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# Electric Arc Welding in Shipbuilding

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## Introduction.

This paper is intended to give some indication of the use which is being made of electric arc welding in shipbuilding at the present time, and to present the principal technical problems which have to be met in designing merchant ship structures suitable for welding. The design and construction of existing all-welded ships has not been dealt with, as each ship has already been described in papers read before various institutions.

For convenience, the paper is divided into three sections :—

Section I. (*a*) Welding carried out on deep sea trawlers.
(*b*) Welding as applied to parts of the structure of large ships.
(*c*) The practice adopted in a relatively small all-welded ship 150ft. in length.

Section II. Practical considerations influencing the design of joints.

Section III. Technical considerations in the design of ship structures.

From Section I it will be seen that there is great variation in practice and method, and that obviously the special conditions obtaining in a particular case must influence the choice. The treatment of Sections II and III is on broad lines, and details which might confuse close investigation have been deliberately avoided.

## Section I.

### (*a*) *Deep Sea Trawlers.*

There is no doubt of the real benefits which have accrued from the adoption of electric welding in the hulls of deep sea trawlers, as will be seen from the following description of its use in the construction of 36 vessels of this type. Most of them were about 160ft. in length B.P., 26ft. 6in. in extreme breadth, and of about 15ft. moulded depth. The fishing grounds in arctic regions are up to 2,000 miles distant from the fishing ports, so that the importance of a quick return journey with their perishable cargoes can be appreciated. The

*In which The Institute of Marine Engineers participated.

saving in weight made possible by welding has contributed to this.

Electric arc welding has permitted features to be introduced into the construction of these vessels which would otherwise have been impracticable. The shell protective mouldings, which are subject to blows from the fishing gear, frequently gave trouble when riveted, owing to leakage from "started" rivets. Welding these mouldings on the shell has overcome this trouble. Welding the steel decks has produced a water-tightness which had previously not been experienced, and is much appreciated by the crews. These steel decks are preconstructed in sections from 15 to 25ft. in length, each section being complete with beams, beam knees and any other stiffening required, and the gunwale bars. The seams and butts of the deck plating are butt welded; the beams of inverted angle bars are attached to the deck plating by intermittent fillet welds; the beam knees are overlapped on the beams, and attached by fillet welds, this being done before the beams are placed on the deck; the gunwale bars are overlapped on to the deck plating and secured by continuous fillet welds. Each completed section is erected along with the ship's framing, and they are joined together by flush welded butts.

Tanks of welded construction and adjoining one another have been built into these ships for the carriage of boiler feed water, liver oil, and drinking water; they are of a form which would be impracticable if riveted, and have proved satisfactory in service. They are bounded on the top by the after lower deck, at the after end by the after peak bulkhead, on the port and starboard sides by the shell plating, at the bottom by the shaft tunnel, and at the forward end by a transverse bulkhead; two transverse bulkhead divisions complete the boundaries of the three tanks. These tanks are built as one preconstructed welded unit with the exception of the shell plating. The lower deck is first welded upside down, the plates forming this being butt welded; then the beams, which are formed of steel flats, are attached by intermittent fillet welds. The transverse bulkheads, which have previously had their stiffeners attached by welding, are then placed in position on the deck and fastened with continuous fillet welds, after which the tunnel is added and welded in position. This completes the unit, which is then removed and turned over ready for placing in the ship as her frames are erected. The boundaries of the tanks, where joining the shell of the ship, are attached by continuous fillet welds.

The engine seatings are welded as complete units, each consisting of engine-room floors, fore-and-aft girders and the heavy top plates. They are built upside down in the welding shop and afterwards turned over for placing in the ship as the framing is erected. These seatings are lighter, stronger, and more rigid than those formerly riveted, with the result that the engines are remarkably steady when running at full speed. Other parts of the ship's structure which have been welded are the bulkheads, double-bottom tanks, water-tight tunnel through the bunkers, auxiliary engine seatings, hatches, deck erections, skylights, etc. The reason for welding these items is to save weight, and this is achieved at a cost no greater than that of equivalent riveted structures. The bulkheads are preconstructed—each a complete unit—the butts of the plating being flush welded. The stiffeners are formed of steel flats, and are connected by intermittent welds; the boundary frame bars and beams are overlapped and welded to the bulkhead plating.

The double-bottom tank, about 30ft. in length, is built as a complete unit. The tank plating is first welded (flush butts), after which the inside framing is added and attached by intermittent welds, the water-tight divisions being attached by continuous welds. When completed it is removed, turned over, and placed in the ship as the frames are erected. The water-tight tunnel through the bunkers, about 30ft. in length, is built together with the fore-and-aft divisional bulkhead as a complete welded unit, and afterwards placed in the ship during the course of building.

The deck erections, consisting of the engine and boiler casings, chart and wheel house, after-galley house, stern house, etc., are preconstructed in as large pieces as practicable and joined together on the ship by welding. Butt welds are employed where possible, the stiffeners being attached by intermittent welds. The hatches and skylights are welded as complete units and afterwards welded in position on the ship. In one instance oil fuel was carried in a bunker extending from the keel to the deck and from one side of the ship to the other. This bunker had three longitudinal divisions, and these and the two transverse bulkheads were completely welded. The bulkheads in this case were welded direct to the shell plating with double fillets.

