since the masts and derricks were to be in steel for the reasons already given, it was felt wise not to introduce any more aluminium other than the midship house and after deck house.

Appendix 1, columns (c) and (e) should now be studied for a consideration of riveting v. welding; the influence of welding on the economics of the project will be appreciated at a glance. Corlett's saving of 5·8 tons weight (see Appendix 11) used plates calculated to 1/100in., but this weight saving was not paralleled by proportionate saving in cost, since the odd dozen sizes required increased the cost of production. The advisability of such detailed calculation of plate thicknesses has to be considered in each individual case, for in some there will be substantial savings, whereas in others the added cost in design and production will offset any possible advantage to be gained. The welded midship house was 20 per cent lighter and 21 per cent less costly than the riveted equivalent. This aluminium steel ratio of 0·37 : 1 compares very favourably with the weight ratio of 0·55 : 1 as suggested by Lenaghan(4) some 2$\frac{1}{2}$ years later. Corlett's design actually gave stronger structure with less weight and this enhanced profoundly the economy of the project.

Fireproofing in the accommodation when aluminium is used for the structure is controversial. Several schemes were considered (see Appendix 3). Schemes A, B, and C cover the same area but differ in quality and finish, whereas Schemes D and E cover the areas which were required by the Ministry of Transport. The extra costs are self-explanatory and reveal the enormous influence fireproofing has on the economics of an aluminium project. As far as fire resistance is concerned, all schemes would stand up to the required one hour fire test at 1,500 deg. F.

Finally, scheme D was chosen, covering 3,700 square feet of linings and 2,600 square feet of ceilings. Scheme E, however, would have fulfilled the requirements where insulated aluminium replaces bare steel, as in the outside linings and boat deck. Fire of sufficient intensity to break through this scheme of insulation would make positions on a bare steel structure equally untenable. Fireproofing does not penalize the aluminium structure as far as weight is concerned, since it involves substitution of one material for another—hardboard, asbestos for plywood, or sprayed asbestos for fibre glass or other temperature insulation. Fireproofing extends the time of self-liquidation of the structure and therefore necessitates looking for the least expensive material. Appendix 1, column (m), gives an appreciation of the influence of the above factors in the form of cost per ton of deadweight gained.

It is estimated that, in running from Jamaica to Kitimat, this ship would pay for the cost of the aluminium superstructure in about eight years, assuming 8$\frac{1}{2}$ voyages per year, thereafter producing income which, during the life of the ship, estimated at twenty years, would amount to about £35,800 sterling.

The aluminium structures start above the upper deck, where they are riveted to steel coamings extending above the deck. The heights vary, their principal purpose being to place the joint between dissimilar metals high above any place where sea water might collect. The house sides are connected to a coaming 3ft. 6in. above the deck, but the steel has been extended just above the bridge deck on the midship house front. Probably these clearances are somewhat excessive. The sheathed screen is connected about 6ft. above the deck, while minor bulkheads inside the house are riveted to a coaming 6in. higher. All connexions are by a single row of steel rivets. Details of joints between dissimilar metals are given in Figs. 8 and 9.

Both in design and construction, care was exercised to produce a stiff structure, transmitting stresses smoothly from one member to another with a minimum number of stress concentration points. Apart from the funnel, the outside of the superstructure is unpainted and unprotected, and this has saved considerably in paint costs as distinct from the extra weight attaching to the ship as gathers when the ship's superstructure is painted time after time in service. The net annual saving on painting amounts to £1,065, as opposed to an initial extra of £1,750 for buffing and grinding.

(b) Hatch boards and hatch beams
(c) Piping
(d) Lifeboats and davits
(e) Ventilation trunking
(f) Windows
(g) Air sounding pipes
(h) Fire and deck service
(i) Bilge and ballast systems
(j) Fittings and pipe systems
(k) Water systems in accommodation, fresh water, hot and cold, and salt water
(l) Miscellaneous items
(m) Awning stanchions, rafters and guard rails
(n) Refrigeration room flooring
(o) Engine room flooring and walkways

See Appendix 2 for full details of weights, costs, materials and construction methods.

Welding Techniques

(a) *General*

Speed of arc welding is greater than with a gas flame, resulting from the rapid heat generation concentrated over a small area. Both distortion and any tendency to crack are reduced because the area of parent metal affected by the welding heat is smaller. In the welding of aluminium, the natural oxide film hinders consolidation of the metal on fusion, re-

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* The application of aluminium in any particular case definitely depends upon the type of ship and the manner in which the shipowner uses the saving in weight. There are three ways of doing this:—

(1) To increase the deadweight, assuming the extra and necessary cubic space is available.

(2) To increase the metacentric height in cases where this is necessary, as in large liners having considerable superstructures and top weight, and certain classes of warships.

(3) Due to a reduction in displacement, to be able to reduce basic power and fuel, the speed remaining constant.

forming almost instantly in air when broken down. In metal arc welding, carbon arc welding and in gas welding, flux is used for the dispersal of the oxide, but one of the main disadvantages of the use of flux is from the corrosive nature of the flux residues. In addition, careful cleaning is essential after welding. Flux entrapment must be avoided and this is an influencing factor on design. In the inert gas arc shield method the need for flux is eliminated by the use of the inert gas arc shield. This method allows the arc to disperse the film and prevents its forming due to the exclusion of oxygen. Subsequent developments have been the application of consumable aluminium electrodes. Inert gas shielded arc processes have developed quickly in America and have almost been adopted as standard.

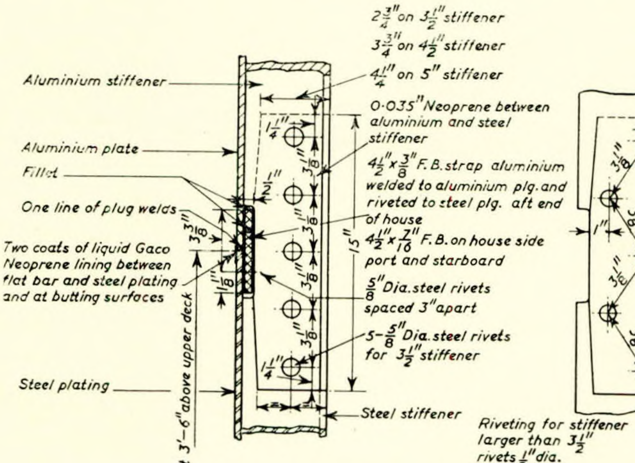
There is a similarity between the metal arc process and the inert gas shielded arc process, the arc being struck between a metal electrode and the work involved, whereas in metal arc welding the use of flux is required for consolidation; this is not the case with the gas shield.

There are two types of inert gas shielded arc welding processes:—

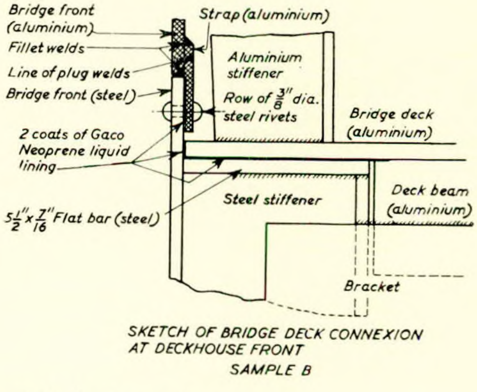
1. Tungsten argon arc (referred to as A.T.A.).
2. Self-adjusting arc or aircomatic (referred to as I.M.A.).

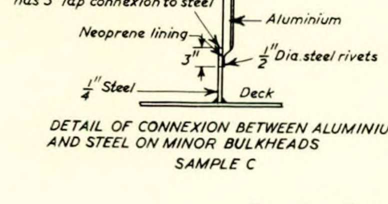
Both types are suited to automatic as well as manual application.

Both types use an inert gas surrounding the arc in the weld pool, the difference between them lying in the type of electrode and type of control. Whereas the A.T.A. uses a non-consumable tungsten electrode, the I.M.A. uses a consumable aluminium or aluminium alloy electrode. Both types were used in this particular ship. In the A.T.A. method, the equipment requires the argon gas cylinder, a source of electricity, control mechanism and the welding torch, which may be air or water cooled (see Fig. 10 for diagrammatic representation). In consumable electrode welding, there are several possibilities, but the use of a filler wire is used in all cases. The American aircomatic system as well as the "Sigma" are known types, whereas in Britain the "Argonaut" and the "Sigma" (the quasi arc and the filler arc types) are other methods. Both helium and argon are available in the U.S.A., helium not equally available in this country. Argon arc has certain advantages over helium, and although requiring greater arc current and greater current density than helium, argon has equal penetrating power as well as an inherent smoothness, allowing higher welding speeds, which results in its greater suitability for the welding of thinner material. Arc length can be controlled by feeding the electrode at constant speed or by controlling the rate of electrode feed by external device, both methods giving a constant arc length during welding. In consumable electrode welding, plates of $\frac{1}{2}$in. can be welded in a single pass using $\frac{1}{8}$in. filler wire at a speed of about 18in. per minute; also 1in. thick plate has been welded at 4in. a minute[*]. Fig. 11 shows a diagrammatic representation of consumable electrode welding; a comparison between this figure and Fig. 10 will explain the differences between the two methods. In the I.M.A. the electrode is a wire, coiled and reeled, fed through a device giving control over feed rate, the



DETAIL OF CONNEXION BETWEEN ALUMINIUM AND STEEL ON DECKHOUSE SIDES AND END
SAMPLE A





DETAIL OF CONNEXION BETWEEN ALUMINIUM AND STEEL ON MINOR BULKHEADS
SAMPLE C

SKETCH OF BRIDGE DECK CONNEXION AT DECKHOUSE FRONT
SAMPLE B

FIG. 8—*Connexion of dissimilar metals*

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[*] Whilst argon arc is available as a shielded arc welding process, aircomatic has the following advantages:—

(i) It is quicker in the proportion of 3·3:1.
(ii) It gives greater test elongation—1·07:1.
(iii) It is cheaper in the ratio of 2·86:1.
(iv) Simpler, more efficient, and does not require cooling.
(v) It was available in the shipyard in question.
(vi) Experienced welders with this equipment were also available.

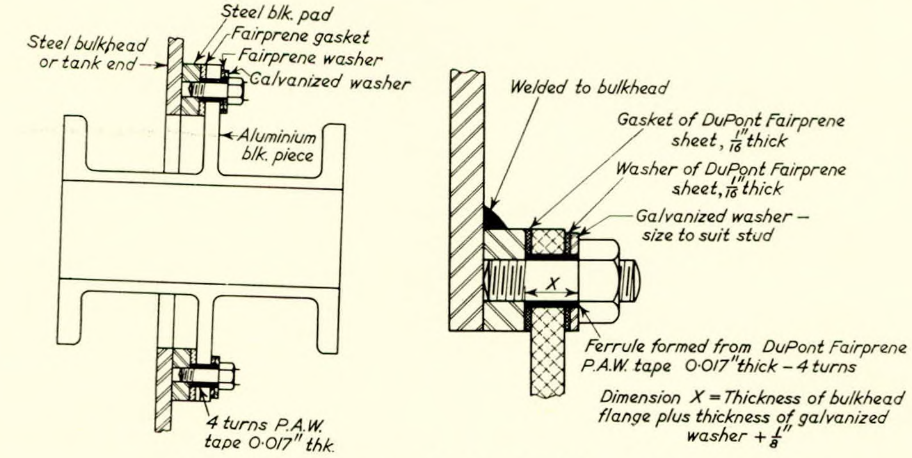


FIG. 9—*Isolation materials for aluminium bulkhead pieces*

Gaskets are cut to suit flange dimensions shown on D.S. and R. Standard Sheet—"B5" aluminium bulkhead.
"Fairprene" washers are cut to suit stud dimensions plus ⅛ inch; galvanized washers similarly.
P.A.W. tape is fitted after studs are screwed into bulkhead pad and extends from face of pad to face of nut when nut is tight.
"Fairprene" to be of 65 Durometer hardness.

wire passing through the conduit which conducts argon gas to the welding gun with trigger operating both gas and electric controls. D.C. reverse polarity, with the electrode positive, maintains the arc, and metal transfer across the a.c. is by means of a fine spray. The high current density and the small diameter filler wire causes a very powerful magnetic field, and this directional field also causes the ultra-fine droplets in the spray to be transferred in the same line as the wire over appreciable distances. Therefore the arc is smooth and steady and the metal can be transferred even vertically upwards which, of course, is an enormous advantage, and this allows the torch to be used for vertical or overhead welding.

Turning now from the more theoretical to the practical aspect, in this ship both A.T.A. and I.M.A. methods were used. 33S and A.T.A. equipment were used to weld 61S flanges to 1S and 57S piping, established procedures being followed in accordance with Figs. 8, 9, 10, 11 and 12.

Most of the welding involved alloys of high magnesium content such as B.54 S, A56 S and some 57S, the welding being done with 56S wire or rod and with both I.M.A. and A.T.A. I.M.A. was preferred except where the welding gun could not be manœuvred properly, but the A.T.A. was often used when the pressure of work load could not be carried by the I.M.A. machines available.

Almost all welds were made continuous, some exceptions being the attachment of internal stiffeners in the hatch boards, and of beams to weather deck heads in parts of the superstructure. Welds were designed and completed so that at no time could a weld start or finish where stress might concentrate. Fig. 12 shows a few details of the design of brackets, emphasizing the placing of the weld fillet near the neutral axis of sections wherever possible. Butt welds in plates were made mostly without backing but difficulty was encountered in maintaining the proper fit up between the plates and it became necessary to use A.T.A. equipment for the first pass in many cases. Fillet welds of stiffeners to plate were all made with I.M.A. equipment and do not cross butt welds in the plates (Fig. 13).

The pillars between decks were fabricated from two angles with or without face bars, depending upon their location, I.M.A. equipment being used. (Design details shown in Fig. 12.) The butt welding of plates in the shops introduced some distortion and this increased considerably upon the addition of stiffeners. When prefabricated sections were placed together on board, fitting was difficult and jacks had to be used, and these were butt welded without packing and the jacks removed. On cutting holes for windows and doors, the distortion became much more evident, and it was corrected by torch shrinking whereby the surfaces were heated and quenched by being held up against a strong back. To avoid overheating the plates, "Tempilstiks" were used. It may well be argued that the appearance of the strong backs suggested a great deal of extra work. This is undoubtedly true, but there is no point in indulging in a paper of this nature without explaining the difficulties that were combated.

High current density seemed most effective in welding the high magnesium content alloys. The use of high welding currents places an added burden on the operator since he has to

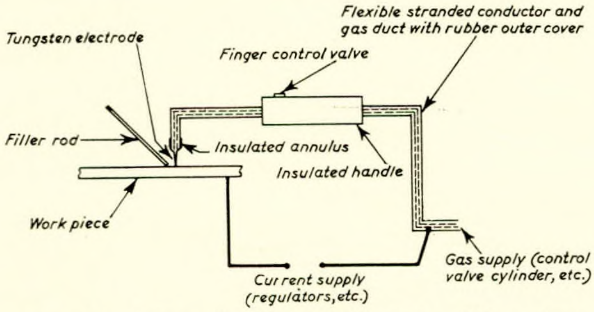


FIG. 10—*Schematic diagram of ATA welding plant*

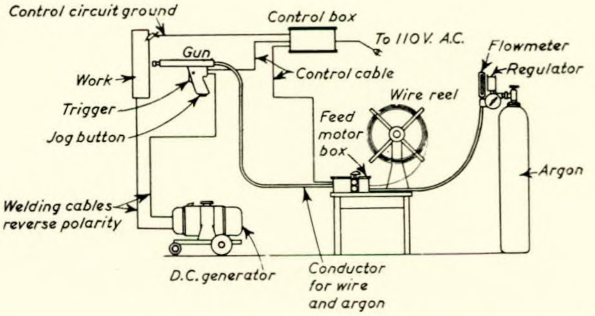


FIG. 11—*Schematic diagram of consumable electrode welding plant*

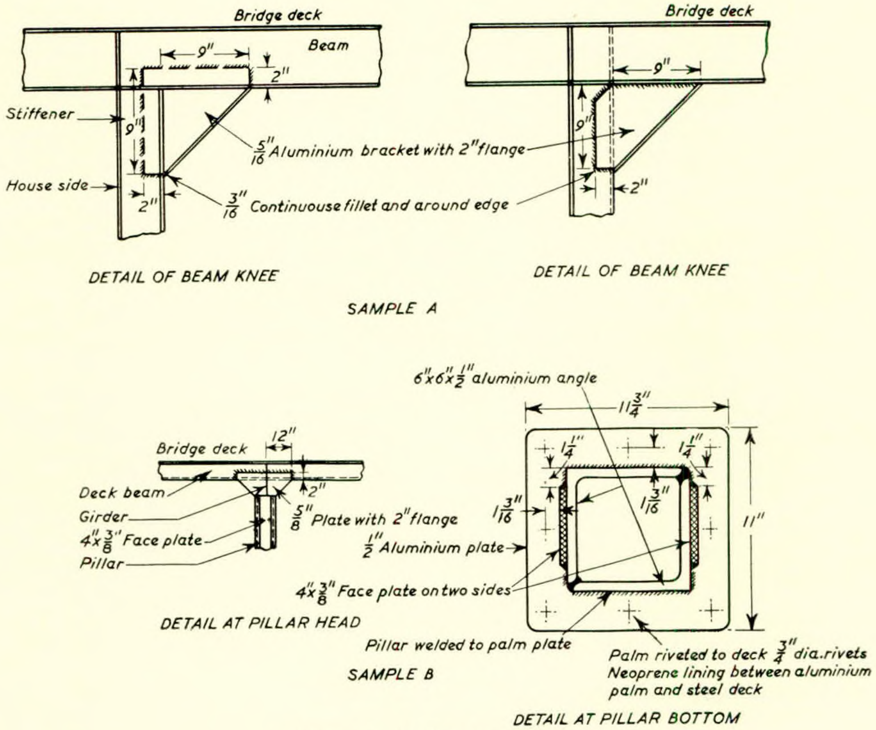


FIG. 12—*Welded connexions*

go faster and control becomes more difficult unless the wire size is decreased, which makes welding more expensive. Use of the highest possible current and welding speed minimizes the distortion otherwise introduced when heat is supplied too slowly; the slower the heat is supplied, the more emphasis must be placed on the sequence of welding. It should be noted that clamping arrangements or jigs to hold such expanse of plates as were welded are not readily available, most welding being done with the plates loose and just tacked prior to the final weld run. The improper placing of tacks may produce distortion on subsequent welding. It is believed that mechanization of butt and fillet welding would be most helpful. A word of warning here: when A.T.A. equipment is used, great care should be taken in following a proper welding sequence.

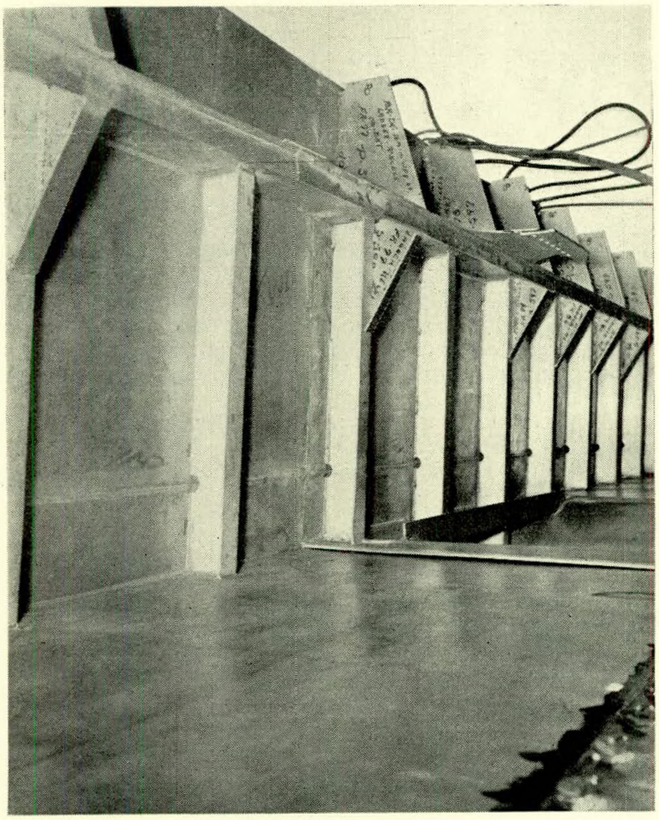


FIG. 13—*Showing fillet welds of stiffeners to plate with IMA equipment without crossing butt welds in the plates*

The positioning of plates to provide the proper gap is very important. The fitting of prefabricated sections on board is difficult and much effort was put into trying to obtain uniform fit; therefore in joints between fabricated sections that have to be made on board it might be better to design away from plate butts. Any effort spent in good welding is worth while since the straightening of the plate is extremely expensive and introduces a problem in subsequent finishing if the surfaces are to remain unpainted. A minor point was the welding of $\frac{5}{8}$-in. studs, which had to be done with A.T.A. equipment since no stud gun was found that could consistently produce good stud welds in the size used.

Fitting-out Details

(a) *Connexion Between Dissimilar Metals*

This extremely important part of the project requires careful but simple design to avoid galvanic corrosion. It is normally achieved by isolating the metals one from the other, or by painting the outside surfaces of the connexions to exclude moisture, and in some cases both methods are used. In this particular case, all joints between dissimilar metals have been isolated and in addition the outside surfaces of joints in the superstructure have been painted. The insulating compounds used are synthetic rubber in liquid form such as "Gaconeoprene" and other brand names, and in sheet form such as "Fairprene" sheet, and "Fairprene" PAW tape. There is no conclusive evidence of the relative advantages of liquid or paste type insulation versus sheet or tape types, and the choice is one of convenience and availability. All rivets used in the superstructure connexions are hot driven steel for two reasons: —

(a) The steel coaming is on the weather side of the joint.
(b) The area ratio of rivet to plate is then less favourable for galvanic corrosion.

Contact between the steel rivet head and aluminium plate occurs on the inside of the house, where corrosive conditions are less severe, and where there is less chance of salt water spray lodging under the rivet head.

The design used for the connexion of houses to deck coaming is due to the desire to have a flush butt joint, as it was felt that the use of joggled plates would leave too large a gap at the joints which would be unsightly and hard to isolate, the aluminium being on the inside; the actual connexion has the aluminium on steel plates butted with a minimum gap between them (Fig. 8). An aluminium strap, ⅜-in. thick by 4½-in. wide, bridges the gap on the inside of the house. This strap is welded to aluminium side plates to two fillet welds, one along the top of the strap and one along the bottom of the side plate; the fillet was ground down to permit a narrower gap at the butt and to make up for the decreased size of the fillet. A line of plug welds was added. Connexion to the steel is by ⅝-in. diameter steel rivets with hot driven 3-in. centres. The faying surface of the aluminium strap received two coats of zinc chromate primer and two coats of "Gaconeoprene" paste were brushed on before completing the connexion. The finished connexion was painted on the weather side by two coats of zinc chromate primer and one coat of aluminium paint, whereas on the outside of the house the connexions received two coats of zinc chromate only. Stiffeners on side plates are lapped 15in. and riveted by ⅝-in. diameter hot driven rivets (see Fig. 8).

The details of insulation are similar except that the design calls for 0·035-in. "Fairprene" sheet rather than paste. It may be noted that stiffeners are not exposed to the weather and the joints received two coats of zinc chromate only. The connexion between the house side to the upper deck coaming is 3/6-in. above the upper deck, except that of the midship house front, where the connexion is above the bridge deck. This introduces a slight variation in design (Figs. 8 and 14).

Another case is at the sheathed screen, which protects the open deck around the house. This joint is similar to that on the house sides except that the connexion is just below the bridge deck. Both faces of the screen are exposed to the weather and therefore both received painting. (See Fig. 15.)

The details of the connexion of minor bulkheads to steel coaming on upper decks is seen in Fig. 8.

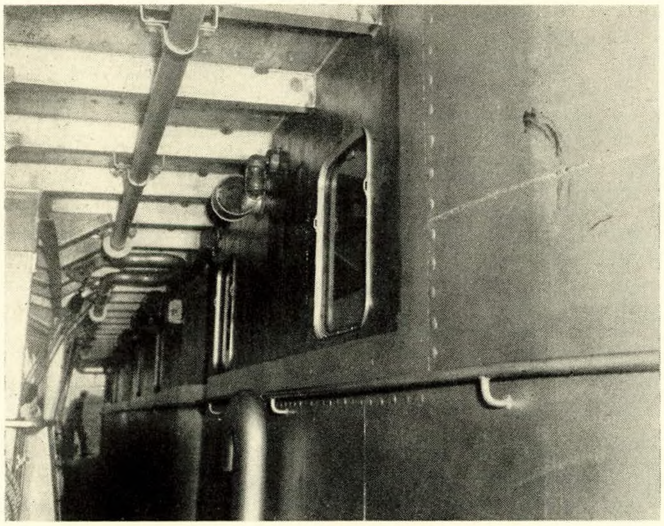


FIG. 14—*Connexion of house to deck. The house sides are connected to a coaming 3ft. 6in. above the deck*

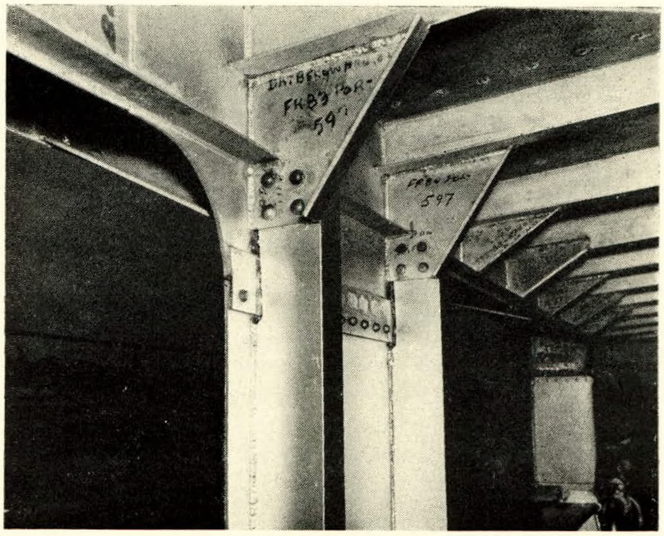


FIG. 15—*Riveted beam knee connexions*

Great attention was paid to perfect isolation in the bilge and ballast systems, and the connexions of pipes and brackets of different materials has already been described. Other connexions used and described were engine guard rail stanchions and the walkway gratings, there being many others such as cables and cable trays attached to the aluminium, etc. It was considered at the outset that long life in joints of dissimilar metals, leading to complete success or otherwise of the whole installation, depended upon much effort going into the simple yet important details, and this effort and supervision, and indeed subsequent inspection, were maintained throughout.

(b) *Finishing of Aluminium Surfaces*

Most aluminium exposed to the weather has been left unpainted, this being the company's policy. The only maintenance expected is washing of the surface with a soap solution and some special bristle brooms. Not everyone likes an unpainted superstructure and there are those who attach a great deal of importance to appearance. In these cases efficient systems of covering and painting are available which cost less than the lead paint required for the preservation of steel. Finishing of the superstructures was by scratch brushing, using rotary brushes on electric and air powered tools, the bristles being crimpled stainless steel 0·005in. in diameter.

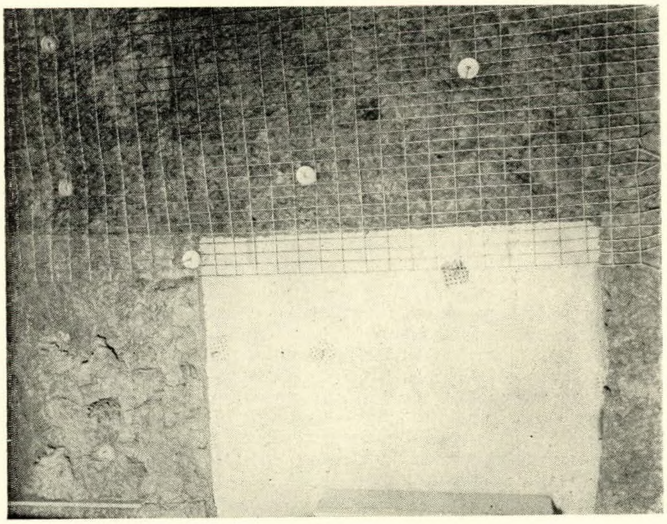


FIG. 16—*Method of hanging "Spintex" insulation*

Aluminium decks exposed to the weather were covered by 2½-in. fir planking, planks being held by threaded studs welded to the deck, holding nuts being covered by dowels. Studs and nuts were packed with zinc chromate paste. Aluminium decking was first painted with one coat of zinc chromate primer and then with one coat of waterproofing compound, "Camrex" No. 52, which was applied hot. Cracks between planks were caulked in the usual manner with an asphaltic compound.

Inside surfaces of the aluminium houses were coated with two coats of zinc chromate primer. As only condensation was expected on these surfaces and as they are not normally accessible, being covered by permanent insulation lining, it was considered that two coats of primer would stand in good stead. Decks inside the house were not primed. All deck area in the living quarters was covered by linoleum composition of the "korkoid" type but, before laying this floor covering, the aluminium received a layer of rubber latex which was applied as an emulsion with a slight etching effect on the deck before adhering to it. Bathrooms, showers and toilets had tile or terrazo floorings laid or poured over ¼-in. layers of rubberized paste. A special application was in the battery room, where the deck was etched with a solution of trisodium phosphate and then an acid proof floor was poured. This particular type of flooring is chlorinated rubber with a setting resin, and a filler grout which sets on the deck, adhering to it and forming a flexible waterproof and acid resistance covering. Fig. 16 shows the method used to hang the 2-in. "Spintex" insulation. "Spintex" B×4 is a mineral wool insulation.

ELECTRICAL

A.C. v. D.C.

Clearly, many factors influence the choice between a.c. and d.c. Generalizations are misleading and the correct selection can only be made after a careful analysis of all factors for the type of vessel and the service for which it is intended. The main inherent advantages and disadvantages are recorded below on which the decisions were based:—

TABLE I.—ADVANTAGES AND DISADVANTAGES OF A.C. AND D.C.

(a)—ALTERNATING CURRENT

Advantages	Disadvantages
Allows employment of the squirrel cage motor, with its inherent rugged, simple trouble free qualities.	A.C. generators are not self-exciting and it is necessary to provide a d.c. exciter.
Availability of various voltages by means of suitable transformers. Transforming to higher or lower voltages is accomplished at very high efficiency.	It is necessary to provide each generator with a voltage regulator because of the poor inherent voltage regulation.
Components and ancillary equipment such as generators, switchboards, cables, controllers and motors are smaller, lighter and cheaper.	Speed control of motors is complicated and expensive. The squirrel cage motor can give a maximum of four fixed speeds by regrouping of windings. Wound rotor, or slip ring induction motors, can give exact variable speed, but again the controls are expensive and complicated. At reduced speeds, the efficiency is low because of resistor power losses. In addition, the speed load characteristics are not always desirable.
Greater selectivity under fault conditions because of inherent short circuit (current v. time) characteristics of the synchronous generator and because there is no commutator employed. This allows higher instantaneous trip settings of the generator current circuit breaker; in the d.c. machine the instantaneous trip element has to be set to protect the machine against flashover.	Switchboards are more complicated because of the need of additional instruments such as frequency meters, synchroscopes, synchronizing lamps, power factor meters, speed control switches, current and potention transformers, etc.

(b)—DIRECT CURRENT

Advantages	Disadvantages
Speed variation is readily obtainable for any drive.	Motors and generators are mechanically more complex.
Starting of large motors presents no trouble because of the automatic limiting of the starting current by the control equipment.	Motors and generators are large, heavier, more expensive and need more maintenance.
Simplicity of switchboards.	Where voltage other than generated voltage is required, additional generators must be installed.
Generators are usually self-excited and voltage regulators are not required.	Systems are limited in size because of relatively low voltage levels and resulting high currents.
	Switchboards of comparable ratings are more expensive.
	Cable installations are heavier and more expensive, i.e. 240 volts d.c. versus 450 volts a.c.
	Motor controllers for comparable horsepowers and speeds are larger, heavier, more expensive and complicated.

Tabulated Comparisons

Two actual comparisons are given below, Table II being a ratio comparison for the normal cargo and passenger vessel being discussed, and Table III an actual price and weight comparison for a similar vessel using two 500-kW generators, with switchboard and normal motors and controllers. The prices are American in each case.

Further Comparisons

(a) Although figures are not available, a comparison of distribution wiring costs favours a.c. considerably, including the cost of the step-down transformers.

(b) Cable losses in a.c. are slightly higher due to operation at higher current, making allowance for an average 0·8 power factor. The d.c. system, of course, operates in effect at unity power factor.

(c) The a.c. system also has to face transformer losses, small as they may be.

TABLE II—A.C. AND D.C.: AUXILIARY POWER SYSTEMS COMPARED (COST AND WEIGHT SAVINGS)

Equipment	Initial cost			Weight		
	D.C.	A.C.	Saving per cent	D.C.	A.C.	Saving, per cent
Motors and controls	100	53	47	100	60	40
Turbo-generator sets	100	88	12	100	94	6
Switchboards	100	86	14	100	88	12
Total for all equipment	100	77	23	100	75	25

TABLE III—PRICE AND WEIGHT COMPARISON

Equipment	Weight, lb.				Price, £			
Generators (500 kW drip-proof)								
Two A.C. generators with exciters and voltage regulators	15,000				7,150			
Two d.c. shunt wound generators with exciters and voltage regulators	27,000				13,610			
Two d.c. compound wound generators (less exciters and generators)	26,000				9,950			
Switchboard								
Consisting of two generator sections, a synchronizing section of a.c. only, a shore power connexion and a distribution section containing two back-up feeders and twelve feeder breakers								
Two a.c. generators with exciters and voltage regulators	5,940				3,100			
Two d.c. shunt wound generators with exciters and voltage regulators	7,950				4,075			
Two d.c. compound wound generators (less exciters and generators)	7,950				4,075			
Motor Controllers (Constant speed, non-reversing, drip-proof, local push button u.v. protection)	A.C.		D.C.		A.C.		D.C.	
7½ h.p.	40		65		62		114	
15 h.p.	80		165		88		163	
A.C. 440v. across the line 30 h.p.	120		180		116		221	
D.C. 230v. 60 h.p.	150		375		186		375	
Motors (Constant speed, drip-proof horizontal, ball bearing)	A.C.		D.C.		A.C.		D.C.	
	Type 1*	Type 2*	Shunt	Com-pound	Type 1	Type 2	Shunt	Com-pound
7½ h.p.	192	192	285	285	57	59	193	199
A.C. 440v. 1,800 r.p.m. 15 h.p.	288	288	415	415	83	86	253	259
D.C. 230v. 1,750 r.p.m. 30 h.p.	430	430	715	715	143	152	361	367
60 h.p.	875	875	1,120	1,120	257	292	558	575
100 h.p.	1,285	1,285	2,040	2,040	393	438	830	850
Motors (Same as above, except for two speed operation and controllers	Variable torque motors		Controllers		Variable torque motors		Controllers	
7½/1·9 h.p.	192		85		62		142	
15/3·7 h.p.	288		120		98		117	
30/7·5 h.p.	620		190		175		218	
60/15 h.p.	1,010		220		290		309	
100/25 h.p.	1,425		220		425		309	

* Type 1 refers to the squirrel cage, normal starting torque, low slip induction motor for driving equipment such as fans, saws, lathes, centrifugal pumps, centrifugal compressors, etc., which impose a normal starting torque.

Type 2 refers to the squirrel cage, high starting torque, low slip induction motor for driving equipment such as reciprocating pumps, reciprocating compressors, loaded conveyors, etc., which impose a high breakaway starting load.

(d) An evaluation of maintenance costs would enhance the a.c. prospect because there are no commutators or brushes in the main power circuit.

(e) Some comments on operating efficiencies are necessary; a.c. generators, because of the elimination of brush friction and because of reduced windage losses, are about 2 per cent more efficient than d.c.

(f) Overall, the a.c. system will be about 2-3 per cent less efficient than d.c.

(g) Clearly, the advantages lie with an a.c. system, except in respect of one important application—winches, where speed adjustment is the outstanding advantage of the d.c. motor. Certain other variable speed applications are also necessary, e.g. forced draught fans, fuel oil service pumps, main condenser circulating refrigerator compressors and all deck machinery. Normal two-speed motors can take care of this, with, say, four-speed for forced draught and fuel oil service. In the case of cargo winches and windlass, unless an expensive Ward Leonard type of control is fitted, the variable speed characteristic of d.c. gains favour.

The Choice

To summarize, the following may be said:—

First cost. An a.c. system will cost less than the corresponding d.c. system by about 23 per cent.

Maintenance. An a.c. system will cost considerably less in maintenance.

Weight. The a.c. system will weigh less by about 25 per cent.

Efficiencies. There is little to choose as regards efficiency, but d.c. has perhaps a 2 per cent advantage.

A combined system was therefore chosen, i.e. a.c. throughout, but with MG conversion to provide d.c. for deck machinery. The cost of the MG sets robbed some price gains, but in spite of this, and including a comprehensive group control system, there was still a saving of approximately £5,720.

The system chosen was a.c., 60 cycles, single- or three-phase, as required, the distribution voltages being:—

(i) 450-volt three-phase for general power.
(ii) 230-volt three-phase for galley and laundries.
(iii) 230-volt d.c. for cargo winches.
(iv) 117-volt a.c. one- or three-phase for lighting, fractional h.p. motors, internal common systems and minor power requirements.

The generating plant consisted of two 250-kW turbo-driven generators with one 180-kW Diesel, all three being capable of independent and parallel operation. Two 160-kW 230-volt d.c. compound wound MG sets were fitted, also capable of running in parallel.

Two centralized or group control boards were fitted for the protection and control of auxiliaries. They were of the dead front type with each controller in an individual compartment with stop and start push buttons mounted adjacent to the pumps and in the control board. Group control unquestionably makes more room available and adds to appearance and general efficiency. Naturally, load was well balanced between the two in case of damage to one. An emergency 25-kW Diesel generator was positioned at boat deck level for essential lighting and power distribution. This emergency arrangement of generator, fuel and battery starting is clearly integral and independent. Examination of the one line wiring diagram shows that the emergency switchboard is normally energized by the main switchboard, the former being connected to all essential services. A failure of voltage from the main busbars is followered by automatic starting of the emergency generator. In the choice of units, very careful and special attention was paid to the following:—

(i) Maximum use of full voltage line starting.
(ii) Avoidance of overmotoring.

Squirrel cage motors are designed for full voltage line starting for normal marine auxiliary duty. In all respects of cost, weight, space and maintenance, they are advantageous. The difficulty lies in the starting current required being about six times the rated full load current. Line starting was limited to motors (or groups which start simultaneously) to 12 per cent of the kW rating of the individual 250-kW generators. Another point is that a.c. motors operate inherently at low power factor, which accounts for line currents not decreasing directly with the load. Hence, in a.c. systems, overmotoring causes waste of cable and generator capacity as well as unnecessary high first cost of the motor. "Pyrotenax Mineral" insulated cable was used for the wiring of the power system (some lighting was of the fluorescent type).

Lighting at 117 volts is safe and since the transformers are air cooled and non-rotating, location is by choice—obviously near the load they serve with further saving in respect of long wiring runs. As a prudent measure, each bank of transformers was connected in closed delta which permits the supply of 58 per cent of the load, even when one transformer has been damaged and/or cut out.

A useful arrangement was the inclusion of a low power room at 'tween deck level; this being near the centre of gravity of the ship it was a good place for the master gyro also. In this low power room, certain low power control panels were grouped, including the gyro, radar, battery charging panel, echo sounder, IC panel, SRE equipment. Often this equipment is scattered; their grouping together seems useful, tidy and simplifies maintenance.

MACHINERY

Choice of Steam Turbine (Figs. 17, 18 and 19)

It was said earlier that the final selection of machinery might well be a question of arbitrary choice, both Diesel and turbine machinery having advantages and disadvantages.

Steam turbine machinery was chosen for the following reasons:—

(a) Lower maintenance costs.
(b) Difficulty of Diesel maintenance at places like Kitimat and Kingston, Jamaica, the vessel's regular run.
(c) Less weight, hence more cargo and better economic position to face canal dues.
(d) Availability of cheap heavy low grade fuel at San Pedro.

The naval architect's tentative selections of form, dimensions and characteristics indicated a need of 5,000 s.h.p. to give 13½ knots. By comparison with previous designs, revolutions and propeller diameter were fixed. Some slight modifications to the form were required as a result of the subsequent Washington Tank Test.

Interruptions in service could not be tolerated, and as this dwarfed other considerations it led to the choice of the

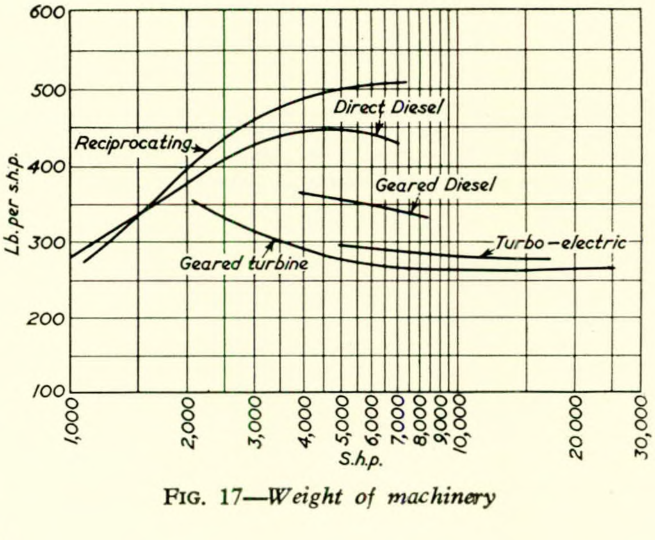


FIG. 17—*Weight of machinery*

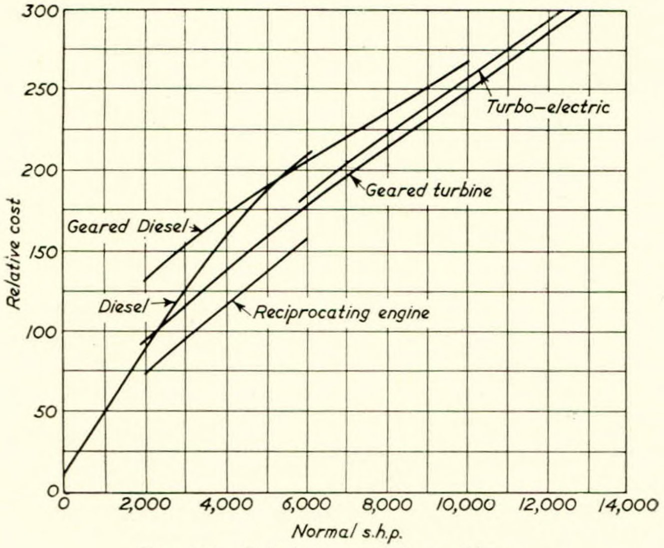


FIG. 18—*Relative costs of machinery*

established steam conditions of 470lb. per sq. in. gauge and 760 deg. F. at the superheater outlet and a back pressure at the turbine exhaust flange of 1½-in. Hg abs. These conditions are not advanced within the meaning of the term but were dictated quite clearly on the choice of personnel available. The two-cylinder turbine chosen was expected to have a water rate (non-bleeding) not greater than 6·93lb. per s.h.p.

The Steam Cycle

Fig. 20 indicates the steam flow diagram and heat balance for the normal sea conditions of 5,000 s.h.p.

Steam is generated at 470lb. per sq. in. gauge and 760 deg. F. by the single-pass boiler and flows to the geared turbine. When developing 5,000 s.h.p. the single shaft rotates at 115 r.p.m. There are two bleed conditions in the h.p. casing supplying steam to the third stage heater, the deærator, the first-stage heater and finally, the evaporator after throttling. The l.p. turbine exhausts at 28·5-in. Hg whence the condensate passes through the condenser extraction pump, and in turn to the air ejector and gland exhaust condenser. The condensate then passes through the salt water evaporator condenser and then in turn through the drain cooler, first-stage feed heater and the deærator, before being taken by the main feed pump and delivered to the boiler drum via the third-stage feed heater.

Main steam also serves the turbo-generators at the condition of 470-760 deg. F., whence it exhausts to its own underslung condenser in each case at 28-in. Hg. The auxiliary condensate does not pass through the auxiliary air ejector, but is led via the auxiliary condensate pump to the gland exhaust condenser and air ejector. A small amount of live steam is desuperheated in the boiler drum and, after throttling, is used for main and auxiliary air ejector, the gland exhaust condenser and air ejector, the whistle, and in harbour the l.p. steam generator (when required).

The l.p. steam generator is supplied with first-position bled steam, which steam exhausts to the deærator. Contaminated steam and drains are kept clear in this way of the main feed system and hence fouling of boiler tubes is eliminated. The drain collecting tank in the main system keeps to a minimum fresh water loss.

Reverting to the l.p. steam generator, this supplies steam to the heating coils and the accommodation services, which return to the generator via the observation drain tank and the l.p. feed pump.