Welding has been employed for securing most of the fishing gear fittings, gallows stay connections, cleats, ring and eye-plates, leach line blocks, etc. A considerable number of blacksmith fittings have been replaced by welding together plates cut to shape by a gas profile cutting machine. For example, the steel mast hoops and eyeplates have been replaced by bars which pass through the masts and are secured by welding. Steering gear fittings, blocks, deck stops and channel guide supports are welded. The rudder double plates have been welded on the frames, and up to the present there has been no evidence of leakage; double-plated rudders, when riveted, invariably show signs of leakage when in dry dock. Other items welded are pillars, fish-room channel posts, deck pound sockets, gratings, ladders, chain and hawse pipes, etc. Steam boilers for extracting oil from fish livers have been welded. These boilers are of special shape, the top and bottom being a pyramidal form, with a rectangular middle portion. Boilers of this form would be difficult to make without welding. Large numbers of these boilers have been built and no leaks have occurred. Previously a simplified form of riveted boiler was used, and it had to be welded at the corners in order to ensure tightness.

The major constructional work on these vessels is done in as large units as possible in a special shop laid out for the purpose. It consists essentially of a large floor made of cast-iron blocks about 5in. thick, with numerous holes for dogging materials in position; such an arrangement permits of the work being assembled and welded under the most favourable conditions.

Whilst up to the present the welding of the shell plating on these trawlers has not generally been undertaken, there is undoubtedly a desire on the part of some owners for this to be done, particularly in the case of the insulated fish rooms where, if rivet leaks develop, they occasion considerable trouble. It is practicable to weld the shell plating *in situ,* but it is questionable whether it could be done without additional cost and delay. No doubt it will prove best to alter the design of the structure so that units of framing and shell plating can be preconstructed and afterwards assembled in position. Where additional facilities are necessary for dealing with the further extension in the welding of preconstructed units, and where, if such facilities were introduced, it would mean encroaching upon the existing arrangements for the preparation of materials for riveting, shipbuilders will naturally hesitate before embarking on such a step until welded construction is more generally accepted by shipowners.

(*b*) *Large Ships.*

In ships of about 500ft. in length welding is gradually replacing riveting in the construction of internal work, and particular attention is being paid to important work such as oil bunkers and tanks in parts of the ship's structure which are subject to stress, and which, when riveted, give trouble in maintaining oil-tightness. The following is a list of the principal parts of the structure which are now being welded in most large ships, and which so far have given satisfactory results in service :—

- Water-tight bulkheads, oil-tight bulkheads, and bunkers.
- Deck houses and engine and boiler casings.
- Ventilators.
- Tubular pillars, solid pillars welded in place, rail stanchions.
- Auxiliary engine-seatings.
- Generator seatings.
- Masts, complete with outriggers; derrick posts.
- Minor bulkheads.
- Bridge and boat decks.
- Boundary flats for wood decks and insulation.
- Fresh water and sanitary tanks.
- Engine room and all other skylights.
- Angle shoes for riveted work.
- Numerous clips and fittings.

*Bulkheads.*—These are designed for welding in panels arranged to suit the maximum lifting capacity of the cranes. The plates are all butt-jointed except the centre seam, which, when the bulkheads are made in halves, is given an overlap to allow for fairing. The plates are laid on specially-constructed welding tables, set to shape, and clamped down with the seams directly over a steel member of the table. Two welders start on the centre of the seam and work outwards; during this operation large circular weights are rolled along the edge of the seam, keeping pace with the welders; this keeps the edge level. After all the seams are welded the stiffeners are placed in position and welded with one light continuous run on each side. Two welders work on opposite sides of the stiffener, one following about 3ft. behind the other. Where stiffeners are not bracketed at the ends, compensation is given by running a full fillet for 15 per cent. of the stiffener length. The bulkhead is then turned over and a bead run on all butt-jointed seams and butts. The advantages claimed for this method of construction are a saving in weight and of caulking, and the certainty of obtaining an absolutely water-tight or oil-tight job, which is of the utmost importance, especially in insulated vessels. In oil-fuel bunkers placed in the midship portion of the vessel, where the structure is subject to considerable and varying stresses, it has been proved possible with this method of construction to obtain greater strength and freedom from leakage than was possible in the riveted structure.

*Auxiliary Engine Seatings, Shaft Stools, etc.,* are marked off on the ship and erected in position by tack welds. Although the "finish" welding necessitates a large quantity of vertical and overhead work, this is compensated for by the saving in weight, additional rigidity, strength, and neat finished appearance. The advantages claimed are simplicity of construction due to the omission of numerous small lugs, a saving in drilling and riveting in position, and the avoidance of the difficulty of fitting ground bars over tank top butts and seams.

*Generator Seatings* are designed in units up to about 25ft. in length. They are lined off in the positions they are to occupy on the tank top, completely assembled with tack welds, turned on one side, and as much finish welding as possible is carried out in the down-over position; they are then turned through 90° on to the top plate, and so on until they are back in the upright position, after which they are set in their correct positions, and sides, ends, and all brackets finish-welded to the tank top. In addition to the strong, clean and neat appearance, a considerable saving in weight over riveting amply justifies the welded construction, which is also found to be more rigid.