Description of Machinery

The machinery as such is not advanced, and therefore only certain features are described.

(a) *The Feed System*

Unless the system is fully closed, oxygen in the air will dissolve in the water and the resulting corrosive solution will be taken into the boiler. An order for a sister ship had also been placed in this country and a very strong feeling favoured the application of the standard closed feed system with regenerative condenser, but no deærator.

Now a condenser, even of the regenerative type, whilst removing free air mixed with steam at its particular partial pressure, will not remove dissolved oxygen. There is also usually associated a small percentage of carbon dioxide which is more soluble than either oxygen or nitrogen. The carbon dioxide will combine with water to form carbonic acid, thereby rendering the feed water corrosive in the presence of dissolved oxygen. Feed water, with a particular air content, will become more corrosive with increase of temperature, the convertibility of iron into rust being directly proportional to the quantity of oxygen in the feed water (dissolved or free). The aim, therefore, should be to create conditions rendering oxygen and carbon dioxide insoluble in water and then to remove the gas. Fortunately, the properties of saturated steam are such that the solubility of oxygen in water, exposed to air saturated with water vapour, is nil at the condition of ebullition.

The creation of these conditions and the removal of the gas are very adequately executed by a deærator of the direct contact type (Fig. 21), which first boils the feed creating the insolubility conditions required and then "scrubs" it with a jet of auxiliary steam, thereby removing the gas. If in various sections of the feed system pressures range from condenser pressure to slightly above full boiler pressure, there is a choice of pressures at which to operate a deærator. If the operating pressure is, say 14lb. per sq. in gauge, then the feed will be heated to about 248 deg. F., which is very well on the way to the desired optimum final feed temperature.

In some cases (such as this) it is conceivable that the in-

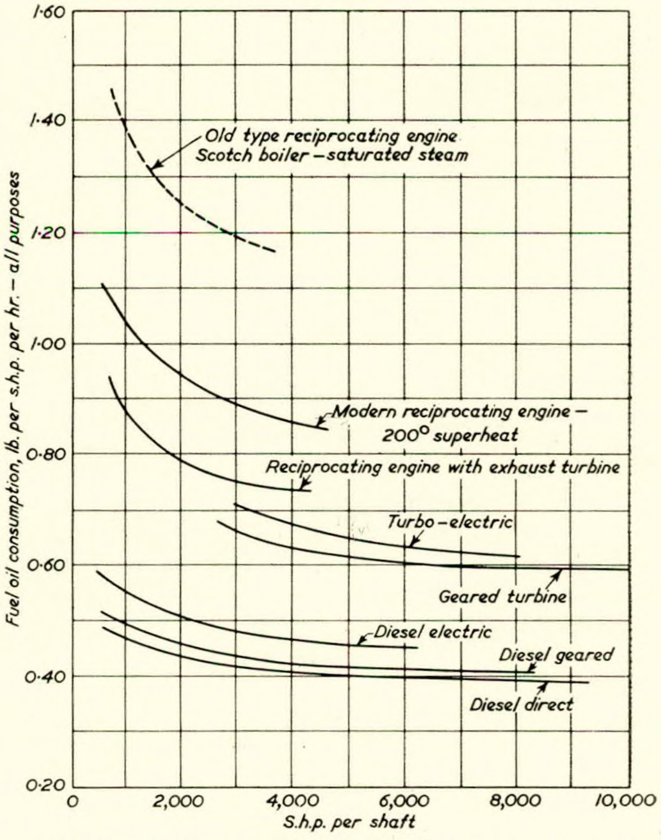


FIG. 19—*Fuel consumption curves for various types of machinery*

clusion of the deærator may absolve the necessity of an l.p. heater, the final feed temperature being achieved by the l.p. heater and the gland steam condenser. The use of the deærator as opposed to a surface tube heater will give an efficiency of, say, 1 : 0·7, but even if it is still necessary to have both an h.p. and an l.p. heater, the deærator is justified on account of its accomplishment of almost complete and absolute deæration. Deæration of feed water is still a problem but the use of a direct contact deærator in the pressure closed feed system solves that problem within practical and economic limits, which applies to operation both at sea and in harbour. Of course, the design of the regenerative condenser aims at vacuum temperature being maintained and does so within a few degrees. Test figures show condensate to be delivered with an oxygen content of not more than 0·02 c.c. per litre but there is no guarantee of this performance. The deærator tank guarantees performance to less than 0·01 c.c. per litre. It may be argued that this is a small improvement in performance only, so why go to the trouble of a deærator to achieve this little extra. The author ventures to suggest that the treatment of boiler water today is practically a science, and to say the least, a troublesome and worrying necessity. Corrosive activity will commence at an oxygen content of about 0·05 c.c. per litre and it is obviously well worth preventing from the start, even in the greatest detail. (B.S.S. 1170/47 requires not more than 0·02 to 0·05 c.c. per litre depending upon boiler operating conditions.)

To recapitulate, the following has been achieved by the inclusion of the deærator:—

(i) Complete deæration of the feed water in the lower part of the deærator to a guaranteed figure of less than 0·01 c.c. per litre.

(ii) A reserve of feed, heated and deærated, has been provided to meet varying load conditions.

(iii) The deærator has been used as a feed tank and first-stage heater. Is it necessary to have a feed tank? Why not let it take the form of a heater and deærator all in one?

(iv) The feed has been heated to about 245 deg. F., assuming 12lb. per sq. in gauge pressure.

Deærator Operating Characteristics (Fig. 21)

The inlet water enters the deærator through the inlet nozzle (A) and flows directly to the water inlet manifold (B). From there it passes through a necessary number of spring-loaded spray valves. The water passing through these valves forms into conical sheets, or streams, and finally into fine particles in direct contact with saturated steam and is heated to approximately steam temperature.

Because of the efficient heating and counterflow relationship of water and steam in this chamber, all but a small amount of oxygen and other dissolved gases are liberated from the feedwater. The water spray surface is partially enclosed by suitable air cooler baffles to maintain a strict counterflow relationship between the water and heating steam and to provide a cooling zone for sub-cooling the released gases prior to their being vented from the deærator.

The spray is directed into the water collecting cone (C) where further heating takes place because of the temperature gradient between the steam chest (D) and the collecting surface of the water collecting cone.

The water, in the water collecting cone, drains through a water downtake pipe (E) to the entrance of the deærating element (F) whence it is drawn up into the steam scrubbing

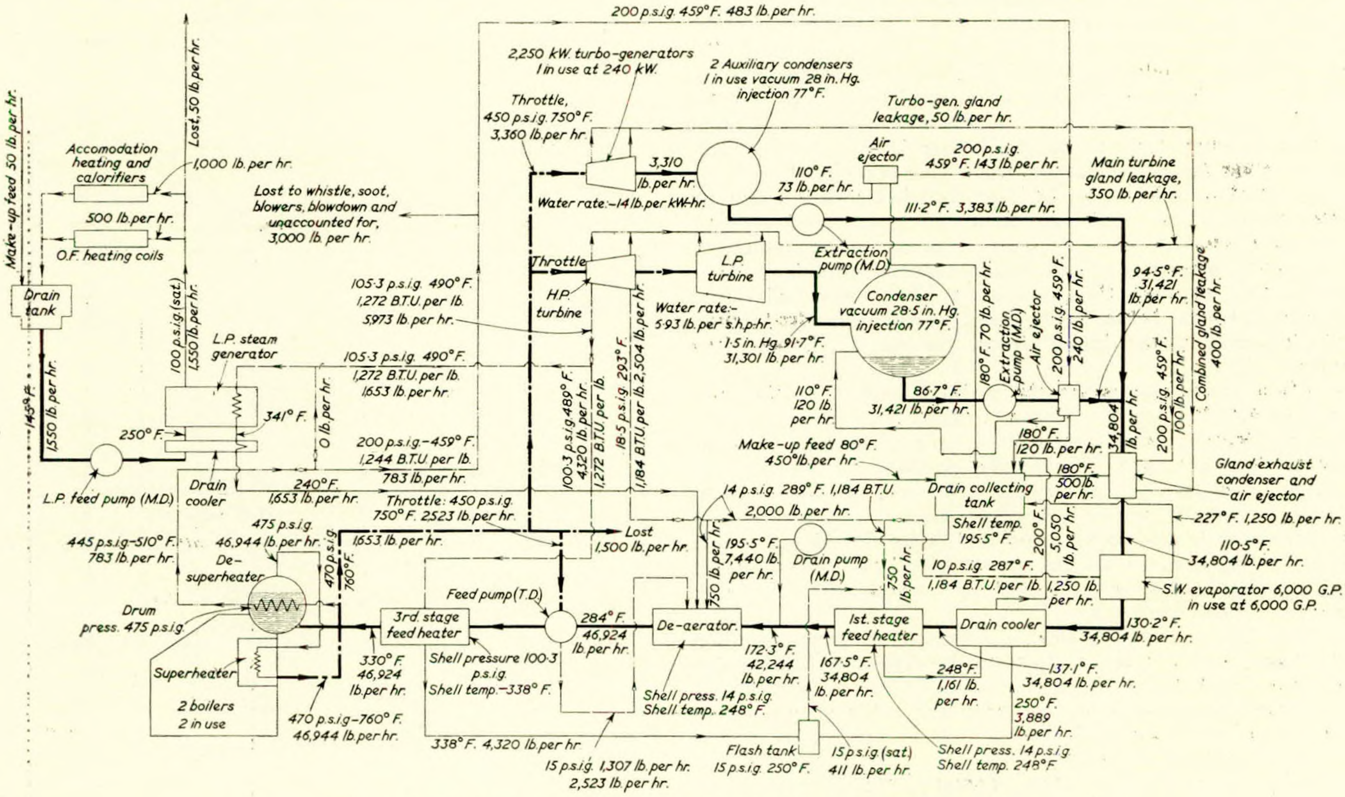


FIG. 20—*Steam flow diagram and heat balance: normal power*

Feed and condensate ━━━━━━━━
Superheated steam ━━━ ·· ━━━ ·· ━━━
Bleeder and exhaust steam - - - - - - - -
Desuperheated steam —— · · —— · · ——
Saturated steam (l.p. line) — — — — — —
Exhaust steam (l.p. line) —— - —— - ——
Gland leak-off · · · —— · · · ——
Drains ————————

T.D. = turbine driven; *M.D.* = motor driven

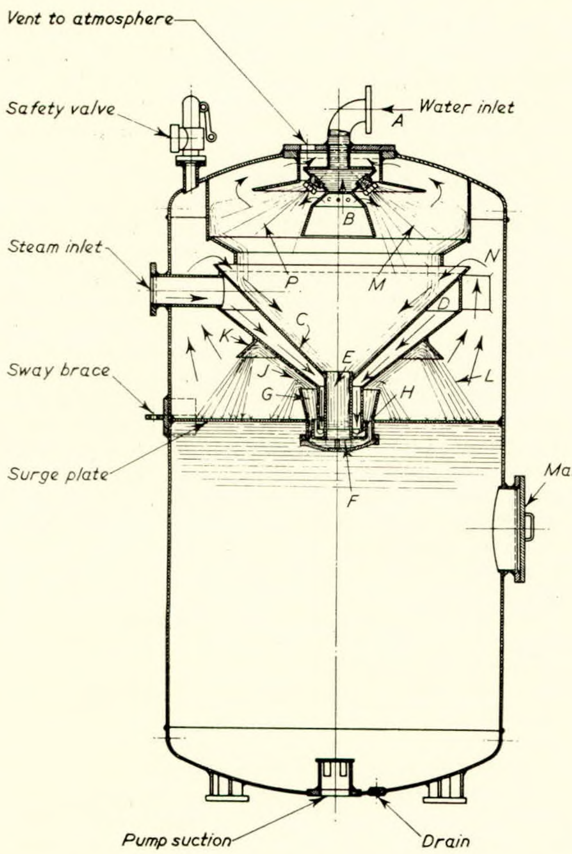


FIG. 21—*Diagrammatic sketch showing operating principles of deærating feed water heater*

and mixing passage (G) within the element by the eductor action of the steam, leaving the annular steam discharge (H). The high velocity steam water mixture is jetted from the deærating element through an annular opening (J) and impinges on the deærator impingement baffle (K). Here the spray is deflected downwards into the deærated water storage section of the deærator.

A very small amount of the total steam required for heating the feedwater is condensed at saturated steam temperature. This thermal relationship allows virtually the full amount of heating steam to transmit its velocity energy to the water, break it into minute particles and extract, absorb and carry away the last traces of dissolved oxygen and other non-condensable gases.

As the steam water mixtures leaves the throat of the deærating element its velocity is reduced and its pressure and temperature increased. As this mixture leaves the deærating element through the annular steam discharge opening, it enters a zone of lower pressure where flashing occurs which further agitates the water particles and assists in gas water separation prior to impingement on the deærator impingement baffle.

The steam, in order to enter the primary heating chamber, must break through the water spray (L) leaving the deærator impingement baffle and in so doing carries liberated non-condensable gases along with it and prevents their accumulation above the deærated water in the storage compartment. After starting their upward travel, the steam and non-condensables enter the primary heating chamber (M) and come into direct contact with the sprayed water (N) where initial heating and deæration takes place as previously described.

A very large percentage of the steam entering the primary heating chamber is condensed and the residual steam along with the non-condensables proceeds along the sprayed water surfaces in a counterflow relationship and within the confines of the air cooler baffles enveloping the spray pattern. Here further condensation of steam takes place and the non-condensables are cooled by the colder water (P) emitting from the spray valves. Further cooling of the non-condensables takes place as they come in contact with the cold surface of the water inlet manifold in their passage to the vent opening.

Approximately ½ to 1 per cent of the total steam required for heating the feedwater at full load is vented from the deærator and this steam contains all of the dissolved gases removed from the feedwater.

Optimum Feedwater Temperature

The greatest economy occurs when the maximum amount of steam is diverted from the condenser, which reduces to a minimum the heat lost in warming-up sea water. Readers will be familiar with the fundamental arguments in favour of bleeding. If there were an infinite number of bleed points and heaters to match, such that in each case the feed temperature is brought up to saturation temperature for those conditions, then optimum conditions of economy will have been achieved. In this case the maximum amount of steam is passing through the turbine and only the latent heat of vaporization of the bled steam is used for feed heating. Unhappily, neither an infinite number of heaters nor bleed points is possible, usually three (and in certain cases four) being considered a normal maximum. The more the heaters the greater the optimum feed temperature, the final optimum being the saturation temperature of the throttle steam. An empirical expression for optimum feed temperature(7) is:—

Feed water temperature rise = 40 + 8 (No. of heaters) (1)
As percentage of possible rise ... ... = 40 + 8 (3) = 64 per cent
e.g. Saturation temperature at 450 ... ... = 460 deg. F.
Exhaust temperature 28·5 Hg (with no sub-cooling) = 92 deg. F.
Maximum possible temperature rise using three heaters ... ... = 368 deg. F. (2)
By (1) in (2), actual rise ... = 0·64 × 368 = 236
Hence optimum feed temperature ... ... = 236 + 92 = 328 deg. F.

(b) *Pumping Arrangements*

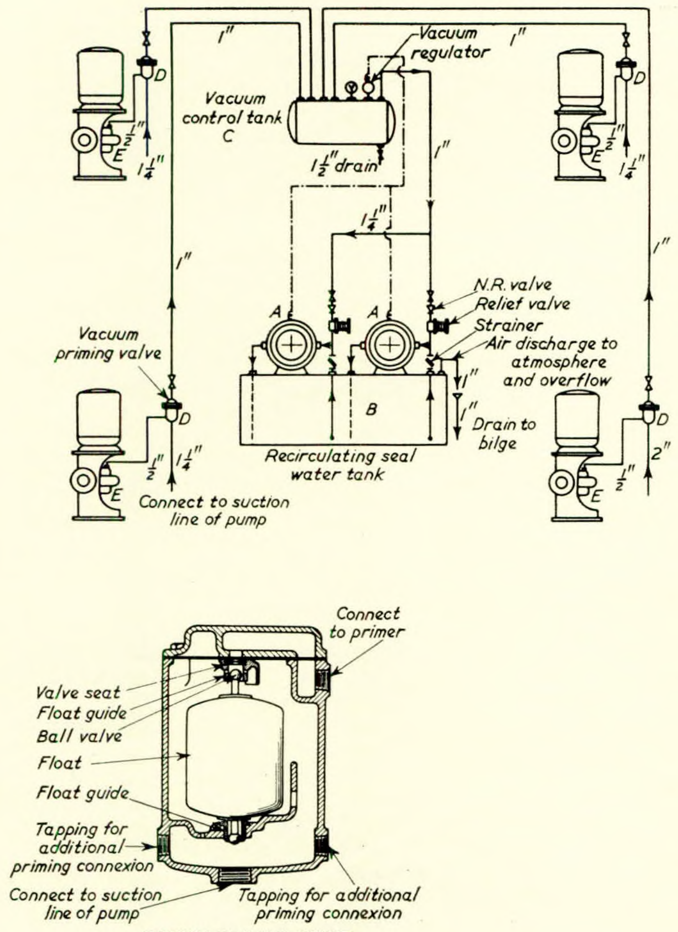
Almost exclusively pumps were centrifugal for water duty and triple screw type for positive displacement duty, the exception being the l.p. steam generator feed pump and the domestic fresh and salt water pressure systems, where direct acting types were fitted; but an improvement could have been effected by using turbine type regenerative pumps for both these duties. The screw pump characteristics give smoother flow free of pulsations, less NPSH required (i.e. better suction lift), almost completely silent operation and much greater speed of operation because of small rotor diameter and consequently lower peripheral velocity. This allows for cheaper electric motors.

In all pumps, especially centrifugal, comparatively high speeds were used with success, but yet in accordance with Hydraulics Institute Recommendations, as follows:—

> "Fire and General Service, Drain Transfer, Auxiliary Condensate all at 3,500 r.p.m. with Bilge, Ballast and main condensate at 1,750 r.p.m. The condenser circulating pumps, of course, operated at the much lower synchronous speeds. Rotary (positive displacement) at 1,750 r.p.m."

Perhaps the unusual feature of the pumping arrangements was the method of priming. The integral self-contained constant running liquid ring primer has not established itself in America; they use what is called the central priming system, which is now described.

Where several pumps (usually centrifugal) require priming, it is frequently advantageous to install a central priming system, which is used as an *alternative* to pumps fitted with



VACUUM PRIMING VALVE

FIG. 22—*Central priming system*

(1) Vacuum switch arranged to start primer when vacuum drops to 15-in. Hg. and stop primer when vacuum reaches 20-in. Hg. Switch to contain manual operating feature.
(2) Vacuum priming valve to be located as close to venting point as practicable.
(3) Vent piping between pump and vacuum priming valve to be led as nearly vertical as possible.
(4) Vacuum tank about 5 cu. ft.
(5) Seal water tank about 5 cu. ft.
(6) At 1,750 r.p.m., air pump will handle about 27 cu. ft. per min. of air measured at suction vacuum and when the vacuum is about 15-in. Hg.

Units of much greater air handling capacity can be fitted at need.

constant running primers, and *not* in addition. In addition to avoiding the necessity for individual primers, float chambers are omitted, standard motors can be used because there is no shaft extension required, and small motors can be used, there being no prime horsepower required. If this is combined with group control, it leads to very compact and neat units. Another advantage which applies more especially to larger pumps is that the pump is never started until its volute is completely filled with water; this prevents the pump running dry, with consequent reduction in wear of wearing rings and gland packings.

Clearly, there is also a reduction in priming time, because the control tank has its high vacuum always ready in addition to the exhauster air handling capacity. The fact that there are two exhausters available to prime any pump should not go unnoticed. There are three separate and distinct methods of controlling central priming systems, which are:—

(i) Vacuum control
(ii) Pressure control
(iii) Barometric separator control

The diagrammatic system as shown in Fig. 22 is as fitted. It consists of two priming pumps (A) (one as standby), mounted on the sealing water tank (B) and connected to the vacuum tank (C) which in turn is connected through priming valves (D) to the suction main and to the pump casing at (E), usually the highest point in the volute.

Fresh water is used for sealing the priming pumps and arrangements are made for the recirculation of the sealing water through the pumps from the sealing water tank on which the pumps are mounted. The priming valves permit the flow of air while the system is being primed, but close to prevent water entering the vacuum tank when the water level reaches the valve. The priming pump units consist of two horizontal liquid ring vacuum pumps, each direct coupled to an electric motor and mounted on the seal tank. Priming valves are not absolutely necessary, if the vacuum tank can be elevated and located at sufficient height to overcome the exhauster operating vacuum (between 34ft. and 50ft.). This is usually most undesirable, the vacuum tank normally being placed against the ship's side a few feet above the tank top. This saves piping (hence cost) and reduces to a minimum the possibility of leakage. It is, of course, necessary to fit a NR valve on the delivery side of, and as close to the pump as possible, for without this valve the pump will never achieve its prime. In mercantile practice, as distinct from naval, priming times and conditions are hardly ever specified. This is a pity as primers can take anything from ½ h.p. to 7½ h.p. and clearly air handling capacities are related somewhat to these powers.

(c) *L.P. Steam Generator v. Donkey Boiler*

In most ships low pressure steam is required at about 100lb. per sq. in. gauge for fuel oil service heaters, heating coils and for domestic services. Traditionally, the donkey boiler is included, but it is often a troublesome unit—separately fired, neglected because it is seldom used, and insufficiently maintained. Furthermore, donkey boilers are seldom suitable for oil burning, most of those in existence having been designed to suit coal. To adapt such a boiler for oil burning a skirt is necessary, and, apart from adding height to an already tall unit, it is a compromise at best.

Now this vessel was intended to spend even less time in harbour than the tanker and consequently the practice of "dying down and banking" for long periods would not arise, as distinct from being a practice to be avoided. Consequently the need for service steam was reduced to a minimum*.

The donkey boiler was therefore excluded and a small l.p. steam generator fitted consisting also of a drain cooler observation drain tank and l.p. feed pump. The generator duty was only 1,550lb. steam at 100lb. per sq. in. gauge and used bled steam at 105lb. per sq. in. gauge at 497 deg. F., although a shore steam connexion was also provided. This small, neat unit was positioned in the engine room.

(d) *Evaporation and Distilling Plant* (Figs. 23 and 24)

It has always been the author's view that ships carry an excess of water due mainly to the difficulties associated with evaporation and distilling. The task is often viewed by engineers as irksome and troublesome, hence the tendency to carry water at the expense of cargo. The early fall in performance of the submerged coiled types necessitates the fitting of larger units than really is required.

The equipment chosen was a comparatively new American type called the "Maxim", which has been adopted largely by the U.S. Coastguard Service and the Royal Canadian Navy after extensive tests and trials.