*Tubular Pillars.*—Two plates are used for each pillar, rolled to the required diameter with each plate edge chamfered; where the diameter is sufficient to allow of inside welding, and the material is ⅝in. or over in thickness, the plates are chamfered from both sides. The pillars are welded direct to the tank top and head plates; no angle rings are required for attachment. The advantages are a saving in weight and of anglesmith's work in making rings, and simplicity in fitting in place.

*Solid Pillars* are welded direct at head and heel. The rounds are ordered in exact lengths ready for placing in position. The benefits are a saving in weight by the omission of connecting lugs, and a saving of blacksmith's labour in making palms and feet.

*Minor Bulkheads* are designed in panels, and where the plating is under 0·26in. in thickness they are overlapped; the welding is carried out in a similar manner to the water-tight bulkheads. A 6in. flat is welded to the deck with a light continuous weld on each side to form a ground bar, and the bulkhead is lapped 1½in. to this, which allows easy fitting in the ship. The advantage gained by this method of construction is a saving in weight, and the neat flush-finished appearance.

*Light Superstructure Decks up to $\frac{5}{16}$in. in thickness* are constructed with ½in. overlaps on butts and seams, the plating being joggled to suit. The decks are erected complete, faired, and held in position with tack welds, the finish-welding consisting of one continuous full fillet on top. Where the decks are sheathed with wood, all studs for holding the planks are welded, thus avoiding piercing the deck, with the consequent danger of leakage.

*Deck Houses.*—The method of welding the panels, complete with stiffeners, on the welding tables is similar to that for the bulkheads. Two plates joined by a joggled lap give the necessary height, the panels when erected being joined by flush-welded butts. The rounded house corners are formed by one plate carried the full height and overlap-welded to the side plating. On most large houses a foundation bar all round the house provides the connection to the deck, the bar being riveted in place, and the house welded thereto. All inside partitions are either lap welded to beams or welded direct to the deck overhead, with a 6in. flat forming the ground bar to allow for fitting. Strength, lightness, and the very neat flush-finished appearance fully justify the adoption of welding for this class of structure.

*Masts and Derrick Posts* are constructed with two plates in the round, the circumferential butts being shifted clear of each other; the edges of the plates are double-bevelled, as for large pillars. In place of the full inside and outside doublings usually fitted in riveted-construction, flats or narrow thick doublings are fitted inside, these being welded with a light continuous fillet on each edge. The outriggers are welded direct to the mast.

*(c) Construction of an All-welded Ship.*

It has been predicted that when large welded vessels are the rule, shipyard cranes will have to be capable of lifting, say, 50 tons to take full advantage of preconstruction. Some experiences in dealing with a small all-welded vessel have a bearing on this point. It was agreed at the start that the vessel should be built in the shed or on the ground in the largest sections that could be handled, and at first it was considered that these should be 24 by 8ft.; but because the economy of preconstruction was soon obvious, the extent to which it was carried was gradually increased until, even with the somewhat limited facilities available, dimensions of about 50 by 24ft. were attained. The flat bottom sections were built with floors, intercostals, and, in the machinery space, with engine girders, etc., complete, and each unit was taken to the building berth for assembly. In these cases, edge-to-edge butts were adopted to avoid unnecessary overhand welding. The side sections were built complete with frames and side stringers, the frames consisting of reverse angle bars having the toes welded to the plating; the curved bilge sections amidships were finished with the bilge brackets ready for erection as a unit. The bilge brackets were arranged to overlap the bottom floors, and also the side frames in the side sections, and to facilitate erection one or two bolt holes were provided in the overlaps, but not afterwards filled in. While the bottom plating, transversely, was fitted edge to edge, the bilge plating overlapped the bottom and side plating to simplify erection. These overlapped edges were drawn close to one another with temporary tack-welded bolts and washers before the final welding together of the sections was commenced (*see* Fig. 1).

Each of the deck sections was complete with plating, beams and girders welded in position before erection. The plates of the bottom end sections were rolled to shape, the floors cut to the correct curvature, and the complete sections, about 30ft.

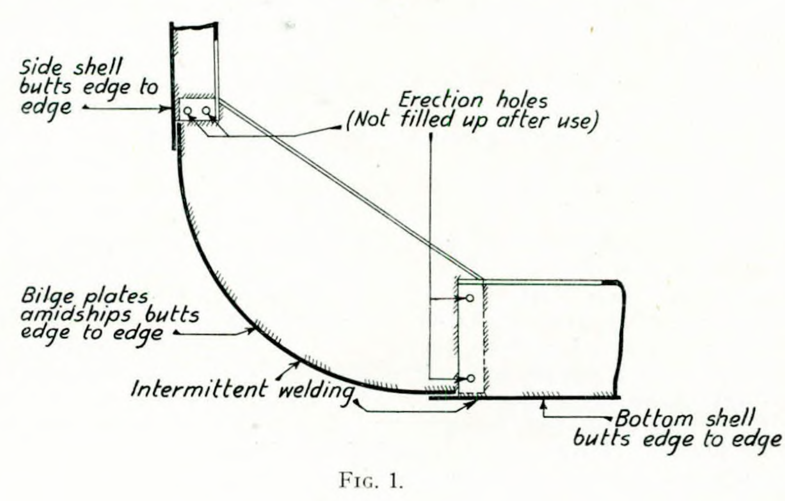


Fig. 1.

in length, finished in the shed. Some difficulty was anticipated with the curved sides of the ship at the ends, and here it was arranged to erect the frames singly, attaching them to the floors of the bottom sections which were already in position, and fitting the completed end deck sections on top of them. The end side plating was done separately, and this was plated vertically and was overlapped at the joints, as was also the lower edge to the bottom plating. Despite curvature in two directions, there was no difficulty anywhere in drawing the overlapped edges of the plates together by means of tack-welded bolts and washer plates. These bolts were removed after the welding was completed. Experience with this ship has emphasized the fact that to obtain the maximum efficiency large preconstructed sections should be built wherever possible, as the welding is both easier to do and to inspect, and a considerable amount of overhand welding can be avoided.

In connection with the welding bay in which preconstruction was carried out, it was found after various trials with temporary skids, etc., that the most satisfactory method to adopt was to lay down a separate bay with a floor formed of iron furnace blocks. When properly built such a floor remains level, and, by means of dogs, all the work can be clamped down during the process of erection. It has been found of very great benefit when dealing with bulkheads, complete engine seatings, skylights, deck houses, etc., the work being lined off on the floor, the plating laid down accordingly, flat and vertical work being clamped by dogs or loaded as required. When small deck houses are being completed in the welding bay it has also the advantage of allowing the work to be clamped down to the correct sheer and camber.

In constructing this ship the necessity for detailing how the welding was to be done was realised at the start. In the riveted structure the width of overlap, the number of rows and spacing of rivets and the diameter, are all specified, and a corresponding procedure should be adopted in welding. Thus the size of V in a butt joint, the size of electrodes, the length over which one electrode is to be deposited, current, direction of welding, the spacing of intermittent welds for stiffeners, etc., and all essentials were carefully specified and not left to the discretion of the individual operator.

It is beyond the scope of this paper to deal in detail with such a branch of the subject as distortion, but even in design it must be carefully considered. It is not a new trouble and occurs with riveted work, although neither the cause nor the effect is quite the same. In the ship described, butt joints of long plate edges were welded, after being closely tacked, by the stepping back process, Nos. 10 and 8 gauge electrodes being used at a rate corresponding to from 7 to 9in. per 18in. electrode.

## Section II.—Practical Considerations Influencing the Design of Joints, etc.

One of the most important points to be considered in designing a welded structure is that of the most suitable types of joint to adopt. Shipbuilders are so accustomed in riveted structures to overlap everything that it is a little difficult at first to break away from this and to consider the possibilities of the edge-to-edge joint. It seems impossible to lay down hard and fast rules, as the benefits accruing theoretically from a particular type of joint may be outweighed by practical difficulties when the actual erection of the work is undertaken. Joints of ordinary plating may be either edge-to-edge, plain overlaps, or joggled overlaps. It is generally admitted that the edge-to-edge joint is nearer the ideal than the overlapped joint, and there is not the danger, found with overlapped joints, of failure at comparatively low stresses due to laminations in the plating; in fact, it is the opinion of some designers that the overlapped welded joint should not be given a greater value than a riveted joint. This does not, however, hold to the same extent with joggled overlaps. If edge-to-edge joints are adopted it is essential for economical welding to keep the edges of the plates parallel to one another, and this sometimes forms a serious practical difficulty. This does not refer to the effect of distortion consequent on welding, but merely to the care necessary to get two 30ft. plate edges parallel to one another. It is hopeless to adopt the line that it does not matter if the gap, is, say $\frac{1}{16}$in. at one point and $\frac{3}{16}$in. at another, and that it can be filled up. Such a course would not give either satisfactory or economical welding, and if welding is neither satisfactory nor economical there is no object in adopting it. In passing it may be said that if accidents occur (and such a position must be met), no attempt should be made to close the wide end of the joint by means of weld metal contraction; the position must be faced boldly and the gap wedged and built in. On the other hand, if overlap joints are being used a slight variation in the width of the overlap does not matter, and this type of joint has much to recommend it on this account. Shipbuilders are familiar with joggling, and joggled overlaps may be found to possess the merits of both types.

There are many cases where expediency rules the choice, and with experience the best type of joint for the particular circumstances is soon settled. As an example of this, in the assembly of some large preconstructed sections of the bottom of a vessel, transverse butt joints were adopted to eliminate overhead welding as much as possible. With overlapped sections one edge would have been under-hand and the other overhand, while with butted edges with a single V, all welding was under-hand except a sealing run on the under side.

In designing a welded structure such as a ship, it is important that a concentration of welding at one point, such as occurs at a right-angled crossing of two butt joints, should be more carefully avoided. The attachment of stiffeners to plating may either consist of two light continuous runs on both sides of the web of the stiffener, or intermittent alternate welds, and in this also there is a divergence of opinion as to which is the more economical. Such a variation in views is probably beneficial from the point of view of the industries concerned; even after many years' experience of riveting one shipyard will work wholly with pneumatic riveting, while another considers that hand work is the more economical.