This design uses a basket type heating element of deeply corrugated Monel metal arranged in cylindrical form, which gives maximum heat transfer surface for unit space and permits easy descaling. The flat sides of the corrugations of the heat-

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* Accommodation, heating, calorifier, and OF heating coils, although the first two had electric alternatives.

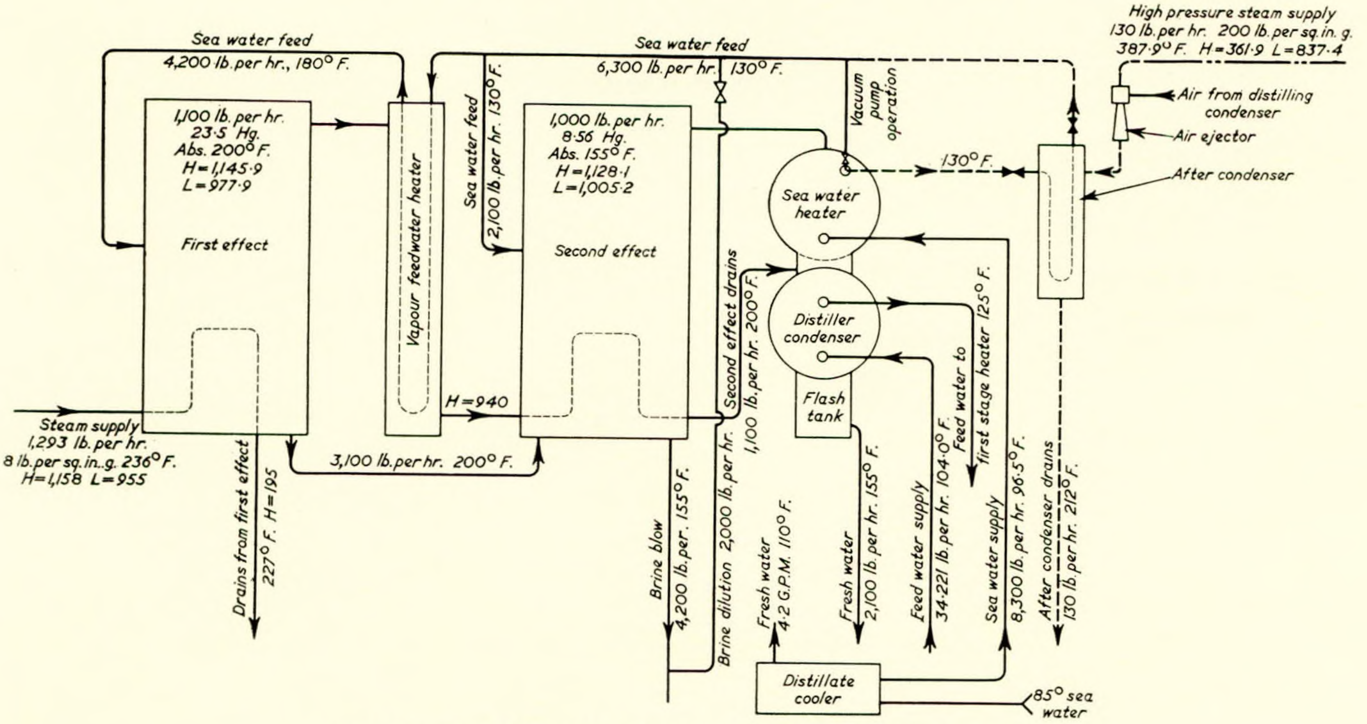

FIG. 23—*Heat balance diagram of double effect distillation unit*

Flow rates are for clean tube rates. Radiation losses of approximately 40,000 B.t.u. per hr. are assumed from each of the first and second effects.

H = total heat content, B.t.u. per lb.

L = latent heat of vaporization in B.t.u. per lb.

U = coefficient of heat transfer B.t.u./hr./sq. ft./deg. F. temperature difference.

Units (one)	Total effective heating surface, sq. ft.	Rated capacity		Clean tube capacity			
		Velocity through tubes, ft./sec.	Required U value	Velocity through tubes, ft./sec.	Required U value	Pressure drop through tubes, lb./sq. in.	Pressure drop through shell, lb./sq. in.
Evaporator, 1st effect	45		710		710		
Evaporator, 2nd effect	45		475		475		
Sea water heater	20	2·6	350	2·6	350	3	
Distiller condenser	37·7	3·3	490	3·3	490	2	
After condenser	15·5	1·66	133	1·66	133	2	
Vapour feed water heater	9·2	2·5	570	2·5	570	3	
Distillate cooler	15·5	1·7	155	1·7	155	2	

ing section expand and contract under "shocking" and the brittle scale drops off, leaving the metal surface almost completely clean. The author believes that this was the first British ship fitted with this equipment and subsequent experience has justified the decision. In the loaded condition the ship can sail with negligible feedwater and this has an important effect on cargo carried and earning capacity. This type of evaporator has the following advantages†:—

(i) Purity of distillate produced (less than 0·2 grains of salt per gallon).

(ii) Ease of descaling due to flexibility of heating section walls when shocked.

(iii) Less space is taken up by the unit due to compact design of separator and heating sections.

(iv) Less weight due to (iii) and also to the avoidance of heavy castings in the construction, the entire system being constructed of Monel metal with interconnecting piping of 90-10 cupro-nickel.

(v) The operation is entirely automatic after start-up.

(vi) It is independent and does not need the assistance of additives such as ferric chloride.

The detailed flow circuit is now described and should be read with reference to Figs. 23 and 24.

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† It has the disadvantage of greater cost and this must be acknowledged.

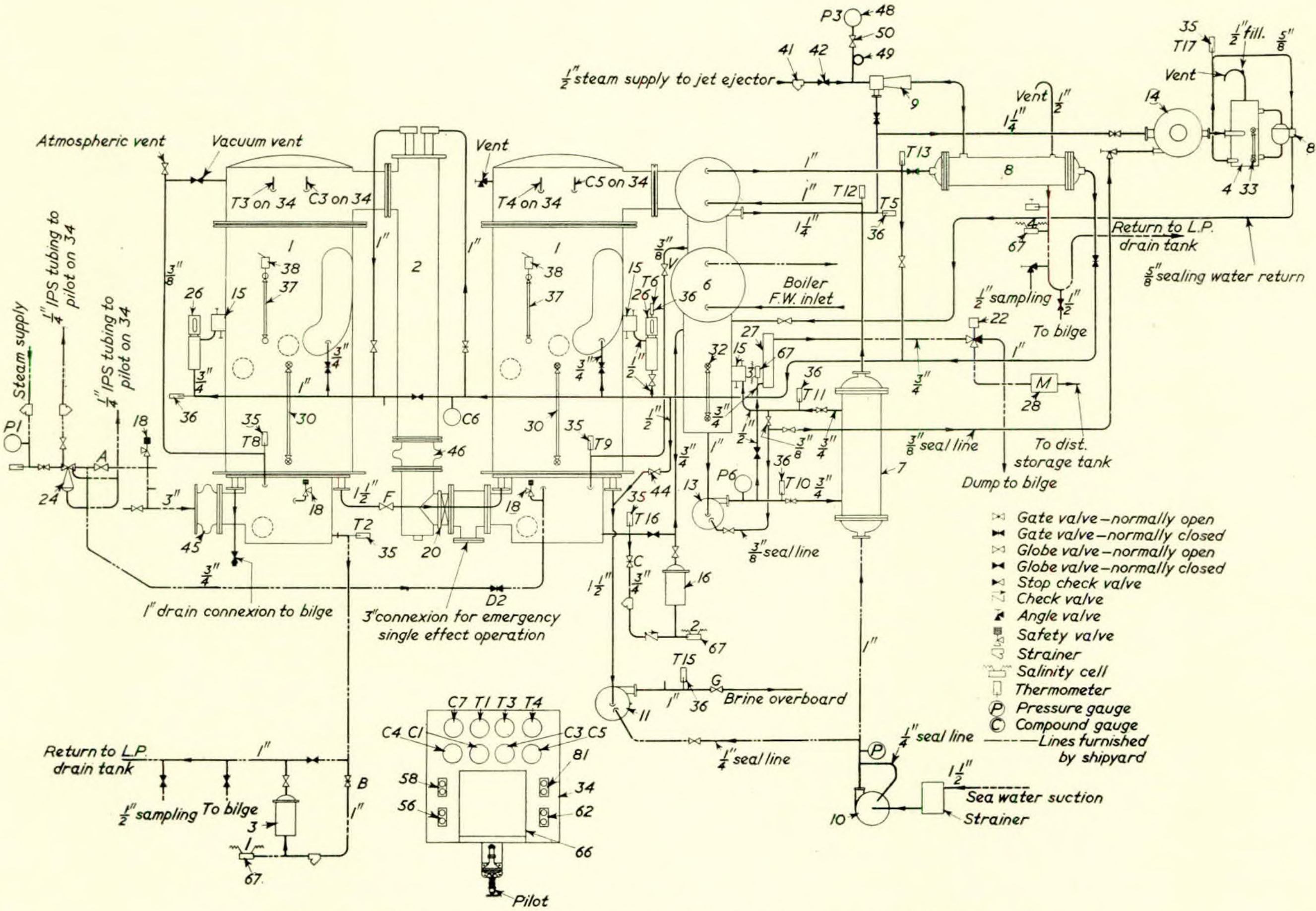

FIG. 24—*Diagrammatic arrangement of double effect distillation unit*

(1) Evaporator; (2) Feedwater heater; (3) Drain trap; (4) Air water separator; (6) Condenser; (7) Distillate cooler; (8) After condenser; (9) Air ejector; (10) Salt water circulating pump; (11) Brine pump; (13) Fresh water pump; (14) Vacuum pump; (15) Level controller; (16) Steam trap second effect; (18) Tell-tale safety valve; (20) Vapour valve; (22) Solenoid valve (three-way); (24) Pressure reducing valve steam inlet; (26) Rotameter; (27) Rotameter; (28) Water meter; (30) Gauge glass shell; (32) Gauge glass condenser and tank; (33) Gauge glass air water separator; (34) Gauge board; (35) Thermometer; (36) Thermometer; (37) Gauge glass (shell); (38) Lumenite control; (41) Air ejector steam strainer; (42) Air ejector shut-off valve; (44) Brine dilution valve; (45) Expansion joint 3-in. steam inlet; (46) Expansion joint 6-in. feedwater heater; (48) Pressure gauge, 0-300lb.; (49) Syphon for (48); (50) Cock for (48); (55) Starter for (10); (56) Push button for (10); (57) Starter for (11); (58) Push button for (11); (61) Starter for (13); (62) Push button for (13); (63) Starter for (14); (66) Salinity indicator; (67) Salinity cell; (80) Level controller; (81) Push button for (14)

Steam from the ship's auxiliary exhaust main is fed to the first effect steam chest through a pressure control valve set to maintain a constant steam supply pressure to the first effect. It should be set to 8lb. per sq. in. gauge for optimum output and lower for reduced ratings. This heating steam is condensed inside the corrugations of the evaporator basket and returned to the l.p. drain tank through the first effect drain trap (3).

The incoming sea water is taken from the sea water main through a strainer by the sea water circulating pump (10) and pumped through the distillate cooler (7), at 16·6 g.p.m., thus cooling the distillate from the evaporator to approximately 25 deg. F. above the temperature of the incoming sea water. The sea water then passes through the sea water heater of the condenser (6), on into the after condenser (8), and hence to the second effect, at a temperature of 130 deg. F. Here 4·26 g.p.m. are taken from the line through the rotometer (26) and level controller (15) into the second effect evaporator (1). The balance of the sea water flows into the vapour feed water heater (2), then on into the first effect evaporator (1) at a temperature of 180 deg. F.

It can be seen from the diagrams that, assuming the in-running sea water temperature to be 85 deg. F., and the sea water rate about 16·6 g.p.m., a distillate rate of 4·2 g.p.m. will raise the sea water to a temperature of about 96·5 deg. F. in cooling this rate of distillate.

Proceeding further on the flow diagram, in the standard case, the sea water passes through the shell and tube type distiller condenser and combination feedwater heater (6), where it condenses the vapour from the second effect. In this particular case, however, in order to achieve maximum economy, the full flow of main boiler feed water is passed through to the distiller condenser where a heat gain of 718,641 B.t.u. per hr. is achieved. [34,221lb. per hr. × (125 − 104) deg. F. heat rise.]

The method of feeding the distilling plant differs from conventional units in the following respects. Firstly, the effects are fed partly in parallel as well as in the conventional forward feed system; this system permits the use of automatic feed valves and greatly simplifies operation. Secondly, the feed is introduced into the base of the cyclonic separator section where further heating drives off the entrained gases, mainly CO_2, before the feed goes down the down-takes to the evaporator section.

The vapour, in passing from the first effect to the second effect, travels by way of the vapour feedwater heater (2) where some of the vapour is condensed in heating the feedwater to the first effect. The major portion of the vapour at a temperature of about 200 deg. F. boils the sea water in the second effect at a temperature of about 155 deg. F.

The condensed vapours in the second effect steam chest (now known as the distillate), pass through a loop seal (16) to the flash tank of the distiller condenser under the pressure differential existing between the second effect steam chest and the flash tank. The loop seal acts like a trap and will allow only water to pass and not vapour. Therefore, in order to vent properly the second effect chest of non-condensable gases it is very important to open the vent valve V wide enough to assure complete venting. When temperature T_9 reads the same as T_3, an indication that some steam vapour is coming through, complete venting is assured. The temperature of boiling in both the first and second effects will automatically adjust themselves, dependent on the surrounding conditions of steam supply pressure, condenser vacuum and feedwater temperatures, etc.

The combined distillate is taken from the flash tank of the distiller condenser and is pumped through the distillate cooler (7) into the distillate storage tank by distillate pump (13), the discharge rate of which is controlled automatically by a level controller.

A salinity cell is inserted in all fresh water lines, which indicates by alarm devices any possible leaks of sea water into the fresh water system. If such a leak should develop, the salinity controller actuates the solenoid dump valve (22) and dumps the charge of the bilge until the plant is secured and this prevents any contamination of the feedwater storage tanks.

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Figs. 17, 18 and 19 have been reproduced from Volume II of "Marine Engineering" by H. L. Seward, by permission of the Society of Naval Architects and Marine Engineers, New York.

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APPENDIX 1

ALUMINIUM SUPERSTRUCTURES

TABLE IV—A COST AND WEIGHT ANALYSIS COMPARING WELDED STEEL, RIVETED ALUMINIUM, AND WELDED ALUMINIUM

Case no.	Specification	Weights in tons							Cost in £ sterling					Cost per deadweight ton gained in £ sterling
		Welded steel structure	Riveted aluminium plates and shapes, Alloy 65ST	Weight saved	Weight ratio	Welded aluminium plates B54S, shapes 65S	Weight saved	Weight ratio	Welded steel	Riveted aluminium	Extra cost	Welded aluminium	Extra cost	
	(a)	(b)	(c)	(d)		(e)	(f)		(g)	(h)	(j)	(k)	(l)	(m)
1	Construction of midship deckhouses only above the upper deck, including machinery casings, but excluding funnel and wheelhouse.	150	62·5	87·5	0·417	53·2	96·8	0·354	25,950	52,400	26,450	42,500	16,550	i Riveted 302 ii Welded 171 iii Welded, fire installation A 349 iv ditto B 257 v ditto C 241 vi ditto D 259 vii ditto E 194
2	Construction of midship deckhouses, including machinery casings, after deck house and masthouses of aluminium but excluding funnel and wheelhouse	209	90·7	118·3	0·434	77·2	131·8	0·37	32,200	76,200	40,000	61,300	25,100	i Riveted 338 ii Welded 190 iii Welded, no fire installation A 316 iv ditto B 254 v ditto C 242 vi ditto D 255 vii ditto E 211
3*	Construction of midship deckhouses, including machinery casings and after deck house, but excluding masthouses, funnel and wheelhouse	175	—	—	—	65·3	109·7	0·374	30,200	—	—	48,400	18,200	i Riveted: not considered ii Welded, no fire installation 166 iii Welded, fire installation A 307 iv ditto B 242 v ditto C 228 vi ditto D* 244 vii ditto E 187

NOTES:

The cost of the ship overall was about £118 per dwt. A similar ship in the United Kingdom at that time might cost about £88 per dwt.

(a) One ton=2,240 lb.

(b) £1 sterling= $2·80

(c) Average price for steel—5·85 cents/lb. (£4·68 per ton)

(d) Average price for aluminium—40 cents/lb. (£320 per ton)

* Specification No. 3, Fire Insulation ' D ' was chosen

APPENDIX 2

TABLE V—ALUMINIUM APPLICATIONS

Case no.	Application	Details	Weights			Cost		Material		Construction details	Notes
			Steel	Aluminium	Saving	Actual	Extra	Alloy	Sizes		
1A	Hatch boards	(a) McGregor steel covers	85			29,800		B54S-F Sheet	3¾in. deep 1ft. 6½in. wide standard lengths, 6ft. 9in., 7ft. 6in. 8ft. 6in.	(i) Fabricated from ⅛in. sheet and 3-3½in. × 1in. × ⅛in. channels	(i) (b) and (c) include £6,000 for tarpaulins and battens
		(b) All-steel beams and "Metallumber" boards	60·8			25,000			(ii) Beams: Webs 0·6in.; plate face bars, 1in. × 9¼in.	(ii) Channels intermittently welded 1in. at 6in. centres closing sheet plug welded with ½in. plugs at 6in. centres	(ii) 592 hatchboards 7,340 sq. ft. hatches
		(c) All-aluminium beams and "Metallumber" boards	56·7	27·2	29·5	33,600	8,560	A56S-F Extrusions		(iii) Beams continuously IMA welded with —in. nominal size fillet in 56S filler	(iii) Hatch beams subject to stiff deflexion regulations; weight ratio 0·575:1; likely future reduction due to this experience
1B	Hatch beams	Aluminium hatch beams (included in above)	23·6	13·4	10·2	7,150					
2	Piping	(a) Air and sounding pipes	35·10	10·9	24·2		20,810	(a) IS-F IPS pipe: some 65ST above upper deck	1½in. (1,200ft.) 3½in. (150ft.) 5in. (645ft.) 6in. (145ft.)	Made up of pipe, welding neck flanges, bulkhead pieces and tank top pieces with bolted connexions except at welds	(a) Welding of neck flanges to lengths of pipe 33S Rod and ATA equipment. (b) Liquid tight joints, gaskets of "Fairprene" sheet, $\frac{1}{16}$in.
		(b) Fire and deck service						(b) 57S½ H IPS pipe	1½in. (110ft.) 2in. (110ft.) 2½in. (620ft.)	ditto	ditto
		(c) Bilge and ballast systems						(c) IS-F IPS pipe for ballast 57S-F IPS	3in. (70ft.) 3½in. (50ft.) 5in. (200ft.) 8in. (20ft.) 3in. (810ft.) 4in. (60ft.) 5in. (90ft.)	ditto	Main reason for difference in alloy is that forward of the engine room the ballast piping goes in the double bottoms whilst bilge lines go above the tank top. Hence latter are exposed to mechanical damage and a stronger alloy was chosen.
		(d) Water system in accommodation, fresh water, hot and cold and salt water						(d) 57S-O	0·049in. W × ½in. OD (1,220ft.) 0·065in. W × 1in. OD (755ft.) 0·065in. W × 1¼ in. OD (350ft.) 0·072in. W × 1½ in. OD (1,680ft.)	(a) Hot water lines sheathed in ¾in. felt insulation and wrapped in 8-oz. canvas. (b) All connexions, tees, unions and bulkhead pieces are of compression type in alloy 24 S-T anodized and dyed.	The use of aluminium in these plumbing systems is an effort to ascertain the resistance of aluminium to fresh water taken from many ports which may contain corrosive elements.