The choice of type of connection will be influenced largely by considerations of preconstruction. It would, however, be of real service if the relative strengths of butt joints, overlap joints and joggled overlap joints were known, not only in tension but also in compression, buckling and under alternating bending stresses.

It is, perhaps, not out of place to mention here one of the facilities of welding and also one of the dangers. It is sometimes found that when a bulkhead, part of a deck house, or other expanse of plating has been completed, the plating has bulged in certain parts. The introduction of an extra stiffener sometimes merely accentuates the defect by further localizing it. A very easy cure is to burn a slit the length of the bulge and then weld up the slit, the contraction of the weld being sufficient to straighten the plating. Such welding, if visible, must be buffed to leave the surface flush. This practice, however, should be used with discretion, as the welded slit may form a hard spot and give way under service deflections.

## Section III.—Technical Considerations.

Some indication has already been given of the extent to which welding has been applied to ship construction, and its success provides technical justification for its adoption to that extent; but the success of the relatively small all-welded ships already built must not be taken as absolute proof that a large all-welded ship would be equally successful. As will be seen later, the working stresses in the structure of a small ship are much less than those for which provision must be made in larger ships.

In designing ship structure it must be borne in mind that there are no absolute values for loads or bending moments, nor are the stresses and deflections definitely known. Therefore, calculations for welded structures must be based largely on proved experience with riveted hulls. Certain parts of the ship are regarded as main members of the longitudinal girder and subject to major stress, while the load (or stress) on others, such as tank bulkheads, can be estimated fairly closely. But there is no part of a ship's structure not subject to strain, and none in a static condition, free from movement, vibration, change or alternation of stress, or from the possibility of failure under constant repetition of minor stresses. Hence the appearance of cracks in material which is not under calculable stress.

The riveted ship of to-day is reasonably satisfactory, and this is due to intelligent scientific deductions from past experience; only experience will solve the new problems of welding, with its accompanying structural rigidity and the lack of that capacity for adjustment which is inherent in a riveted structure. This rigidity may be, and probably is, in the main an asset, but it is possible that it may prove to be the cause of defects in new and unexpected places. Present experience is too limited to make it possible to predict or anticipate the effect of constant repetitions and reversals of stresses in individual members of the structure of a welded ship, in some of which the actual movement may be measured in inches.

The complicated nature of a ship's structure, and the impossibility of estimating with any degree of accuracy the various stresses—their direction as well as magnitude—present a problem in design which has only been partly overcome by experience in a riveted ship, and that experience may not wholly serve for a welded design. For instance, it is well known that a ship as a complete unit will, and does, continually hog and sag to an appreciable extent without disturbance of riveting and caulking. This hogging and sagging connotes minute elongations and compressions of parts of the steel structure, and it is not possible to say whether these occur entirely in the steel material of a riveted ship. A riveted joint is admittedly weaker than the adjacent solid steel plating, and therefore these joints must possess sufficient elasticity to enable them to accommodate themselves to the normal movements in a hull structure. If, however, full benefit is to be derived from welding, the joints must have tensile and shearing strengths and elasticity approximately to those of the parent metal.

Electrodes which deposit material having mechanical properties approximating to those of mild steel can be depended upon to give welded joints which will withstand reasonable stresses from grounding, quay wall damage, etc., but such stresses may be termed "simple" in that there is no rapid repetition, or reversal of stress. The quality of elasticity in deposited weld material is necessary to meet, not the exceptional accident, but the frequent alternations of tension, compression, and possibly buckling between supports in one or more directions. In actual instances of riveted hulls failure has occurred in areas clear of connections, through the buckling of plating between supports, or through the lack of provision for unsuspected stresses at corners, etc., and while welding may be of great assistance in reinforcing corners, it may in other instances cause concentration of stress.

In comparing riveted and welded hulls it may be accepted that corrosion will be similar in similar steel areas whether riveted or welded. The present corrosion margins of thickness must therefore be

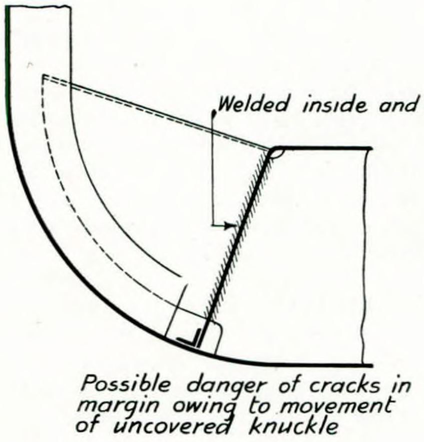


FIG. 2.

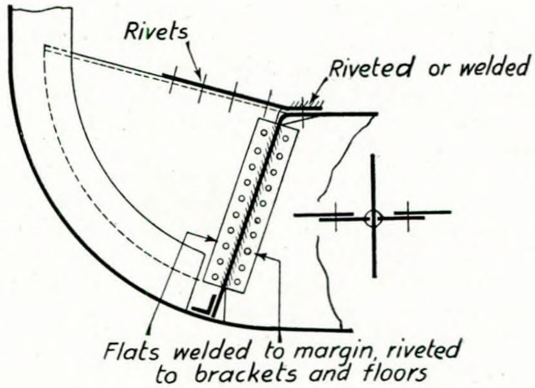


FIG. 5.

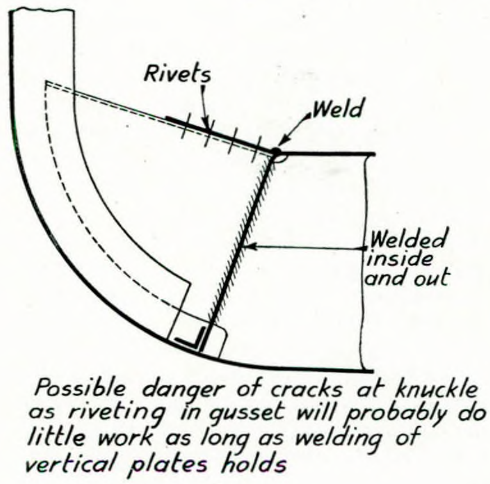


FIG. 3.

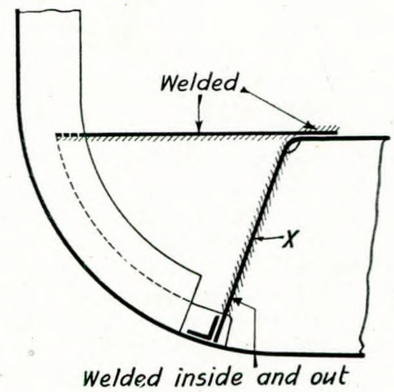


FIG. 6.

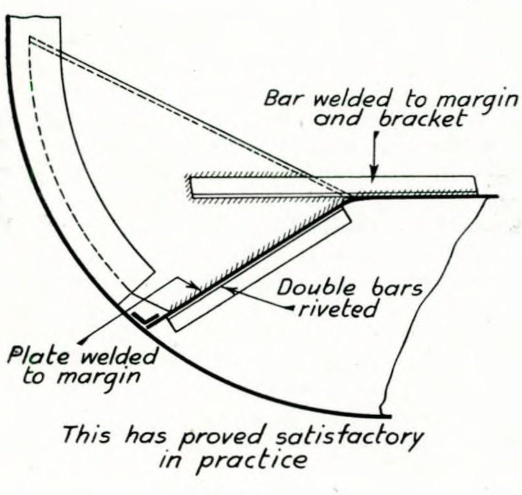


FIG. 4.

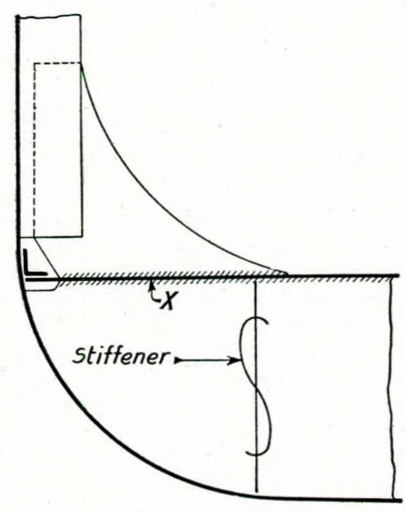


FIG. 7.

provided and should not be included in a comparison of the effective strengths of riveted and welded girders. The fact that corrosion margins are independent of steel thickness, and therefore constant for any size of ship, explains why calculated working stresses based on the gross steel thickness are normally much less for a small than a large ship. In these calculations due allowance is made for rivet holes in those parts subject to tension, and it is reasonable to give credit to this extent in a welded structure; but, as all parts of a hull girder may be alternately in tension and compression, steel plating must not be reduced below the thickness necessary to prevent undue buckling or deflection under the assumed compression loads.

Apart from what may be described as the major problem of designing an all-welded ship, there are many problems involved in the adoption of welding for individual portions of the hull, and despite the amount of such work already being done successfully, it is doubtful whether the full benefit is being obtained. The apparently simple case of a welded bulkhead is perhaps a good instance. In merchant ships of all kinds, including tankers, the renewal of bulkhead plating is largely due to wastage by corrosion or erosion, and it follows that reduced thicknesses in welded work may not be welcomed in spite of calculations showing the superior efficiency of good welding. Tank bulkhead stiffeners are designed for a working stress of approximately 7 tons per sq. in., and in riveted ships the margin between success and failure is very small. Riveted bulkheads of an oil fuel tank are seldom free from oil stains, which are irritating although hardly worthy of the term "leak", and an efficient welded bulkhead appears to be the obvious cure; but true efficiency may lie in a design quite different from accepted riveting practice.

It is usual to fit stiffeners inside the tanks in order to leave a clear outside surface for caulking, but this necessity does not arise with welding, and with the elimination of faying flanges the maximum efficiency is apparently obtained with stiffeners on the side opposite to the load. Thus the best arrangement of stiffeners may be different from accepted practice, and possibly also the type or section of stiffener. It may be that the corrugated or zig-zag bulkhead without stiffeners will prove the most satisfactory welded type, considering all the factors of efficiency, such as weight, corrosion, and economy of construction.