Case no.	Application	Details	Weights			Cost		Material		Construction details	Notes
			Steel	Aluminium	Saving	Actual	Extra	Alloy	Sizes		
2 (cont.)		(e) Fittings and pipe systems						(e) Welding neck flanges; forged-T unions; sand cast bulkhead pieces; sand cast tank top connexions; welding rod. Bolts and nuts	61S-T6 135-T22 135-T22 135-T22 33S 65S-T	Oil pipe systems are bolted sections, each section consisting of a length of pipe with a welding neck flange at each end. Welding of flanges to pipes made by 33S filler rod and ATA equipment used. Suction then bolted together with 65-ST bolts 1/16in. "Fairprene" sheet gaskets. Branching pipes connected to main lines through cast T-unions, although in many cases branches originated from a valve chest.	Air and sounding fire and wash deck bilge and ballast all have similar connexions and fittings and are supported by similar brackets. 4½ tons of aluminium fittings were used.
	Piping—general									CONSTRUCTION DETAILS: To cross a steel bulkhead to which the pipe is to be secured a cast bulkhead piece is used, the pipe sections ending and starting on either side of the bulkhead piece, being a simple double flanged straight union that has a third larger flange at its centre point. The large flange is bolted to the bulkhead with galvanized bolts. "Fairprene" 1/16in. sheet is used for gaskets at the faying surfaces and also for washers under the normal washers. In addition, 0·017in. "Fairprene" P.A.W. tape is wound around the bolts where they are in contact with the aluminium. The piping is secured in place by brackets. This pipe has a strip of 1/16in. "Fairprene" all around it. The aluminium bracket in two pieces completely surrounds the pipe. Another strip of "Fairprene" separates the aluminium bracket from the steel lugs to which it is bolted. The bolts are galvanized steel wound with 0·017in. "Fairprene" P.A.W. tape and with gaskets under the washers. Note that some of these joints are continuously immersed in sea water and this apparently complicated system presents a double barrier against the conduction of current.	(a) The success of these systems depends on complete isolation from the surrounding steel, especially inside ballast tanks where unfavourable area relationships occur. (b) The extra of £20,800 includes a material difference of £2,900 and an extra labour charge for insulating brackets which are used with aluminium piping. There is clearly a very substantial charge for contingencies to cover the builders for the working of new materials and processes. It is estimated that the charge will fall by more than 50 per cent with more experience. Use of aluminium piping was justified by previous excellent experience in fire and deck service lines.
3	Davits	4 "Columbus" pilot davits and 1 "Crescent" type		1·34	2·24	2,820		B54S-F		Davits all-welded aluminium except galvanized steel extensible leg. Winch frames also welded aluminium.	The use of aluminium was dictated by the desire to have boat stations that require the minimum of attention and maintenance. This material is equivalent to 57S and B54S. The boats were supplied primed with zinc chromate and were painted. At that time welded construction had not been approved although it is understood that since then it has been.
		2 "Viking" lifeboards and 1 workboat		2·24	2·68	2,570		"Birmabright" riveted	24ft. × 9ft. × 3ft. 9½in. 26ft. × 9ft. × 3ft. 9½in. 14ft. × 5ft. 3in. × 2ft.	Riveted	

Case no.	Application	Details	Weights			Cost		Material		Construction details	Notes
			Steel	Aluminium	Saving	Actual	Extra	Alloy	Sizes		
4	Ventilation trunking	The mechanical ventilation system serves midship house through two systems — a supply with two 3,100 cfm. air conditioning units and an exhaust with four 3,100 cfm. fans. This equipment is on the boat deck and the trunking extends from these to the rest of the midship house.		0·65	1·34	7,720	1,535	57S½H0·025in. B54S-F 56S filler	0 025in. sheet Sheet and plate	The average duct perimeter is 3·1ft. with sizes ranging from 20×13in. to 3in.×4½in. Construction is by seam welding and mechanical seaming. Seam welding was done with ATA equipment, mostly without filler, which was used for touch-up only. Joints between sections of duct were riveted and " Neoprene " paste was used as a caulking compound. The ducts were coated with zinc chromate primer and then received a coating of "Neoprene" paste, which acts as a binder for the ¾in. felt insulation. The duct is finished with canvas covering. Cowl vents, torpedo vents and mushroom vents were fabricated and welded.	As only £107 of the difference was due to material costs, the differential incorporates a surcharge for contingencies that would disappear as the use of aluminium increases. In view of the very high relative costs an increase in the life of the trunking is clearly necessary to justify the expense. Aluminium trunking was used in the superstructures only. The contract cost for all trunking was £12,110.
5	Windows	Approximately 100 "Beclawat" imported from the United Kingdom.		0·65	1·34	4,920	—492 (see note)	50S	29in.×25in.	The glass was spring balanced and slides in the grooves of the extended frames. 65-S-T flathead screws (⅜in.) secure the windows to the house sides. "Neoprene" paste was used as a caulking compound. The front of the upper deckhouse was steel and faying surfaces were painted each with a coat of "Plas-ti-co," ("Neoprene" type paste) prior to caulking of the joint. The screws were also coated.	In this case there was no extra, the saving of 10 per cent being estimated.
6	Miscellaneous items	The miscellaneous items as such cannot be justified economically, but were included because of their lower maintenance.		10·7	19·2						

Case no.	Application	Details	Weights			Cost		Material		Construction details	Notes
			Steel	Aluminium	Saving	Actual	Extra	Alloy	Sizes		
6 (cont.)		Ladders, awning supports and guard rails are presented separate from the superstructures because the reason for their acceptance was different and might be adopted with non-aluminium superstructures. Engine room ladders, flooring, grating and rails account for 12·5 of the 21·5 tons saved. This makes it worth while to look for less expensive design and construction. Use of pipe stanchions instead of cast, relaxing the deflexion requirements of gratings and a more economic supply of checkered plate will do much to this end.									
	(a) Awning stanchions and rafters	Used in way of aluminium structures only. Approximately 22 stanchions were used per 1,000 sq. ft. canvas (3,340 sq. ft. actual).						57S½ H	Extra heavy 2 in. nominal for stanchions. 1½ in. rafters.	All connexions welded, using ATA equipment and 56S welding rod. Stanchions welded direct to deck, or to bulwarks by means of palms.	Mainly approved for better appearance and reduced maintenance.
	(b) Guard rails and bulwarks	Superstructure guard rails are fixtures. 100 stanchions approximately for the 3ft. 3in. guard rails.						57S½ H A 56S-F	1¼in. and 1in. ¾in.	Completely welded using ATA and 56S rod to 5in. high curtain plates by means of ¼in. × 2in. end bars attached to each stanchion. Bulwarks, teak rail connected by 65 S-T bolts with zinc chromate paste in the faying surface.	
	(c) Engine room guard rails	These had to be removable and thus a different scheme was evolved						Stanchions 135-T22 Bolts 65S-T Rails A56S-F	39in. high walkways 19in. high ladders 1in. round rod	Stanchions are connected to the steel structure that supports the walkway by 65S-T bolts. For ladders, stanchions are connected to the aluminium side stringers by bolting "Neoprene" paste, or canton flannel soaked in zinc chromate is applied to faying surfaces.	

Case no.	Application	Details	Weights			Cost		Material		Construction details	Notes
			Steel	Aluminium	Saving	Actual	Extra	Alloy	Sizes		
6 (cont.)	(d) Refrigerator rooms	Meat room, dairy room, vegetable room, fish room and handling room						Standard flow extrusion		Removable aluminium floor is laid on top of concrete floor.	Total of 300 sq. ft. was installed. Used because of easy cleaning.
	(e) Engine room flooring and walkways	The walkways extend all the way up the casings space and the grating used is aluminium. The supporting structure which spans the machinery space and the casings space is made of steel channel. It was felt that due to the possibility of fire, steel was a better choice.						6 S-T		The gratings are fabricated and laid directly on the primed steel.	
		The flooring consists of ¼in. checkered plate (4 tons) covering approximately 2,880 sq. ft. in spans of about 4ft. 8in.						A56S	3in. × 3in. × ¼in.	The flooring is secured to an angle framework by ⅜in. 65S-T flat head screws. Framework is partly welded and partly bolted for easy dismantling. Floor and framework are supported above the tank bottoms by steel angle stanchions approximately 4ft. high. Stanchion and floor framework connexions are galvanized bolts and canton flannel soaked in zinc chromate paste.	
	(f) Ladders	Outside ladders from deck to deck on the outside of the superstructure. Engine room ladders are all bolted and readily removable.						A56S-F extrusions		Welded with 56S filler wire. Connexions between ladder and deck are bolted. $\frac{5}{16}$in. plate lugs are welded to the deck and deck aprons. Ladders are secured to the lugs by stainless steel bolts. "Neoprene" paste is used to prevent faying and galvanic corrosion. Channels which support steps by ½in. bolts.	
								A56S channels 65S-T steps and bolts			

APPENDIX 3

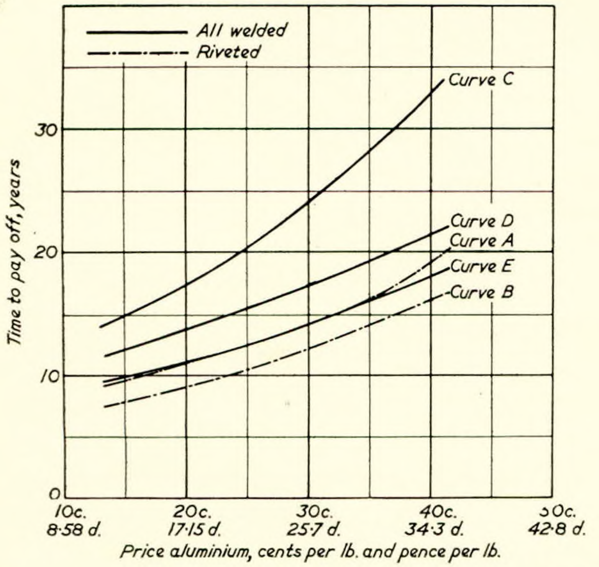

FIG. 25—*Curve showing time to pay-off superstructure*

NOTES

1. All-welded structures—"Marinite" included—see specification in Appendix 1.
2. Riveted structures—no "Marinite" used. Alloy 65ST.
3. Tax and depreciation not considered: interest at 4¾ per cent.
4. Curve A: all superstructures of aluminium.
5. Curve B: midship house only of aluminium. After deck house and masthouses of steel.
6. Curve C: all superstructures are aluminium.
7. Curve D: midship house only of aluminium, the remainder of steel.
8. Curve E: midship and after deck house of aluminium, masthouse of steel.

APPENDIX 4

NOTE: 1. Interest on capital at 4¾ per cent: tax and depreciation no considered.

2. Curve assumes cost of aluminium to be constant and to specification No. 3 in Appendix 1. Standard extra cost—£18,200.

3. " Marinite " schemes as in table.

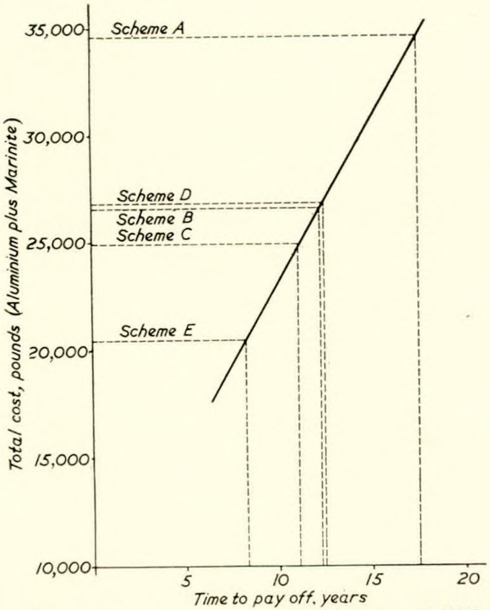

FIG. 26—*Curve showing effect and influence of "Marinite" on time for aluminium superstructure pay-off*

TABLE VI—FIREPROOFING OF SUPERSTRUCTURE USING " MARINITE "

Scheme	Specification	Extra cost in £ sterling
A	Bulkheading and lining within living quarters to have hardwood veneer faced " Marinite," bulkheading and lining in passages, pantries, lockers, etc., to have marine veneer on " Marinite." Ceilings to be ⅜-in. " Marinite " sheeting.	16,420
B	Bulkheading and lining to be marine veneer faced " Marinite." Ceilings to be ⅜-in. marine sheeting.	8,310
C	Bulkheading and lining throughout to be " Marinite " standard base, finished with paint, similar to that in the Mariner Class vessels, ceilings to be ⅜-in. marine sheeting.	6,790
D	Outside linings below the boat deck to be ½-in. hardwood faced " Marinite " and on underside of boat deck, to be ½-in. finished " Marinite " (painted).	8,540
E	Leave the plywood lining, but apply 1-in. sprayed limpet asbestos behind it on the outside linings below the boat deck.	2,250

APPENDIX 5

POSSIBLE ALUMINIUM APPLICATION CONSIDERED

Superstructure

For the construction of the 'midship superstructure complete, including the wheelhouse, funnel and machinery casings, the after deckhouse and the mast houses.

Hull Fittings

Accommodation ladders and gangways.
Accommodation ventilation trunking.
Air and sounding pipes.
Awnings.
Boats.
Boat davits.
Doors and hardware.
Furniture.
Galley cupboards, dressers, etc.
Guard rails and stanchions.
Hatch covers.
Ladders.
Machinery space ventilation.
"Marinite" panels, aluminium clad for lining of accommodation.
Masts and derricks.
Port lights.
Lining of refrigerated spaces.
Storeroom shelving.
Ventilation heads and cowls.
Windows.

Engineering and Electrical System

Boiler casings.
Electric fittings.
Engine room flooring.
Engine room gratings.
Hangers for electrical cables.
Machinery gear guards.
Telegraphs.
Scuppers.
Various piping systems in the engine room and boiler rooms.
Voice pipes.
Wash deck pipe line.
Whistle, etc.

APPENDIX 6

TABLE VII—APPLICATIONS AND WEIGHT SAVING OF ALUMINIUM USED

Application	Aluminium weight, long tons	Weight saved, long tons
Midship house	57·2	93·0
Afterdeck house	8·1	17·0
Funnel	1·8	3·6
Hatch beams	13·4	9·8
Hatch boards	13·9	20·5
Lifeboats	2·2	2·7
Davits	1·3	2·7
Ventilation trunking	0·7	1·3
Windows	0·7	1·3
Piping (air and sounding, bilge and ballast, I.M.S. fire, and deck service fresh water).	10·9	24·1
Miscellaneous (ladders, awning supports, guard rails, engine room floorings and gratings, refrigerator gratings)	10·7	18·8
	120·9	194·8

TABLE VIII—SUMMARY OF ALLOYS CHOSEN

Application	Material
Plate and sheet	B54S–F
Extruded sections and shapes	A56S–F
Sheet for ventilation ducts	57S½–H
Welding wire and rod	56S
Welding rod used on piping	33S
Pipe and tubing in various hardnesses, for bilge lines, fresh water lines, awning, stanchions and rafters and guard rail stanchions and rails	57S–OF–½H
Pipe for ballast lines and air and sounding pipes	1S–F
Pipe for air and sounding pipe and goosenecks	65S–T
Pipe fittings and engine room stanchions	13S–T22
Fittings of the compression type	24S–T
Welding neck flanges	61S–T6

APPENDIX 7

TEST RESULTS CARRIED OUT ON ALLOY 65ST AT LAVAL UNIVERSITY, QUEBEC, 30TH FEBRUARY 1956

MECHANICAL TESTING OF BUTT (GROOVE) WELDED 65ST WELDED ALUMINIUM PLATES

Nature of Work

Five samples of 65ST aluminium plates were submitted for test. Two of these samples had been butt (groove) welded under an argon shield; the three others came from the same plate but were not welded. It was requested to conduct a tensile test of these samples which were machined to the standard 8-in. gauge length, 0·388in. thick and 2·0in. wide. Lloyd's Register was represented during these tests.

TABLE IX—TEST RESULTS

Case	Sample	Tensile strength, tons/in^2	0·1 per cent proof stress, tons/in^2	Elongation in 8in. per cent	Fracture position
1	Welded 65ST	14·3	8·7	3	In the weld
2	Welded 65ST	14·5	10·5	2	In the weld
3	65ST plate, not welded	20·4	18·1	12·5	2in. from punch mark inside
4	65ST not welded	20·4	18·1	11·5	1·25in. from punch mark inside
5	65ST not welded	20·5	18·2	13·7	In middle

NOTE: These results should be compared with Lloyd's Register Test Requirements (Appendix 8). The author does not consider that this elongation (3 per cent) represents a satisfactory test. A second series was requested and, although no record is available, it is believed they were executed with results similar to the above.

APPENDIX 8

LLOYD'S REGISTER OF SHIPPING TESTS AND REQUIREMENTS FOR ALUMINIUM ALLOYS

1. *Tensile Tests*

	Plates and sections
0·1 proof stress, tons per sq. in.	8
Ultimate tensile strength, tons per sq. in. ...	17
Elongation per cent on 8-in. test piece	10
Elongation per cent on 2-in. test piece	12

2. *Chemical Composition*

(*a*) Plates and sections of non-heat-treatable aluminium alloy to have the following chemical composition:—

Copper	not more than 0·10 per cent
Magnesium	not more than 5·50 per cent
Iron	not more than 0·75 per cent
Silicon	not more than 0·60 per cent
Manganese	not more than 1·00 per cent
Chromium	not more than 0·50 per cent
Zinc	not more than 0·10 per cent

(*b*) Plates and sections of heat-treatable aluminium alloy to have the following chemical composition:—

Copper	0·10 per cent
Magnesium	1·50 per cent
Iron	0·60 per cent
Silicon	1·30 per cent
Manganese	1·00 per cent
Chromium	0·50 per cent
Zinc	0·03 per cent

(3) *Additional Tests*

Bending tests can be asked for within the limits of Lloyd's Register Rules.

Note: See also Appendix 9.

APPENDIX 9

TABLE X—CANADIAN AND AMERICAN ALLOYS MENTIONED IN THIS PAPER, WITH THEIR NEAREST BRITISH EQUIVALENTS

	British Standard equivalent	Approximate composition, per cent	Typical properties				Shear strength, tons/in.^{2}
			U.T.S., tons/in.^{2}	0·1 per cent proof stress, tons/in.^{2}	% elongation on 2in.	Brinell hardness, 500kg. 10mm	
Alcan B54S	N5/6	Mg. $4\frac{1}{4}$ Mn. $\frac{1}{4}$	19·5	13·0	20	65	10
Alcan A56S	N6	Mg. 5 Mn. $\frac{1}{3}$	18·5	9·0	27	70	11·5
Alcan 65ST Alcoa 61ST	H20-WP	Mg. 1 Si. $\frac{1}{2}$ Cu. $\frac{1}{4}$ Cr. $\frac{1}{4}$	20	18·0	12	90	13
Alcan 57S	N4	Mg. 2 Mn. $\frac{1}{4}$					
Alcan 33S	N21	Si. 5					
Alcan 1S	S1B	99·5% pure aluminium					
Alcan 24S	—	Cu. 5 Mg. 2 Mn. 1					
Alcan 135	—	Si. $7\frac{1}{2}$					

NOTES

1. The first three alloys listed all meet Lloyd's Register Requirements (Appendix 8). B54S (N5/6) plate and A56S (N6) sections are now almost standard for structural ship work, although where there is no welding or hot forming 65S (H20), or a similar alloy, is often used for sections, where its lower price recommends it.
2. In the British Standard nomenclature, H indicates an alloy which is heat-treatable and N a non-heat-treatable alloy. Thus B54S and A56S are non-heat-treatable and 65S is heat-treatable. Note that a heat-treatable alloy may *not* be heated in the yard, and *vice versa.*
3. Suffixes such as " T " (N. American) and " WP " (British) indicate the type of heat treatment applied. Non-heat-treatable alloys may have one of the following suffixes:—

O	Annealed
F or M	As manufactured (hot rolled)
$\frac{1}{4}$H, $\frac{1}{2}$H, etc.	Quarter hard temper, etc. (cold rolled material)

4. The corrosion resistance of the magnesium or magnesium silicide alloys (B54S, A56S, 65S, 57S) in a marine atmosphere is excellent, and painting is not normally needed.
5. The first three alloys listed are shipbuilding structural materials to Lloyd's Register requirements and the figures for the properties are of interest on that account. The remaining alloys are not structural materials and were used for ventilators, welding rods, ballast pipe tubing, compression type tubing fittings and sundry castings. Apart from the fact that there are often no *exact* British equivalents, the properties will vary widely according to the temper or heat treatment used. To try to give exact figures might be misleading and the interested metallurgist is invited to study the " Handbook of Aluminium Alloys (5)."

APPENDIX 10

TABLE XI—SCANTLINGS OF MIDSHIP DECKHOUSE

Deck and deck house	Upper deck	Bridge deck	Boat deck	Captain's bridge	Navigation bridge	Compass platform
Plate						
Front	$\frac{3}{8}$ steel	0·31	0·28	$\frac{5}{16}$	0·26	—
Side	0·35	0·30	0·24	$\frac{1}{4}$	0·20	—
Aft	0·32	0·26	0·34	$\frac{1}{4}$	0·20	—
Stiffeners						
Front	(Steel)	$3\times2\frac{1}{2}\times\frac{5}{16}$	$3\times2\frac{1}{2}\times\frac{1}{4}$	$3\times2\times\frac{1}{4}$	$3\times2\times\frac{1}{4}$	—
Side	$4\frac{1}{2}\times3\times\frac{5}{16}$	$3\times2\frac{1}{2}\times\frac{1}{4}$	$3\times2\times\frac{1}{4}$	$3\times2\times\frac{1}{4}$	$3\times2\times0{\cdot}19$	—
Aft	$3\frac{1}{2}\times3\times\frac{1}{4}$	$2\frac{1}{2}\times2\frac{1}{2}\times\frac{1}{4}$	$3\times2\times\frac{1}{4}$	$3\times2\times\frac{1}{4}$	$3\times2\times0{\cdot}19$	—
Deck						
Sheathed	(Steel)	0·24	0·28	0·26	0·22	0·20
Inside	(Steel)	0·28	0·28	0·26	0·22	0·20
Girders	(Steel)	$11\times\frac{5}{8}\times6\times\frac{1}{2}$	$10\frac{1}{2}\times\frac{5}{16}\times8\times\frac{1}{2}$	$10\times\frac{5}{8}\times5\times\frac{3}{8}$	$10\times\frac{5}{16}\times6\times\frac{1}{2}$	$10\times\frac{5}{16}\times4\times\frac{3}{8}$
Deck beams	(Steel)	$6\times3\times\frac{5}{16}$	$5\times3\times0{\cdot}31$	$4\times2\frac{1}{2}\times\frac{1}{4}$	$4\times3\times\frac{1}{4}$	$3\times3\times0{\cdot}19$
Bulwark around	(Steel)	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	—
Sheath screen	$\frac{5}{16}$ steel	$\frac{1}{4}$	$\frac{1}{4}$	—	—	—
Bulkheads, lavatory	$\frac{5}{32}$	$\frac{5}{32}$	$\frac{5}{32}$	$\frac{5}{32}$	$\frac{5}{32}$	—
Bulkheads, other	0·20	$\frac{5}{32}$	$\frac{5}{32}$	$\frac{5}{32}$	$\frac{5}{32}$	—
Engine casing	—	0·31	0·31	—	—	—

These scantlings saved an estimated extra of 5·8 tons of alloy over the weight that would have been achieved by using standard plates.

OPERATING EXPERIENCES

It would not be fair to create the impression that all had been plain sailing, and some of the difficulties which transpired will now be recorded.

Aluminium

The final decision to apply no paint to the outer surface of the superstructure was not made until the ship was well advanced, and by that time the superstructure was not a particularly impressive sight. The welding and erection techniques were not expert at that time, and after erection a great deal of fairing was required to remove the humps and hollows in the deckhouse sides and ends. It is the author's belief that this distortion resulted largely from the fact that the window openings were cut after the whole job was erected, and consequently there was a general alteration of stress distribution.

At any rate a vast number of fairing lugs had to be welded to the deckhouse sides to provide leverage for the strongbacks. When these were removed by chipping, the superstructure was covered with indentations and welding spots which had to be ground down and buffed off. Therefore, even after allowing credit for no painting labour, an extra cost of £1,750 was incurred. It must be emphasized, of course, that this would not happen today as undue distortion can be avoided by using proper welding speeds and an intelligent sequence of erection. Some trouble has been taken in this paper to emphasize the execution of proper welding sequences and it is important once again to accentuate this point; in the author's opinion it is the kernel of success.

Turning to the question of maintenance, experience has shown that there is every reason to believe that the aluminium superstructure, whether painted or unpainted, would last twenty years. Comparative economics in the initial calculations did not estimate for no painting, and this, as has been shown previously, is an added attraction in so far as economics are concerned. It is more difficult to estimate than would at first appear, as the superstructure may be painted three or four times in a year; say, once in dry dock, and twice or thrice by the crew during normal working hours where the cost is comparatively small. If overtime arises, however, costs may be appreciably enlarged. It has been estimated that an annual charge of £1,070 to cover the cost of paint and labour involved in preparation and painting is a reasonable estimate for this class of ship.

Something should be said also about insulating materials. The author came to the conclusion that on the interface of dissimilar metals the insulating material would be better to have a fibrous base of woven type and of considerable strength. Extrusions of purely plastic materials seem to have occurred, and this, of course, is undesirable. Attention was invited previously to the fact that the whole success depended too largely on small jobs, and any of these small jobs badly done could ruin the whole operation.