The present standards for ordinary watertight bulkhead stiffeners are based on the published results of the experiments of the Bulkhead Committee. For passenger vessels, the standards are laid down in Board of Trade publications, and welded structures must be at least as effective. Very little, however, is known of the value, as a beam, of sectional material welded to plating, and the problem is complicated by the fact that the plating itself is under load between the stiffeners. It is therefore of immediate importance that accurate figures should be available as to the relative values of stiffeners, without faying flanges, welded to plating, as compared with stiffeners of normal form riveted. Experiments covering the limits of normal bulkhead practice would be of great value even if only carried out with beam girders made up of sections and plating, supported at the ends and uniformly loaded. Various experiments have been made to show the relative properties of welded and riveted end connections of beams and stiffeners, but the information yet available is very meagre. A welded end connection undoubtedly can be made to develop the full strength of a girder, but there is no comparative information about the relative values of different forms of end connections to beams, stiffeners, etc., especially about those in a structure such as a ship, which is itself not rigid.

Mention has been made of the use of welding for many parts, such as casings, deck houses, etc., and it is evident from the appearance of cracks and loose rivets at such places as the corners of doors and windows in riveted ships, that these parts may be severely strained under service conditions. Welding construction, must therefore, be properly designed and the welding must be of high quality; subject to these conditions there should be great advantages in its adoption for superstructures—structures which suffer little from corrosion but demand major strength with the minimum weight.

The riveted ship is admittedly satisfactory, but it is not infallible, and a rational adoption of satisfactory welding, in spite of new and unexpected troubles, will probably result in a more satisfactory ship, with less structural defects and a real saving in material and fuel consumption or, alternatively, an increased carrying capacity. Even a more extensive use of welding for individual portions of a riveted structure is to be encouraged; in riveted ships much trouble is caused by irritating little defects, many of them due to the fact that riveted joints may leak at something less than a quarter of their breaking strength; obviously welding will provide a panacea for many such ills.

Theoretically, the combination of welding and riveting in a structure may be unsound, but, practically, it may be quite justifiable and result in a better structure than a wholly riveted one. There are many instances of this, but due care must be taken before merely substituting welding for riveting. For instance, it is bad practice to dispense with the angle or the bar connecting a stiffener bracket to plating, and merely weld the bracket plate direct to the plating, unless direct support is provided on the opposite side of the plating to the bracket, or some effective means of distributing the stress is adopted. It may be that the desired object will be attained in some cases by welding small fillets or webs at right angles to the brackets. Even with angle bars in riveted connections, tank top plating is sometimes cracked. The use of welding in conjunction with riveting in engine seatings was discussed at length when Dr. Montgomerie read his paper* on "Notes on Motor Engine Seatings". It is sufficient here perhaps to repeat a remark that has already been made,

* *Transactions of the North East Coast Institution of Engineers and Shipbuilders,* 1930-31, vol. 47, p. 197.

namely, that riveting is of no use in a welded structure, but welding may be of great assistance to a riveted structure.

Various forms of welded and combined welded and riveted bilge connections have been illustrated in papers read before the different Institutions, and an indication of the trend in design is given in Figs. 2 to 7.

For success it would seem best to provide direct and balanced support inside, as at *X* in Figs. 6 and 7, and, for a dropped margin, to cover the margin knuckle with a horizontal gusset, welded to the tank top and riveted or welded to the bracket, according to whether the vertical connections are riveted and welded as in Fig. 5, or completely welded as in Fig. 6.

There is no doubt that welding can be used with effect in such places as have been illustrated—it might almost be said "should be used"—but welding in conjunction with riveting is sometimes used in other parts of the structure where such a procedure is open to question. The following are a few examples of such applications:

(*a*) Tank top completely welded—butts, seams and connections to floors—the remainder of the structure, including angle connections to the fore-and-aft girders, riveted. Because the tank top is a much lighter and more flexible structure than the shell, and because of the riveted longitudinal connections to the main structure, this procedure is probably justified in practice, and there is certainly an advantage in water-tight surfaces being welded.

(*b*) Keel butts welded; tank top and shell riveted. It would appear that the keel butts must take the initial load until they have stretched sufficiently to allow the riveting to take its full share of the load.

(*c*) Butts of all longitudinal material welded, that is, shell, decks, tank top, girders; all seams and longitudinal connections riveted. On first consideration this arrangement seems justifiable and sound, but the question of getting fair riveting is one of some moment.

One point that must be kept in mind is that with a riveted ship the work is automatically carried out in a certain order which, in fact, has become a habit, but with a welded ship general experience is not sufficient for fixed practices to have grown, and all operations must be considered beforehand if the best results are to be obtained. This again is not to be deplored, but obviously calls for thorough practical and theoretical knowledge in the design office.

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M. E. Denny: "Diesel-Electric Paddle Ferry Boat". *Transactions of the Institution of Engineers and Shipbuilders in Scotland*, 1933-34, vol. 78, p. 381.