The vessel was recently dry docked, and after 2½ years of operation the superstructure was regarded as an unqualified success. The unpainted superstructure has toned down to a dull appearance, similar to grey canvas. Evidence of corrosion between steel and aluminium is virtually non-existent.

The aluminium hatch boards are as they were when fitted and replacements have not been required.

Aluminium piping was installed outside the machinery space in the ballast, bilge, and air sounding systems. It was also used for water service pipes in the aluminium deckhouses. Parts of the bilge and ballast lines show minute pitting in the outside ballast tanks, and it is thought that this is due to the difficulty of maintaining absolutely perfect electrical isolation of the piping from the steel hull. It is also felt that the corrosion rate here would have been much more rapid if magnesium anodes had not been fitted in each of the ballast tanks. So long as the magnesium protection is maintained, there is every likelihood that the aluminium piping will show no further deterioration. This opinion is based on experience with the tunnel wing tanks. These tanks, below the after deep tanks, were designated for water ballast or oil fuel. Magnesium anodes were therefore not fitted because occasional charging with oil fuel would have provided protection for the tanks. So far it has not been found necessary to use these tanks for oil fuel, but they are ballasted regularly, and during the first year of the ship's life the aluminium ballast piping developed severe pitting to a depth of more than 0·10in. in places, the pipe itself being 0·20-in. thick. Magnesium anodes were at this stage fitted to these tanks, and it is interesting to note that, since the fitting of these anodes, no further attacks have been noted, and indeed the pitting has been arrested. The original cathodic protection system adopted was recommended by the Electro Rust-Proofing Corporation of New Jersey. The anode distribution throughout the tank system was as follows:

Tank description	*Number of 60-lb. anodes*	*Number of 15-lb. anodes*
No. 1 starboard deep	20	
No. 1 port deep	20	
No. 2 starboard deep	20	
No. 2 port deep	20	
No. 3 starboard deep	14	
No. 3 port deep	14	
No. 1 double bottom	52	
No. 2 double bottom	65	40
No. 8 double bottom	36	
No. 9 double bottom	24	
Forepeak	21	

The anodes were bolted to the structure inside the tanks at locations selected by the experts on the job. There is no current applied to the system which relies for its effectiveness on the fact that magnesium is at the top of the electromotive scale, whilst steel is several metals lower. The system was designed to last three years with regular ballasting on the return trip from Kitimat. When the tanks were opened in September 1956, most of the anodes had wasted away about 60 per cent, which leaves one year of effective life as planned. The structure of the tanks was covered with a white calcareous deposit but underneath this the steel and aluminium looked bright and new. A great deal of scale had fallen to the bottom of the tanks and this was beginning to interfere with efficient drainage to the ballast suctions. The scale was removed. Six new 60-lb. anodes were fitted in place of wasted units in No. 9 double bottom tank. The 15-lb. anodes in No. 2 double bottom tank were removed because their bolting arrangements had failed, due probably to poor insulation. These were put in as booster units and they are no longer considered necessary.

Taken all in all, the anode system is proving very effective considering the cost of procurement and installation of the anodes at just over £4,000. This is very little more than the cost of wire brushing and cementing the same tanks. Naturally, American prices are being quoted here.

Electrical

No difficulties have been experienced with the electrical system and it may now be concluded that this was successful. The author maintains, of course, that the prospect of fitting motor generator sets for conversion of a.c. to d.c. for winches and other auxiliaries "takes the gilt off the ginger bread", and protagonists of a.c. would do well to develop quickly a definitely reliable static rectifier. For too long now, mercury arc rectifiers and selenium rectifiers have been in process of development. The author is not aware that anyone has really satisfactorily solved this problem.

Machinery

The fitting of a steam turbine instead of Diesel has been proved wise for the very reason for which it was fitted. That is to say, as there are no terminal facilities for machinery overhaul it has been justified, although it may well be argued, and the author would agree, that had the correct personnel been available and were the ship on a better run, Diesel would have offered many advantages.

It was felt at the outset that it would be difficult to achieve a rate of 0·60lb. per s.h.p. per hr., and this was not achieved. The ship is now running at about 0·63lb. per s.h.p. per hr., which may be considered generally to be reasonable.

Experience has also shown that the type of evaporator fitted is the best available today and, whilst great reliance is placed on these evaporators, they have stood up to their job. The double effect, of course, has the advantage that they can be operated as single effect should there be a failure somewhere in the system.

The auxiliary air ejector circulation was altered from condensate to hot water, which had a negligible effect on the efficiency. Also, since the vessel went into service it has been found necessary to bypass the condensate round the evaporator condenser, the temperature of the condensate being too high to vacuum control.

Apart from these difficulties the installation has been perfectly satisfactory.

Discussion

MR. W. SAMPSON (Vice-President) said that although he had a brief for his opening remarks, he had come to the decision only a few minutes ago that Mr. Atkinson had asked all the questions and given all the answers. In fact, there was very little to discuss from a general point of view, though possibly a great deal of detail.

He felt sure it would be recognized, as this was a paper written for a joint meeting of the Institute and the Institution of Naval Architects, that the author had so well arranged his paper that those features of particular interest to the naval architect were dealt with quite separately from the sections dealing with both the machinery proper and the electrical installation. He would point out to each of these professions, electrical and naval, marine and mechanical engineering, that the paper was so well set out that it was quite simple to follow the particular section in which one was more particularly interested.

When ships of a special nature were conceived and built, the manner and skill with which the special requirements were catered for were all matters of vital interest to the two institutions, and there had always been a place in the *Transactions* for papers of this nature.

Before passing some comments on the engineering aspects of the vessel, he would remark that on reading the paper he had the feeling that there must have been, on the part of the owners, a great urge to use aluminium in every possible manner throughout the ship where it was thought to be suitable. He meant to convey by this that in the normal construction of vessels the main requirements governing the use of the aluminium (and he referred particularly to the cross-channel steamers, liners and naval ships) were those of low top weight and stability. But this paper gave the impression that almost everything in the ship was examined to see if it could not be made of aluminium, short of the strength structure.

However, this made the paper even more interesting when one considered that the use of aluminium was extended to the pipe systems, air pipes, walkways, ladders, galleries, and so on. For he could hardly conceive that this great use of aluminium was made because of weight and stability reasons, which were not really vital in this class of ship. The experience gained and the method in which aluminium was used as well as the construction of these items which were not normally made in this way certainly formed interesting reading.

In reading the paper he first looked for the author's comments on the fire hazards, as he had had a very sad experience of a fire with aluminium. It was in a boiler, by the way. The aluminium alloy used melted at 1,100 deg. F. and in this case there were some "Thermit" fires. He was very pleased indeed to see how carefully in the *Sunrip* these fire hazards were taken into account.

Then he looked for the corrosion hazards involved, and obviously great care was taken to ensure high immunity from the corrosion aspect also. The author gave the names of the special materials, packing materials, and it was striking that there was such dependence against corrosion placed on the packing materials. He was left with the feeling that these materials might not give the security required, and he would like the author to confirm his confidence that ten or fifteen years from now the packings, fabrics, faying of the surfaces and so on would be in the same condition as now installed and would not have suffered deterioration, and that in a few years' time serious corrosion effects would not be found between steel and aluminium where moisture existed. He had serious doubts about the length of security against corrosion.

Turning to the electrical section, here there was this continuing controversy as to the choice between a.c. and d.c. Much was heard about this at the Institute, but no doubt other contributors would pick on the quite definite estimates which the author had given. He was struck, though it was not a matter he knew very much about, by the very large percentage given in terms of savings in weight and costs when he saw figures like 23 per cent on first cost and 25 per cent in weight and then the broad statement about maintenance. These were very large figures and he was, after reading the paper, particularly interested in the author's assurance that these matters had been thoroughly looked into by people with open minds.

On machinery he had very few comments to make. He could well imagine that for the small power of 5,000 h.p. it could only be the practical considerations the author had mentioned that governed the choice of steam machinery. But he thought that choice was right in view of the short term and the very heavy fuel. The choice was a very wise one, though economically on the fuel saving bill it was hard to justify. He was surprised, however, at the very low thermal conditions, namely 470 lb. pressure and 706 deg. F. superheat. The author's reason for doing that did not satisfy him, and he was not satisfied that the choice of pressure and temperature was justified because of personnel. In many ships, such as tankers and cargo liners, where the personnel problems were certainly as great as in this particular ship, the 650/850 cycle was almost standard practice. It had been in operation for many years now and had proved very simple indeed. There could have been a worth while gain, for a consumption figure of 0·6 lb. or even less, possibly 0·58 lb. per h.p., could have been obtained in this particular installation.

In all other respects the steam machinery was normal, but it contained some special features, and he had picked out only two. He was intrigued with the system of pump priming the author had mentioned and was interested to see the fitting of a really good evaporator. In the United States and Canada they had been a long way ahead of this country in evaporator design for many years. It was only in the last year or two that this country had taken the trouble to design good evaporators. He would not care to estimate what must have been spent in fuel by inefficient evaporators or the penalty paid for the fresh water which need not have been carried. However, the design of evaporators was now being given the attention it deserved in this country.

In conclusion, it would be agreed, he thought, that the author had read a most instructive paper. It was distinguished particularly by the care taken to give the *pros* and *cons* of every decision taken, the full economic picture, and finally the results obtained.

DR. E. C. B. CORLETT, M.A. (Associate Member) said he also would like to thank Mr. Atkinson for what was, in a way, a classic paper giving more information on the design aspect of the *Sunrip* than any other he could recall reading in this country. It was, in fact, in the tradition of American papers, which had no reservations. Mr. Atkinson had been outspoken in one or two places in the text in a non-technical sense, too, which was all to the good.

His own interest in the paper was mainly not on the engineering side, and he proposed to deal with a number of points more or less in the order in which they arose in the text.

The first was the deadweight displacement ratio achieved. This was very good indeed, and the author had, if anything, been rather modest in his comment on it. If one considered that there were continuous centre line bulkheads in this ship and that she was quite elaborately equipped in many respects, to achieve a value of 0·755 on the speed/length ratio in question was certainly no mean achievement. This ratio had been achieved by a number of approaches. The ship was, of course, a welded ship and the machinery, well designed, although not advanced in its main features, saved considerable weight in certain directions where this mattered.

The distiller was of interest, and he had found in recent cases that to be able to rely—especially in fairly high-speed vessels—on a minimum quantity of feedwater or fresh water, might have an appreciable effect on the design and substantially reduce the overall size of the ship. Following his company's introduction to the particular distiller mentioned, by way of Saguenay Terminals' choice for the *Sunrip,* several ships with which he was connected were having this type fitted on merit.

The 'tween decks hatch feeder arrangement was very ingenious. He had seen it operating, and there was no doubt that it was efficient.

He would be glad to know whether any difficulty was experienced in fitting the panels, bearing in mind the longitudinal sheer. Having made a few sketch arrangements, he had come to the conclusion that this might be a major difficulty, especially if the ship had a considerable amount of sheer in the end holds.

Dealing with aluminium, he said that one basic point brought out by the author with a wealth of comparative data was that, bearing in mind the price of the material, it was absolutely out of the question to consider riveted construction for deckhouses, as opposed to welded construction.

Having, therefore, postulated welded construction, it was necessary to build the houses of an alloy which was weldable and which would give really good properties in the resulting structure. Having done that, one was led back to the types of material used in the *Sunrip.* This, in turn, led to a hobby horse of his own: that it was time there was international standardization of these alloys for ship construction. Without standardization, the shipowner would have to pay in the long run because he would not be able to get repairs carried out on a world wide basis, and, if he did, he could never be quite sure just what had been put into his ship.

Weight ratios were another basic consideration and values under 0·4 were possible. The weight ratio, of course, was the ratio of the actual weight of aluminium to the weight of steel that would have been there had there been no aluminium. It was virtually impossible to obtain an economic design if the ratio were allowed to rise to around and over the 0·5 mark and a number of ships were afloat with ratios between 0·36 and 0·40; indeed, Saguenay Terminals, Ltd., had two at the moment, and shortly would have several more. There were other Canadian ships of British design with ratios of this order and there was nothing problematical in achieving this with any of the classification societies.

The distortion that was apparent during the construction of the house on the *Sunrip* was, he would agree with the author, to some extent due to the cutting of openings after completion of the house. As the author had said, much more was due to the fact that this was the first large welded aluminium ship structure ever produced, and thus there was a great deal to find out.

Subsequently the same shipyard, the Davie Shipbuilding Co., Ltd., Quebec, produced a ship, the *Blue Nose,* a short/sea passenger liner, with houses of the same order of weight and the same type of construction. The distortion problems were much reduced, he understood, probably due to the greater experience of the operators.

The *Bergensfjord* met with little distortion, but he imagined that representatives of the aluminium companies would enlarge on that point, especially as the *Bergensfjord* was of a fundamentally different type of construction with butt welds in the plating made on the flanges with special welding stiffeners. By this means extensive fillet welding was avoided, although light quick sealing runs between the web of the stiffeners and the deck plating had been made.

As to painting, the *Sunrip* at the moment was by no means unpleasant to look at. The house was grey and there was a minute quantity of what might be a corrosion product, although it was doubtful whether this might not be to some extent dried spray. One had to get within a few inches of the house even to see this and from two or three feet away the house was a pleasant uniform grey, although he personally preferred the appearance of white paint. The aluminium to steel joints had stood up to service very well.

He agreed that a fibrous base was essential to the packing materials, although in the case of the *Sunrip* the types of joints were not very sensitive to the extrusion of the plastic material mentioned by the author. In another ship with which he was associated, the weight of a deck and a superstructure rested on the packing material and severe extrusion took place. This taught a lesson, and that type of joint was not repeated.

The author remarked on fairly extensive pitting in the bilge and ballast lines during the first period of service of the ship, in spite of insulation being fitted between the lines and the steel. Was an electrical continuity test carried out? If there was any leak at all there would be galvanic action. Aluminium heating coils fitted in tankers to which a continuity test was applied gave completely satisfactory results, providing periodic attention was paid to the possibility of accidental leaks. For instance, a steel bar dropped across the coil in the hold would establish a short circuit.

Finally, he wanted once again to thank the author for his paper and also to record his appreciation of the enormous amount of information made available about the ship and the considerations leading to her detailed design by Mr. Atkinson, Saguenay Terminals, Ltd., and Davie Shipbuilding, Ltd. The paper in itself might be classified as a minor textbook on the subject of a particular ore carrier.

Mr. A. W. Davis, B.Sc. (Member) said that the author himself had almost seemed a little apologetic about the steam conditions adopted and the speaker would like to endorse Mr. Sampson's remark that one might have expected, in a job where so much advanced thought had been employed, to see the adoption of a higher steam temperature.

He felt, nevertheless, that in making such a remark he was concentrating on a part of the paper that was not intended to be concentrated on, but certain statements had been made and comment upon them was desirable.

The author had been very honest in stating that the anticipated consumption had been substantially exceeded, and it might be that this was to be associated with the amount of water that was being distilled. It would be interesting to have his comments on that point.

But however this might be, the information he had given could lead to misunderstanding and the high consumption rate must not be regarded by readers as further reducing the differential in relation to turbo-electric propulsion as given by the author in Figs. 17, 18 and 19 which, it was gathered, were extracted from a previous publication. Anyone who had examined the practical comparison of geared turbine and turbo-electric designs would probably agree that these curves were too close together and that both in respect of relative weight and cost as well as consumption the information applicable to turbo-electric drive enjoyed some discrepancies in its favour.

The bulk of the paper was devoted to items of novel interest upon which the author was to be congratulated.

Mr. A. N. Savage (Member) said that as an electrical engineer he would confine his remarks to the electrical section of the paper.

He was a great advocate for a.c. in ships' installations and therefore agreed with the author's selection of a.c. for the installation of the *Sunrip*. But he could not entirely agree with his selection of d.c. deck machinery. And he could not but feel that although the author fitted motor generator sets that when it came to the section of the paper on operation he was still searching for something.

He talked about rectifiers and that spoilt any a.c. installation. In this country today they were very fortunate that an a.c. winch was not only being developed but was being fitted which could meet all the requirements of normal cargo work. The author talked about the variable speed d.c. winch, but that was only trying to emulate the steam winch; and the d.c. winch had tried to emulate the steam winch.

If one carried out a survey of cargo working—and this had been done—one would find with these variable speeds and light hook speeds that fast speeds of working meant very little. Four ships in a certain port were loading the same cargo in the same month of the year, and a comparison of their rates of loading revealed some astonishing facts. Two ships fitted with 80ft. per min. winches loaded cargo at an average rate of 22·5 tons per hr. per gang, but two other ships with winches rated at 130ft. per min. only loaded cargo at 17·95 tons per hr. per gang. A ship unloading meat in the London Docks on which a check was taken was only working at the rate of 5 tons per hr. per gang.

On a load cycle being taken, it was found that taking the loaded hook from the lighter and lowering it into the hold took 37 seconds. There was then a wait of 74 seconds before the stevedores could unload the hook. The hook was then lifted out of the hold over into the lighter in 30 seconds and it had to wait 95 seconds before the next load was taken. Therefore variable speed, light hook speeds, under present day circumstances did not mean a thing. In this country today there was a single-speed squirrel cage winch with an absolute minimum of control gear which he was confident would do the work that was wanted, and his company were fitting such winches. Motor generators should not be fitted and they must not search for rectifiers and the like.

With regard to relative costs and relative weights, in the paper* he himself gave to the Institute a fortnight previously he had also given relative volume. He agreed entirely, with all due respect to Mr. Sampson, as to the costs and weights given by the author. But maybe the author was in a better position; he stated that he had co-operation, and that was what was wanted in this country today—a little more co-operation.

There was one point to which he must refer. The author stated under "Further Comparisons" in (*b*) on page 276 that the cable losses in a.c. were slightly higher than for d.c. Presumably the comparison was between 440 volts a.c. and 230 volts d.c. If so, the cable losses would be considerably less with an a.c. than with a d.c. system.

There was another point he would like to qualify. The author said he was supplying his lighting circuits at 117 volts because it was safe. There had been a lot of muddled thinking about a.c. voltage, but he could assure everyone that a lot of thought had been given to this in various committees which were sitting at the present moment, and the only safe a.c. voltage was 50 volts. Anything above 50 volts could be fatal, according to circumstances. Therefore these voltages must be treated with respect. It was interesting to note from H.M. Inspector of Factories' Report that two-thirds of the fatal accidents with regard to electric shock were from electric shocks of less than 250 volts.

He was not blaming the author, because there was much muddled thinking about this, but 117 volts was not safe. All he would say was, "Don't just accept it as being safe, take particular care".

In his comparison of the advantages and disadvantages of a.c. and d.c. in Table I (*b*) the author stated that d.c. systems *were* limited in size because of relatively low voltage levels and the resulting high currents. This was not strictly correct, because there were some very large installations in this country today on low-voltage d.c. If the author had said these systems *should be* limited, then he would agree with him entirely.

The 12 per cent the author mentioned for direct-on starting of motors was without question undoubtedly low. He himself would put a figure of 50 per cent, but a speaker in the discussion on his own paper had said that he had actually seen a test where up to 75 per cent direct starting current was applied and everything was all right. He would have said 50 per cent, but 12 per cent was very low. It must be remembered that the more direct starting could be used the cheaper the control gear would be and the more simple, and there would be less maintenance.

Mr. L. W. Jefferson agreed with previous speakers that one of the most impressive features of the paper was its extreme detail and the way the author had not hesitated to set out all the factors taken into account in the design of the ship, whether they favoured his case or not. This applied in particular, perhaps, to those parts which dealt with the aluminium structure, and some of the figures given were without precedent. In the limited time available, he would confine his own remarks almost entirely to Appendices 1, 3 and 4 on pages 287 and 293.

In Appendix 1, the author compared three possible cases for the aluminium structure, using aluminium to three different extents in the deckhouses and masthouses. Eventually, case no. 3 was selected as giving the most favourable cost per deadweight ton gained. In fact, the cost per ton of deadweight gained, excluding fire protection, did not vary much in the three cases and it seemed more by chance than anything else that case no. 3 was the best. The figure arrived at was £166 per ton for a total of 110 tons approximately, which rose to £244 per ton taking into account fire protection according to scheme D.

These figures were based on Canadian shipbuilding costs and assumed a cost of steel structure as erected in the ship of about £173 per ton and a cost of aluminium structure of £800 per ton. It was interesting to see that the resulting cost per ton of deadweight gained compared reasonably well with present price levels in Great Britain. The author asked them to consider the case without rather than with fire protection, having pointed out in the paper that the serious extra cost incurred in providing against fire risks in aluminium structures was a major factor. That was indeed true, but it was interesting to record that it was possible now with an ordinary cargo ship, which as the author pointed out did not fall within the scope of the 1948 International Convention in these matters, to derive by careful thought a fire protection system which would satisfy the Ministry of Transport, provide for all possible exigencies and—what was equally important—neither add materially to the cost and weight of the aluminium structure nor necessitate the use of compressed asbestos fireproof board, which unfortunately was still not a material at all popular in the average shipyard in this country.

The author had perhaps been a little hard on his general argument in suggesting that the cost of fire protection was still extremely excessive. Perhaps he would say, however, exactly why scheme D fire protection was chosen instead of E which would have achieved the same result and reduced the cost per deadweight ton gained quite considerably, as would be seen from Appendix 4.

Turning now to Appendix 3, the reader found curves showing the variation of "pay-off time" with different extents of aluminium structure and different price levels for aluminium. These needed careful study, because the letters

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* Savage, A. N. 1957. "Developments in Marine Electrical Installations with Particular Reference to A.C. Supply". Trans.I.Mar.E., Vol. 69, p. 217.

A, B, C, D and E did not, as one thought at first, refer to fire protection but simply to the different extent to which aluminium could be used in the structure, as detailed in the notes to that appendix.

If one looked along the horizontal axis to the basic aluminium price of 40 cents and up that vertical line until curve E, which was the relevant one for the ship as built, crossed it, the " pay-off time " appeared to be almost eighteen years. Would the author explain that? There was possibly a misprint or error in Appendix 3, although he would not dwell more on that save to say that in the text the author said that the use of aluminium would be considered justified if it paid itself off in ten to twelve years, and later on that in fact eight-and-a-half years was estimated to be the pay-off period.

The figures again did not check exactly with Appendix 4, although it would appear from that appendix that if the author had used fire protection scheme E the pay-off period would in fact have been eight-and-a-half years. In his own estimation this was very good for a ship that travelled a large part of the time in ballast. It was pleasant to see that the economic case for aluminium could come as near as that to being sound.

He must point out, however, that the author's argument did not lose any of its strength or the paper any of its value even if the economic argument in this case for using aluminium were not an absolutely sound one. He did not think anybody would suggest that in a normal deadweight carrier when no special circumstances prevailed the use of aluminium structure to increase the deadweight was justified at present prices, for it was usually a better proposition to modify the dimensions of a ship and gain the increased deadweight in that way.

Nevertheless, there seemed no doubt that on figures of the level indicated in the paper for costs and weights, there must be many ships, of the types in which restricted conditions of service made it quite impossible to modify the dimensions, where the use of aluminium to gain deadweight would be justified. The information given by the author in the paper would be of immense value to people who were considering ships of that type.

There must be somebody present who was actively concerned with the running of ships and had to consider things like cost per deadweight ton. Would they agree that figures of the type quoted would make a reasonably attractive proposition either for the normal deadweight carrier or for ships of special type with which they might be familiar?

If someone could express an opinion on that, it would be a most valuable contribution to the discussion.

He wished only to mention one further point, also on finance. He noticed that the saving in maintenance which resulted from not painting the structure was estimated at £1,000 a year. At first sight that did not seem very much, considering the total annual cost of operating a ship, but he had compared it with the approximate revenue which came from the increased deadweight, and he found that this itself was only £2,000 to £3,000 a year, and at that was considered a very worth while income. A saving of £1,000 a year on maintenance therefore seemed quite a reasonable proportion of the total gain and might be of more value than one at first thought. It would again be of interest to have the opinion of someone with practical day-to-day experience of operating ships. Did they consider this saving in maintenance a substantial figure?

The author's account of the treatment of the bimetallic connexions throughout the structure was particularly interesting, and showed that very careful thought was given to this aspect of the ship's construction. This was only natural in the circumstances, as the owners and builders would have received the soundest of technical guidance, but the question would doubtless be raised as to whether equivalent precautions could not in places have been taken in a more simple way. For instance, to keep the house side connexion clear of the upper deck, a 3ft. 6in. steel coaming was fitted and a flush strapped joint was made at the top of this. This not only reduced the effective extent of aluminium (especially in the comparatively small aft house) but also necessitated breaking the internal stiffener at half height and making the whole connexion complex. As the author suggested, the height of the coaming might be excessive, and it was probable that a deep steel foundation angle on the deck would have been equally effective.

The chances of serious galvanic corrosion with aluminium deckhouses might not be as great as was sometimes suggested, although the trouble that did occur from time to time through neglect of the proper precautions (for instance where aluminium to steel connexions were buried beneath deck sheathing) was a reminder that careful design and protective treatment were necessary. It was of interest to note that the only galvanic corrosion noticeable in the *Sunrip* after two years at sea was at one or two minor connexions where no paint had been applied in the vicinity, and painting was, he thought, worth while in such places if nowhere else.

The author discussed the choice of aluminium alloys in some detail, and rightly pointed out that it would be very desirable to have a standard aluminium shipbuilding material. Although NP5/6 plates and NE6 sections (which were equivalent to those used in the *Sunrip*) were now almost universally used for welded structures to the requirements of Lloyd's Register or other classification societies, it had been suggested that by making minor adjustments in the specifications a single alloy with a magnesium content of between 4 per cent and 4½ per cent could be internationally agreed and accepted for plates, sections, rivets and welding wire, but one of the difficulties in the way of this was the existence of the " heat treated " materials H10, H20 and H30, which could at times be used with advantage, particularly where welding was not involved, and (which was the critical point) were cheaper in the extruded form than the magnesium alloys. These and other factors delayed international agreement, although it would certainly be achieved in due course.

LIEUT.-CDR. A. F. GILLINGHAM, R.N. (Member) said that with reference to the author's remarks in his extremely interesting paper regarding the alternative machinery installations which were available from which to make a choice, he noticed no mention had been made of a free piston installation in conjunction with a low temperature gas turbine.

Apart from the apparent advantages of this type of plant from the maintenance, simplicity and other points of view, now beginning to become known throughout the shipbuilding industry and amongst owners, there was one advantage claimed over the steam turbine or Diesel installation which seemed to be particularly applicable when the free piston principle was applied to ore carriers.

It would appear possible, by so disposing of the gasifiers and gas turbine to save considerably in engine room length, fore and aft, over a conventional direct drive Diesel or boiler and turbine plant. Figures of up to 20 per cent saving had been mentioned.

In the general discussion early in the paper on the relative merits of the amidships or aft position of the engine room, it would appear that a main disadvantage in each case resulted from the length of the engine room. In the case of the amidships placed engine room there was a large gap in the continuity of loading, which would lead to undue stresses when the ship was loaded with a high density ore, whilst in the case of the ship with the engine room aft there were problems with the trim, the ship being bow down when loaded due to the forward position of the centre of gravity, this having to be compensated for by loss of carrying capacity in the form of a dry cargo hold forward, which was empty when ore was carried.

It would appear that the considerable reduction in engine room length made possible by the fitting of a free piston installation would greatly reduce the problem in each case.

It was interesting to note in connexion with the paper which had just been read that the first ship to be built new in this country with free piston machinery, a 9,400-ton deadweight ship now building on the Clyde, is in fact an ore carrier with a 3,000 s.h.p. installation.

With regard to a comparison with other types of propulsion on a fuel consumption basis, it was a little difficult to reach a conclusion from published figures. The author had based his comparisons in Fig. 19 on specific consumptions *for all purposes*. Owing to the shortage of information regarding these figures for existing free piston propelled ships, there being very little available trials data, it was only possible to find comparative figures for a free piston installation by estimation.

From the direct drive Diesel curve in Fig. 19, he saw the specific consumption for all purposes at 8,000 s.h.p. was about 0·385lb. per s.h.p. hr. As the specific consumption of this engine for propulsion only would probably be of the order of 0·37lb. per s.h.p. hr., it could probably be assumed that there was an increase of 0·015lb. per s.h.p. hr. for all purposes, or 4 per cent.

In all probability a free piston installation would show roughly the same increase of fuel consumption for all purposes by comparison with the consumption for propulsion only as that of a large Diesel. As consumption figures for propulsion only were known for the free piston (as published in the paper* read in 1956 by Beale and Watson before the Diesel Engineers and Users Association), the figure of 4 per cent could be applied to correct, and so obtain a consumption figure for all purposes.

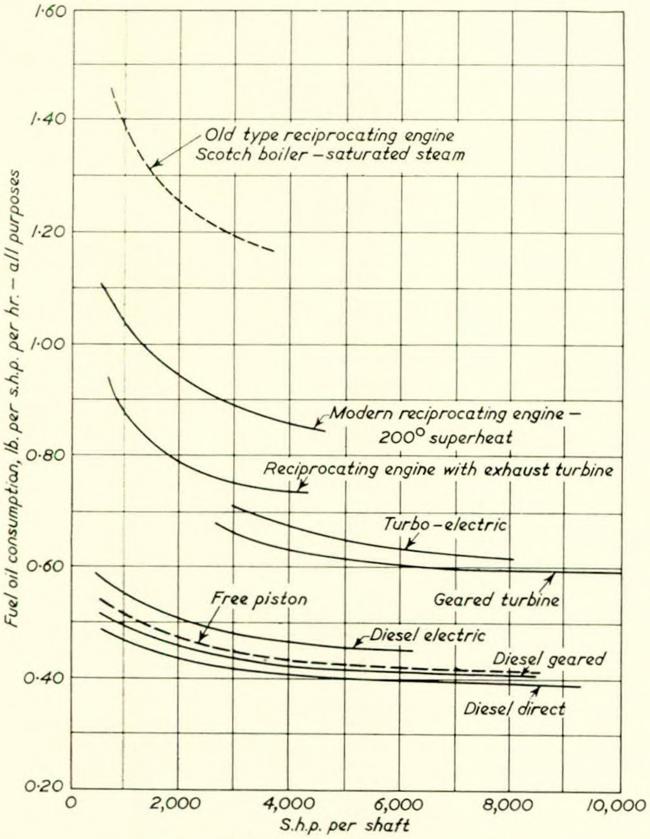

FIG. 27—*Fuel consumption curves for various types of machinery, showing free piston curve superimposed*

Having applied this reasoning to the free piston it was found that at 8,000 s.h.p. a figure of approximately 0·425lb. per s.h.p. hr. for all purposes was obtained. The rest of the curve could be obtained in the same manner, and superimposed on those in Fig. 19 it would be seen (Fig. 27) that it lay considerably less than half way between the direct drive Diesel and the geared turbine as regards economy, which would appear to give it a distinct advantage over the latter.

In a cost comparison with the direct drive Diesel, the free piston installation would cost slightly more than the former on running costs alone. He thought however that the extra running costs would be offset in the long run by the lower maintenance costs, and increased profit ensuing from the extra cargo carried in the space saved.

MR. R. LOWERY said he had not had an opportunity of reading the paper as he had only arrived in London late the previous evening. Mr. Atkinson had informed him that he was reading the paper and he had felt he must come and hear it and say something about it.

It was certainly a classic, and as many of the speakers had said it went into great detail. He had often wished that British shipbuilders and shipowners would follow the American pattern of distributing freely all pertinent information about interesting vessels. In much of the published data in this country the persons producing the data carefully left out some very vital piece of information without which the rest of the data was useless.

The *Sunrip* was a most exciting ship to build. Shipbuilders built many vessels which they merely produced and virtually forgot about afterwards. The *Sunrip* was a stimulating job and a very exacting job for the shipyard and for the staff. When it was remembered that apart from the basic dimensions and the preliminary investigations into the choice of the machinery almost all the investigations set out in the paper were actually undertaken after the order was placed and while the vessel was under construction, it could be imagined that this was quite a great task for both the builder and the owner and did require considerable co-operation and co-ordination.

The builders were just as interested in the economic and practical results of the various alternatives as were the owners, because they felt they themselves had something to learn.

Prior to the *Sunrip,* Davie Shipbuilding had experience in working aluminium on the construction of several anti-magnetic minesweepers; the *Sunrip's* superstructure was, however, an innovation for them. Since then, as Dr. Corlett had mentioned, they had completed the superstructure for the *Bluenose* and he could confirm that this superstructure, which was quite complicated, actually gave less trouble to the builders than the *Sunrip's* superstructure because, of course, some lessons had been learned.

Mr. Atkinson had mentioned the extreme care which was taken to reduce the weight of the superstructure. He could not remember the exact figure, but he believed that after considerable efforts by Dr. Corlett and the Davie staff the original weight of the aluminium superstructure was eventually reduced by some five or six tons. That was a very commendable effort but it would have been useless if when they were saving five or six tons on the superstructure someone else put ten to fifty tons too much steel in the 3,000/4,000 tons of structural hull steel. It must be remembered that the rest of the ship, the steel structure itself, was given just as careful attention in order to save a ton or half a ton here and there in the structure. This also contributed materially to the very high deadweight displacement ratio obtained.

Mr. Atkinson had mentioned the advantageous effect of the comparative Young's modulus, steel versus aluminium, when aluminium superstructures were introduced into steel ships, and whilst this was definitely of considerable advantage in the manner referred to by him, it was one of the features which produced the greatest number of problems, because the aluminium must, of necessity, deflect further before it developed the resistance. In the *Bluenose,* while the structure was quite sound and the distortion quite small, there were vibrations in public rooms and in other areas where they would not normally occur in similar areas with a steel structure. Also the range of sympathetic vibration was much wider with an aluminium superstructure due to its "softness" than with a steel one. But by careful analysis and proper remedial action the vibrations on the *Bluenose* superstructure were entirely eliminated.

He could not agree with the author that when comparing the cost of steel versus aluminium superstructures the cost of special fire protection required on the aluminium superstructure could be ignored. Whatever the reasons for this protection

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* Beale, E. S. L., and Watson, P. May 1956. "Free-piston Gas Generators and Their Applications". Proc.D.E.U.A., S246.

it was, nevertheless, a portion of cost to the owner, brought about by the introduction of an aluminium superstructure. The absence of specific rules on this question also made the shipbuilder's estimating job extremely difficult and it was hoped that in the near future proper regulations would be produced.

The author's figure for the estimated annual saving due to non-painting of the superstructure appeared to be unduly high and was, of course, a major factor in proving the economic advantage of the aluminium structure. He supposed, however, that this figure was supplied by the shipowners and could be taken as fairly accurate.

The problem of the hatch covers forming the sides of feeders looked much easier as the author had sketched it than it actually was in the shipyard where, as Dr. Corlett had said, there were many problems arising out of sheer and fitting clearances, to achieve alumina tightness on the one hand and workability on the other. Nevertheless, they had found out how to do it and he believed it was working satisfactorily.

The problem of a.c. versus d.c. was like the story of Christianity, it was high time they were sure about it. He was not an electrical engineer but on the other side of the Atlantic the battle of a.c. versus d.c. was settled; there was no doubt about it. The shipowners and the shipbuilders were almost 100 per cent for a.c. His company had built some fifteen or twenty a.c. ships recently and of some twenty-five they had to build now he believed that none of them were d.c.

Unfortunately, none of the ships to which he was referring had extensive deck machinery but the other deck auxiliaries, such as windlasses, steering gear and so on, were a.c. Some ships had winches which were electro-hydraulic.

The Maxim evaporator was also virtually standard practice now on the other side of the Atlantic.

Another point he would like specifically to mention—possibly it was mentioned in the paper—was that all the cost comparisons made by the author, both with respect to aluminium and electrical installations, etc., were Canadian and therefore not necessarily applicable quantitatively in Britain. Labour costs in Canada were very much higher than in Britain whereas material costs might be only 20 to 30 per cent higher, and so the balance in favour of any alternative might not be in Britain what it was shown to be in the paper.

He had not had the paper long enough to examine it properly, nor did he now remember the details of the economic analyses which were made at the time; the shipyard did not make the decisions, of course, but he could say that in Canada the shipping company with which he was associated would normally expect in their ship operations a capital expenditure to pay for itself within about ten years after taking into account both income tax and normal depreciation. They felt that the question of taxation could not be ignored, because it was so high. The ten-year figure was rather empirical, because it depended upon what type of item was producing the saving.

He did not think that sufficient attention was generally paid to the type of saving being made in determining the relative economics. If, for example, the same expenditure could, on present day costs, pay for itself in ten years, if applied (*a*) to a device which would result in a reduction of crew or (*b*) to a device which would result in a reduction in fuel cost, he would choose the saving in crew cost since he believed crew costs over the next ten years would increase at a greater rate than would fuel costs and so write itself off in a shorter period. However, in their own company they normally took ten years with depreciation and tax as a fair guide.

This probably covered the majority of the points he felt he might add to the paper. He did want to say that this paper, such of it as he had seen, had stimulated his interest and he had not really appreciated just how hard his staff had worked. He wanted to congratulate Mr. Atkinson on a really excellent presentation, and also to compliment the owners for agreeing to make the data available.

Correspondence

MR. E. A. JACKSON (Member) thought the author was to be congratulated on producing a very informative paper. He was also to be congratulated on his courage in designing a very efficient ship incorporating so many new ideas, which appeared to have been, for the most part, very successful. He was, of course, helped to a considerable degree by the forward thinking which prevailed among shipowners and shipbuilders in the New World.

It was very interesting to note that the author had adopted what was virtually Naval practice, by distilling all the fresh water required both for boilers and domestic consumption direct from the sea. The fact that this could be done using an evaporator of modern design, showed this particular evaporator in a very favourable light. The writer well remembered the anxious hours when he was a Naval engineer spent pouring pints of silver nitrate into tons of water and watching flashing lights—all of which indicated that the water being distilled was very often not pure enough for feed water—and wondering if he could safely switch this slightly contaminated water to ship's tanks without there being too great an outcry from the ship's company. Later, when he was a merchant service chief engineer, he was highly delighted that the owners accepted as normal that the ship should carry large quantities of fresh water. However, this always shut out cargo.

It would be interesting to know from the author what was the extra deadweight carried per voyage by distilling all fresh water as required and what this amounted to in extra freight per annum.

The writer understood that this make of evaporator was only about one-third of the weight of evaporators of other designs. Since the author was so very careful to save a ton here and a couple of tons elsewhere in the construction of the ship, it would also be interesting to know what was the extra deadweight allowed by the installation of these light weight evaporators.

As regards alternating current, the author had again adopted modern practice, with consequent savings, as shown in the paper. The electric motors, however, for marine work must be constructed to the very highest standards, which included vacuum impregnation of the windings to eliminate the breakdown of insulation due to moist atmospheres and accumulation of dust and oil in the windings. By the reduction to a minimum of the various sizes of motors required, a complete spare stator could be carried for each size and the replacement of this in the event of breakdown was a simple mechanical operation which could easily be carried out by ships' staff.

The writer enquired whether in the case of driven machines, which definitely required a variable speed motor, consideration had not been given to the idea of supplying commutator motors with variable positioned brush gear. These motors gave infinitely variable speed control and indeed could be reversed simply by operation of the brush rocker.

In regard to lighting, Mr. Savage's remarks in the oral discussion on the adoption of a 50-volt system was a very sensible idea and there had been in the past far too little knowledge and far too much loose thinking upon the effects of voltage and electric shocks leading to loss of life.

In conclusion, the writer wished the author continued success in putting forward new and workable ideas and was sure that this paper would be studied both by the marine engineering profession and by shipowners with great benefit to both.

CDR. H. G. P. TAYLOR, R.N.(ret.) (Member) considered that this was a most interesting paper, especially to those in the aluminium industry, and particularly as it included statements on the results of 2½ years' experience in service.

The author did not state whether the economics of using aluminium cored (and possibly sheathed) cables were considered when deciding on the extent to which aluminium should be used in the *Sunrip*. Admittedly, a special dispensation would be required from the classification society but the risks of bimetallic corrosion and other troubles would seem to be less than those involved in some of the piping services for which aluminium was actually adopted.

The method of arranging the main aluminium/steel connexion to minimize the risk of bimetallic corrosion was particularly ingenious, though it was doubtful whether many shipbuilders would wish to carry the joint so high above the deck.

Reference was made to the need for a standard shipbuilding aluminium plate and section alloy. Since welding came into general use for joining aluminium, nearly all the aluminium plate used for shipbuilding in this country and abroad would come within the NP5/6 specification. It was agreed that stocks of aluminium plate suitable for shipbuilding might not, at present, be readily available in overseas ports, but this situation commonly arose when one used new equipment or materials and might be expected to improve with time and the increasing use of aluminium in ships. Incidentally, he expected many of them had known of steel plate manufactured abroad, which, when used for repairs, had not been entirely compatible with the original material in ships and had tended to cause galvanic corrosion.

On page 296 the use of magnesium anodes was described. It had been suggested that when using magnesium protective anodes the magnesium chloride which was formed might have a slightly corrosive effect on any aluminium on which it might happen to be deposited. Could it be stated whether any such effect had been experienced in this ship?

On page 270, at the top of the second column, the use of cotton fabric in joints was mentioned. It was important that this should be a non-absorbent fabric, otherwise it might act as a sponge and hold moisture.

He had a minor comment to make regarding a statement on page 270; in the second paragraph it was stated that Lloyd's Register had settled on an alloy containing 5·5 per cent magnesium *nominal;* this should surely be *maximum*.

The author pointed out the great care required in design when building aluminium into a ship. This, of course, was generally the case when one used any new equipment or material, and it was a feature of the times that in order to make the fullest use of new types of equipment and materials, increasing knowledge and skill was almost always required of designers and constructors.

Author's Reply

Replying to Mr. Sampson, the author would say that he was correct in his impression that almost everything in the ship was examined to see if it could be made of aluminium, short of the strength structure. In an examination of this nature he thought it essential that their minds should not be closed (even partially) before the examination began. Few people realized the weight that went into a ship in respect of incidentals such as pipe systems, air pipes, walkways, ladders, galleries, etc. Although a comparatively small proportion of the weight in this ship was in aluminium, the actual weight considered was 76·4 long tons and with earning capacity as a consideration this was fairly considerable.

Mr. Sampson made a very important point in asking for confirmation as to the condition of the insulation in, say, ten to fifteen years' time. Continuity tests were carried out throughout the ship and as the results were satisfactory there was no reason to believe there would be a deterioration, unless there was a deterioration in the fabrics and packing pieces themselves. He could understand Mr. Sampson's doubts about the length of security against corrosion, because such a task had not previously been executed. At the best, one could say it was estimated that the results would be satisfactory and there was no reason to believe that they would not be so.

Regarding the electrical section of the paper, he could only confirm the large percentage saving in cost and weight and that the figures given were factual. An important point, and one the author would like to emphasize, was that when a.c. and d.c. were considered without bias by both the owner and the builder, it was astonishing what excellent results could be achieved.

He was naturally sorry that Mr. Sampson felt the pressure and temperature conditions were low and that he was not satisfied with the author's reasons for this. He would maintain, however, that these thermal conditions were as far as one could go; although difficulties were being experienced in Britain in regard to engineering personnel, they were nothing compared with the difficulties being experienced in Canada. Nothing would have pleased the author more than to have had the opportunity of obtaining the economies applicable to the higher thermal conditions and Mr. Sampson was quite right in his thinking.

Replying to Dr. Corlett, the fitting of the panels in respect of the 'tween deck hatch feeder arraangements was a difficult task in the end holds where it was necessary to deal with sheer. It was overcome, however, as a drawing inspection would reveal, by extending downwards the coamings and getting the box shape wherever possible. The proof of the pudding was in the eating and they had been entirely satisfactory. He would confirm that electrical continuity tests were carried out in the bilge and ballast lines particularly, and especially as Lloyd's Register had recommended the most careful supervision.

Replying to Mr. Davis, the author hoped his question on thermal conditions had been dealt with satisfactorily in his reply to Mr. Sampson. Mr. Davis also made the point that the probable reason for exceeding the anticipated consumption was the amount of water that was being distilled and he thought he must agree with him there. North American crews were notorious for using large quantities of water, of which a great deal was wasted. Figs. 17, 18 and 19 were acknowledged in the paper as having been reproduced from Seward's "Marine Engineering". If Mr. Davis was in disagreement with information given by the curves in these figures, it was quite likely that he was referring to later weight and cost information than was available when these curves were published. He would have thought they were about right, but clearly Mr. Davis had a vast preponderance of comparative experience with, and information about, this class of machinery.

In reply to Mr. Savage, the author was pleased that he was in agreement with the selection of a.c. machinery and he felt sure that his concurrence in this decision would do a great deal to increase its usage.

Mr. Savage's disapproval of rectifiers and motor generators would find general agreement and it was quite true that the author was still searching for something. He was searching for something, like many more, and if Mr. Savage, as he had done, could state that they were fortunate in this country in having an a.c. winch which was being fitted and which could meet all the requirements of normal cargo work, then the author would commend Mr. Savage and the manufacturers for having kept this information terribly secret. This did not seem to be fully realized and he did not think it was an exaggeration to say that adequate a.c. deck auxiliary machinery was the only real hold up in the progress of a.c. If an accepted solution were ready, then clearly there must be a landslide in favour of a.c.

What did Mr. Savage mean by normal cargo work? Was his thinking quite clear in pronouncing judgement on winch performance according to the delay experienced in the lower hold? He must agree that the speed of the winch would have less effect if the overall time were greater, but there would be those who argued that the performance of the winch must be considered independent of labour matters, and he was not entirely convinced that anyone would accept Mr. Savage's argument for the a.c. winch on the performance he had described. One might condemn the old fashioned superheat boiler on the grounds that if good firemen were not available fuel would be wasted in the first place and the economy would not be worth while. Such reasoning of course was illogical.

Mr. Savage, like Mr. Sampson, referred to the cost and weight advantage of a.c. and he would take this opportunity to mention that these figures were North American, of course, and not British. The battle of a.c. and d.c. having been fought and won made the use of d.c. very much less standard practice and therefore one could readily agree that because a.c. was overwhelmingly the accepted standard, the cost differential would be pronounced in its favour.

Regarding cable losses, these would be slightly higher in the a.c. system because normally they operated at 0·8 power factor and consequently higher currents were used with the d.c. system operating at the unity power factor.

Referring to 50 volts being the only real safe voltage, it might be that Mr. Savage had a real point there. His own point was that 117-volt a.c. was better than 230-volt d.c., but of course 50 volts would clearly be better still. One should not jump too readily to conclusions in respect of H.M.I. Factory Reports. Like all statistics, they had to be used with care. If one looked carefully into these reports, one would of course find that a great preponderance of fatal accidents was attributable to ladies reading in the bath and to young ladies standing in front of electric fires in nightdresses, and so on. Clearly, this sort of situation did not arise in a ship and therefore the proportion of fatal accidents should be considered in the light of very different conditions.

He had not intended to say that d.c. systems were in fact limited but certainly they should be limited because of the technical reasons given. In fact, the limiting in size of d.c. systems was something he would like to explain. Marine d.c. voltages appeared to be standardized at a maximum of 240 because higher voltages were dangerous to personnel. At this comparatively low voltage, the rated current output of a 2,400-kW plant would be 10,000 amperes and the short-circuit current which could be produced by a generator fault alone would be 100,000 amperes. Assuming that half this load consisted of motors and their current contribution to the generator under fault conditions was added, then a fault current of something like 130,000 amperes was achieved. As far as he was aware, no air circuit breakers were in existence with a capacity in excess of 100,000 amperes, so it was really not possible to obtain adequate circuit breaker capacity for a 2,400-kW d.c. plant. On the basis of utilizing circuit breakers of 100,000 amperes interrupting capacity at their maximum rating, it would seem that the maximum plant size for a 240-volt d.c. installation was about 1,800 kW.

He had taken the opportunity in answering Mr. Savage's question to explain the matter in the greater detail that the subject obviously deserved.

Regarding the 12 per cent direct-on starting for motors, he must confess that this was something new to him and he was pleased to learn that his figure was incorrect. There were many others who used a figure of about 12 per cent, and he hoped they would profit from Mr. Savage's revelation of a truer figure. This again would have a direct influence on the price advantage of a.c.

Replying to Mr. Jefferson, the author thought he had rather misinterpreted the comparison between various metals with and without fire protection. The point he had tried to make very strongly was that were it not for the cost of fire protection, aluminium could be proved economical much more easily. In discussing different types of aluminium, riveted, welded, etc., one had to use a common basis for comparison, as he would readily agree.

It was true that scheme E from Table VI could have been used instead of scheme D and it would have produced a financial advantage but he hoped that Mr. Jefferson would agree that scheme E was not high class construction. True, it would do, and would satisfy the Ministry of Transport, but very few people built ships merely to satisfy the Ministry of Transport, otherwise it would be difficult to get a crew at all.

Mr. Jefferson had touched on a good point in respect of his question about the basic aluminium price of 40 cents per lb. This was the general sales price at that time for all kinds and the basic raw material for plating and extrusions was supplied at a price of 27-30 cents per lb., and not 40. Some of course was in excess of 40, but he had given the average figure.

Mr. Jefferson seemed to be hinting at the point that probably a sales advantage was given to Saguenay Terminals, Ltd., because they were a subsidiary of the Aluminum Company of Canada, which was the manufacturer concerned. Papers of this nature were useless unless one was scrupulously honest and therefore, to dispose of this point, he must say that it was true that this sales advantage was given. The reason for it was that a fall in price of aluminum was expected as more marine experience was gained, and he believed this had now been realized.

Replying to Lt.-Cdr. Gillingham, he must say of course that the question of the free piston was not even considered. It might well be that in the light of developments in the past four years, this type of installation would demand consideration if the tests were being made today, but of course at that time no ship had even been put on the drawing board, let alone constructed, and if Diesel machinery were declined due to the shortage of engineers of that particular type in North America, there could not be, in the author's opinion, a case for the free piston, both from the point of view of shortage of personnel available and lack of experience.

Replying to Mr. Lowery, the author would like to commend this gentleman for the enormous assistance given by himself and his staff, without which assistance, of course, the paper could not have been written. It was interesting to hear his comment about Christianity. It was known that those on the other side of the Atlantic were far more sure about most things than people in this country, and it was certainly interesting to note the implication that their minds were made up on Christianity!

His statement regarding the almost universal use in North America and Canada of a.c. equipment would once again help those who were wavering in a decision to take the plunge for a.c. Mr. Lowery had commented on the cost comparisons being Canadian and not necessarily applicable quantitatively in Britain. This was the case and the author had made this point not only in the paper, but in the verbal discussion, and he would take this opportunity once again to record that he was at all times aware that the advantages claimed for a.c. would not be expected to apply so extensively over here for the moment, but clearly they would apply in due course as and when more manufacturers produced a.c. as standard equipment.

Mr. Lowery also made the interesting point in respect of a device which saved labour being more advantageous than one which saved material. This of course was quite right; indeed, it was a national problem and some of the leading industrialists were acting on this particular supposition, not only in their industrial arrangements but also in their investments.

In final reply, the author noted with interest (and not without humour) that Mr. Lowery had to cross the Atlantic some four years later to discover that his staff had been working hard four years ago in Quebec. Associated with this hard work, of course, was the owner and his technical staff who so readily contributed and who were so willing to publish actual costs and weights.

In reply to Mr. Jackson's written comments, the estimated weight saving by fitting Maxim evaporators was about 10,000 lb. He would appreciate of course that this was comparing the Maxim evaporator, largely of monel, with the more commonplace type, of which a large proportion was cast iron.

Would Mr. Jackson forgive the author if he considered his question on the idea of supplying commutator motors with variable position brush gear as one of real academic interest only. Whereas, undoubtedly, they gave infinitely variable speed control and indeed could be reversed simply by operation of the brush rocker, the author felt he was verging towards special machinery, and as suppliers knew only too well it was in "specials" that the costs rose. Academically, unquestionably, his thinking was correct.

Replying to Commander Taylor, the economics of using aluminium cored cables had been considered, but of course there was nothing new in this application. The author had always approved of "Pyrotenax" because of its high quality and anti-fire advantages.

Commander Taylor would, he hoped, accept that there was much greater danger in being supplied with incorrect aluminium plating than there was in a variation of steel. Incorrect aluminium would have a much more rapid effect both on itself and the surrounding plates. This point must really be appreciated if satisfactory progress were to be made with aluminium. All too often one was asked: "What is your opinion of aluminium for marine use?" Many and varied were the applications and only those intimately connected with the industry could give a specification likely to be satisfactory.

Referring to the use of magnesium anodes, the slightly corrosive effect to which Commander Taylor referred had not up to now been experienced. He had an important point dealing with fabrics; this had been mentioned previously by Mr. Sampson and others but the author admitted it to be of fundamental importance.

Regarding his comment on the statement on page 270, the fact that "nominal" appeared instead of "maximum" was a printing error.

INSTITUTE ACTIVITIES

Minutes of Proceedings of a Joint Meeting Held at the Institute on Tuesday, 9th April 1957

A Joint Meeting of the Institute of Marine Engineers and the Institution of Naval Architects was held at 85, The Minories, London, E.C.3, on Tuesday, 9th April 1957, at 5.30 p.m. Mr. T. W. Longmuir (Chairman of Council, I.Mar.E.) was in the Chair and was supported by Mr. L. Woollard, M.A. (Honorary Vice-President, I.N.A.). A paper by R. Atkinson, D.S.C., R.D., B.Sc.(Eng.), A.M.I.Mech.E, (Member) entitled "Design and Operating Experience of an Ore Carrier Built Abroad" was presented and discussed. There were ninety-one members and visitors present. Seven speakers took part in the discussion. A vote of thanks to the author was proposed by Mr. Woollard and accorded by acclamation. The meeting ended at 7.50 p.m.

Section Meeting

Sydney

A meeting of the Sydney Section was held on Thursday, 30th May 1957, at Science House, Sydney. Mr. W. G. C. Butcher was in the Chair and forty-four members and guests were present.

A paper by Mr. H. C. Mullins entitled "Honeycomb Materials in Ship Construction; A Modern Technique from the Field of Reinforced Plastics" was presented and discussed. Messrs. Butcher, Buls, Joselin, Lees, Munro and Lieut.-Cdr. Edwards took part in the discussion.

A vote of thanks to Mr. Mullins was proposed by Mr. Buls and carried by acclamation.

Election of Members

Elected 19th June 1957

COMPANION

Stanley Evan Tomkins, O.B.E.

Elected 17th July 1957

MEMBERS

John Thomas Alcock
Cyril John Bermingham, Lieut.-Cdr., R.N
Jose Perez Del Rio
David Flockhart
Alexander Philip Forbes
James Cyril Glen
John McCallum Jamieson
James Robertson Kidd
Alexander Morrison
David Pinkney Priestly
Henry Rae
Paul Clifford Smith
Thomas Stokell
Stuart Leslie David Young

ASSOCIATE MEMBERS

Robert John Campbell Anderson
David John Blair
Neville Charles Bland
Joseph Benjamin Donnelly
William Dwyer
John Fisher Fry
John Thomas Gunn
Charles Gordon Hewitt
James William James
Peter Jones
Graham Francis Laslett, Lieut., R.N.
Ronald McIntosh
Kenneth Muckle McKay
Harold Rutherford Macpherson
Vilcourt Pierre Mondon
James Douglas Moore
Bernard Francis Pickles
Desmond Kenneth Quin-Conroy
Herbert John Rapson
John Ritchie
Iain Wylie Robertson
William John Savage
Mohammed Shuaib, Lieut., P.N.
Jack Winn

ASSOCIATES

Thomas Gray Boyd
William Henry Cross
Hendrick Johannes Markestyn
Francis Joseph Mooney
Frederick George Palin
Sung Yem Yen

GRADUATES

Tara Charan Banerjee
John Reekie Buchan
Derrick William Hardman
David Taylor Howie
Alexander Cloughley McGregor
Pradip Kumar Purkayastha
Arthur Ronald Scott
Alan Grant Smith
Patrick Jeremiah Strain
Richard William Turnbull
Thomas Gordon Walker
Kees Watts

STUDENTS

John Thomas Gibbs
Colin Francis Rogers
David Hutchinson Kent Simpson
Yan Ming Yip

PROBATIONER STUDENTS

Anthony Guy Clarke
David Roger Crawford
Donald Walter Crick
John Lyn Evans
Alan David Gambles
Roland George Knibbs
Peter Mylchreest
David Albert O'Neill
John W. Osborne

Peter Leonard Patient
Robert Malcolm Rathbone
Anthony Granville Reynolds
Arnold Robinson
Philip Frederick Turner
David Samuel Waind
John Wallis White
David Alan Wickham
James Robin Williamson

TRANSFER FROM ASSOCIATE TO ASSOCIATE MEMBER

Brian Hall, Lieut., R.N.
James Tucker

Ronald Aubrey Wood

TRANSFER FROM GRADUATE TO ASSOCIATE MEMBER

John Stuart Fletcher
Philip Edward Sporle
Archibald George Wilson

TRANSFER FROM STUDENT TO ASSOCIATE MEMBER

Keith Harrison Newman

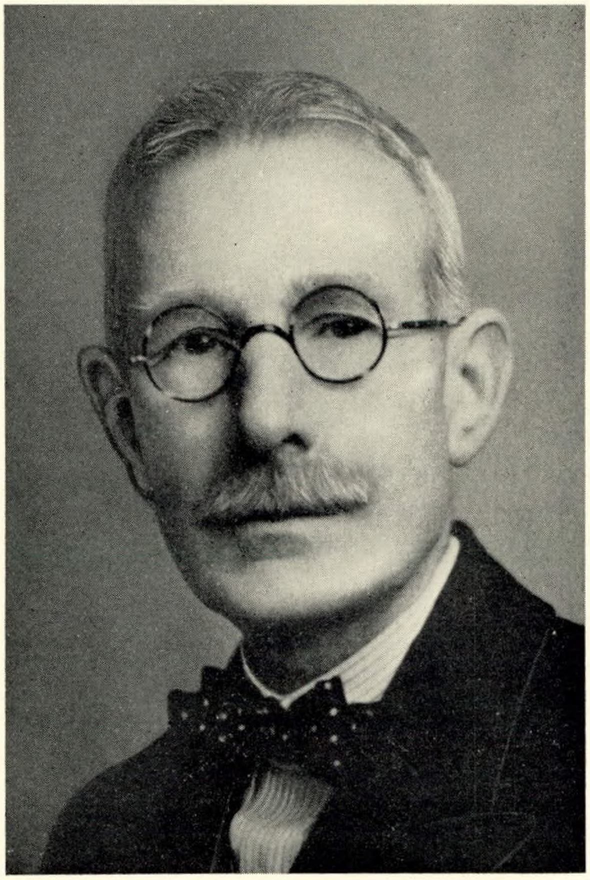
TRANSFER FROM PROBATIONER STUDENT TO STUDENT

Eric Cyril Avery
Colin Alexander Clunie

OBITUARY

HENRY JAMES VOSE

Henry James Vose was born on 17th June 1867. He served an apprenticeship with Messrs. Aveling and Porter, Rochester, Kent, from 1883/88 and was subsequently employed by Messrs. Muir and Caldwell at the Scotia Engine Works, Glasgow, from October 1888 until March 1891. He then joined the British India Steam Navigation Co., Ltd., being appointed fourth engineer of the *Chilka;* he served an an engineer in several of the company's ships, attaining the rank of second engineer, and resigned from the company in December 1900. He obtained a First Class Board of Trade Certificate of Competence in 1894 and an Extra First Class Certificate in 1901.



After shore employment for about a year with one of the boiler insurance companies, Mr. Vose obtained in July 1902, by his success in a competitive examination, an appointment as an Engineer and Shipwright Surveyor in the Marine Department of the Board of Trade. The whole period of his appointment with the Board until he retired in July 1932 as a Senior Engineer Surveyor was served in London in the Survey Office and in the Consultative Branch. He was in good health and spirits throughout his long retirement until his death at his home on 9th May 1957.

Mr. Vose was elected to Membership of the Institute in 1924 (after a preliminary association from 1899/03 as Member 1376) and became a Member of Council in 1929; in 1930 he proved to be so notable a Chairman of Council that he was asked to continue in this office for a further year. He served on various domestic committees during this period and was responsible for the establishment in 1932 of a staff pension scheme. He was the Institute representative on the L.C.C. School of Engineering and Navigation, Poplar, Advisory Committee, from 1931/38. From 1932/46 he was a London Vice-President and from 1947 until his death an Honorary Vice-President of the Institute.

Appreciation by

W. E. McCONNELL (Member)

My first meeting with H. J. Vose was in 1913 when I joined the survey staff of what was then the Board of Trade. As I was appointed to London and lived not far from him we travelled together at times and it was in this way that I first had the opportunity to develop our acquaintance, as our official contacts were not really frequent. But from the beginning of our association I valued his friendship and counsel. He was of a quiet and unassuming nature and I cannot imagine anyone quarrelling with him, for his views on any subject I ever heard him discuss were always founded on an impartial consideration of the matter and they were expressed without bias, and he enjoyed the respect of his colleagues.

Of his work at the Board of Trade I never heard of any criticism and in those matters in which I had personal departmental dealings with him I recall his unfailing courtesy and fairness. His services to the Institute were characteristic and it will be for his quiet and steadfast application of his powers to the effective prosecution of any work to which he put his hand that those who knew him will remember his fellowship and example.

William Robinson Bell (Member 4608) served an apprenticeship with the Barry Graving Dock and Engineering Co., Ltd., and first went to sea as a junior engineer about 1910. He obtained a First Class Board of Trade Certificate and from 1923/27 he was chief engineer of the Australian steamship *Five Islands,* coming ashore when the ship was sold. For the next six years he was mechanical engineer at the Mount Pleasant Coal and Iron Mining Company's Mount Pleasant colliery at Balgownie, N.S.W., and then for several years at the Corrincal Colliery and Coke Works. For a year or so he was in charge of a dredger in Fullerton Cove, N.S.W., but returned to mining work in 1937 as engineer at the Lithgow Valley Colliery. In 1939 he was appointed engineer at the pumping station of the Metropolitan Water, Sewerage and Drainage Board of Sydney, and on reaching retiring age in 1948 he was employed by the Cockatoo Docks and Engineering Co. Pty., Ltd., Sydney, until his final illness which resulted in his death on 5th February 1957.

Mr. Bell was elected to Membership of the Institute in 1922.

Robert Grisedale Cragg (Member 4105) died on 10th June 1956 after a short illness, aged seventy-nine years. He served a seven-year apprenticeship to Messrs. Evans and Graham, engineers of Liverpool, and then went to sea in tramp ships for three years. He joined the Beaver Line in 1902 and transferred with this fleet to the Canadian Pacific Company in 1903. In 1908 he obtained a First Class Board of Trade Certificate and in the twenty-five years he was chief engineer in the company before his retirement in 1937 he sailed in all types of ships, including their flagship, the *Empress of Britain.* Mr. Cragg had his share of adventure while serving at sea throughout the first world war, twice having been in ships lost by submarine attack and being picked up on each occasion after some days in the ships' boats. Mr. Cragg enjoyed good health throughout his retirement until the onset of his last illness, which was only of a few days' duration. He had been a Member of the Institute since 1920.

Henry Redford Fraser (Member 6523) was born in 1897. He served an apprenticeship with the Blyth Shipbuilding Company from 1913/18 and joined Sir William Reardon Smith and Sons, Ltd., as fourth engineer of the s.s. *Orient City* in 1919. He remained with this company for the whole of his career, serving as second and chief engineer in both steam and motor ships. He stood by the building of m.v. *West Lynn* in Glasgow in 1928 and later sailed in her as second engineer for a year when he transferred in the same capacity to m.v. *East Lynn;* in 1930 he was promoted chief engineer to the same ship (later renamed *Santa Clara Valley*), being transferred in 1936 to m.v. *Bradford City,* in which he sailed as chief engineer until November 1939. During the second world war Mr. Fraser was chief engineer of s.s. *Leeds City,* then of s.s. *Empire Sunbeam* and finally of m.v. *Houston City,* from which he was brought ashore in January 1943 to take up an appointment with the company as an engineer superintendent, the position he still held at the time of his death on 24th May 1957.

Mr. Fraser was elected a Member of the Institute in 1930.

Alfred Tierney Gibson (Member 4639) served an apprenticeship with Mordey, Carney and Co., Ltd., Newport, Monmouthshire, from 1903/08. He joined the Shaw, Savill and Albion Co., Ltd., in 1911 after several years at sea as a junior engineer and served the company as third, second, chief (from 1922) and finally commodore chief engineer in the *Dominion Monarch* until his retirement in 1952. He obtained a First Class Steam Certificate with Motor Endorsement.

Mr. Gibson received a C.B.E. in the 1945 New Year Honours and the following quotation from the citation gives particulars of the special reason for this award:

> "An outstanding incident occurred in February 1942 whilst his vessel, m.v. *Dominion Monarch,* was in dry dock at Singapore, when the Japanese overran Malay and were literally at the gates of Singapore.
>
> "Two days before the city fell, the vessel was in dry dock and all the valves on the ship's side, some sixty of them of various sizes, were lying opened up awaiting the surveyor. The labour panicked and despite the shelling and bombing that were prevalent, he personally, with his staff, worked night and day until the boxing up of these valves was completed and with the minimum of assistance flooded the dock and made the vessel seaworthy, bunkered oil and managed to escape from Singapore with a certain number of refugees down to Australia.
>
> "It was mainly through his personal example, which inspired so many people, that this valuable vessel was saved from the enemy."

Mr. Gibson died on 9th June 1957. He had been a Member of the Institute since 1922.

William John Gray (Member 7922), who died suddenly on 30th May 1956 in Penang, aged fifty-one, served an apprenticeship with John Dalglish and Sons of Pollokshaws, Glasgow, and joined the British India Steam Navigation Co., Ltd., as a junior engineer in December 1926. He served in various ships of the company until 1938 when he joined the engineering staff of the Singapore Harbour Board as a foreman engineer, where he rendered valuable service in the dockyard until the fall of Singapore early in 1942. He was amongst the last to leave the colony, working his way to India, where he joined H.M.I.N.S. *Baluchistan* as an engineer officer. He served in this ship for the whole of his war service, being discharged with the rank of lieutenant commander (E). He rejoined the Singapore Harbour Board in 1946 and served in various capacities until 1950/51 when he was transferred to Penang Harbour Board (now Penang Port Commission) as superintendent of Bogan Dalum Slipway, the senior engineering appointment in the Board.

Mr. Gray was elected to Membership of the Institute in 1935.

Stanley Lash (Member 9638) died after a long illness on 5th May 1957. He served an apprenticeship with the Thames Engineering Works, Greenwich, from 1903/08 and went to sea as a junior engineer with the Peninsular and Oriental Steam Navigation Company from 1909/14. Throughout the first world war he was a temporary engineer lieutenant on active service in the Royal Naval Reserve. After further sea experience with the P. and O. S.N. Company he went to the United States of America in 1920 and was employed there for two years by the United Fruit Company of Boston as assistant engineer on the building and fitting out of the electrically driven ship *San Benito,* being appointed later third engineer of this ship. He was in London from 1922/24 as marine engineer representative for the Vacuum Oil Company. In 1925 Mr. Lash went to France where he held shore appointments, first as engineer manager and later as general manager, with Simms Motor Units, Ltd., in Paris and Lyon; in 1936 he became owner and manager of the company but left Lyon in 1940 when the town was occupied by the Germans. From 1941/46 he was temporary civil inspecting torpedo officer at the Royal Naval Torpedo Factory at Greenock but then returned to Lyon to his own works until his retirement in 1955.

Mr. Lash was Associate Member 5076 from 1923/36 and was elected to full Membership of the Institute in 1943.