# Welding in the Shipbuilding Industry.

By Dr.-Ing. W. STRELOW (Hamburg).

Among the various methods of welding that are coming into use, resistance welding has hitherto found only very limited application in shipbuilding, while gas welding has been confined to certain articles of ships' equipment; but even in the latter field, and in the case of quite thin material, arc welding is becoming a competitor, since with the aid, where necessary, of special electrodes it allows of easier and quicker assembly of parts. Arc welding alone has hitherto come into question as an alternative to rivets in forming the connection between the constituent parts of the ship's structure. It is precisely in this application that no more adaptable and efficient tool than the electric arc could well be imagined, for its small size, concentrated as it is at the point of a thin electrode, allows it to be used as a means of heating and melting parts of material in confined spaces difficult of access—a characteristic of great importance on account of the freedom of design with which welded construction is thereby endowed.

The extraordinarily powerful and rapid fusion secured with the arc gives it a great advantage over other sources of heat, such as the oxyacetylene torch, because the instantaneous fusion means that only a relatively small amount of heat is conducted into the material surrounding the weld, and contraction and distortion are consequently minimised. The same property enables the thickest and largest pieces of material to be welded without difficulty, and a quick, dependable job to be made of those lifting attachments which are so indispensable to accuracy in shipbuilding. Welding offers further very definite advantages—and advantages which carry great weight in shipbuilding—in that very simple forms of joint can be adopted and complete unity of the construction attained through the direct connection of all parts of the latter. Moreover, the simplicity and directness of the welded joint enables the members of the ship's structure to be individually much more simply designed than has hitherto been possible when using riveted connections, all intermediate parts such as laps, cover plates and cover angles being eliminated. Loads being transmitted directly, scantlings can be so proportioned as to make full use of the material without the need of increasing its dimensions to accommodate the necessary rivet sections. Again, on account of the direct connections, welded work offers a notably greater resistance to dynamic and fatigue stresses under alternating loads such as arise through the vibrations to which ships are subject. Thus the further consequences of the properties of welded connections include an important reduction in the weight of the ship and a longer life, attributable not only to the greater strength of the actual connections, but also to improved possibilities of maintenance of the whole vessel.

The development of arc welding in German shipbuilding began immediately after the war. Confined at first to ancillary uses in reconstruction and repair work, it was not long before the process advanced, after isolated experiments, to the status of a complete substitute for riveting in the construction of river vessels with excellent results. At the same time welded joints began to be used on a considerable scale for the assembly of parts of sea-going ships, and more recently the point has been reached of relying on welding for the entire construction of items such as double bottoms, margin plates, bulkheads, decks, fore and aft sections of the hull and deckhouses, or for individual seams in the hull, sternpost, machine seatings, etc.—or even for exclusive use throughout the entire fabric of ocean-going ships.

This development within a space of some sixteen years has become more and more rapid in the latter part of that period. It has been conditioned on the one hand by the necessity for obtaining experience and on the other by that of training efficient welders. Such training was at first arranged by individual shipyards in their own interests, but the ever more rapidly increasing demand, augmented as it has been by that arising in other branches of the steel industry, made it impossible to continue this system, and led to the establishment of welding schools where courses are held, on a proved plan of instruction, to teach the basic principles of arc welding. It is entirely due to the good results of these courses that the scope of arc welding has latterly been extended in so striking a manner, and it is worthy of particular note that in Germany shipbuilding has pioneered the advance of arc welding into other fields of industry wherein the experience acquired in shipbuilding could be applied.

To-day there is scarcely a yard in the whole of the German shipbuilding industry which does not include arc welding in its operations, even the smaller builders of river steamers finding it indispensable to meet modern requirements. The partial application of welding to the hull naturally affects chiefly those parts where it offers some advantage over the methods hitherto used, whether as regards greater strength, saving of weight or cost, improved rigidity, greater simplicity or better fulfilment of purpose. The definitely improved performance of welded engine bases, for instance, is now recognised, the transmission of vibrations due to the unbalanced masses of the engines being greatly reduced by this means, with the result of smoother motion and longer life for the ship.

Again, much weight is saved by the adoption of welded bulkheads, and greater rigidity is attained through the welding of tank-top and margin plates and parts connected to them, such as bulkheads, floorplates, longitudinals, engine bearers, frame brackets, pillars, etc. The construction of bow and stern portions of the ship is rendered much simpler by some of their parts being completely welded. Finally, there are deck structures supporting loads or resisting forces which can be made to answer their purposes much better where welded construction is adopted. Generally speaking, the parts to which welding may most appropriately be applied—especially in the case of shipyards where welding has only recently been introduced—are those which admit of being completely welded in the workshop before being built into the ship; in this way the distortions which are apt to attend welding have the least chance of affecting other portions of the vessel.

The mode of application of arc welding, the design of individual types of welded joint, and the methods of construction based upon these, have altered little during the course of their evolution to date. Practically the same forms of connection are still in use as in the first German application of welding to a ship, described and explained by its constructor, the present author, before the 25th

General Meeting of the (German) Institute of Shipbuilding. Their adoption in some other countries, such as England, has not been customary or has always been prevented by the regulations governing ship construction; this is true, for instance, of the substitution of butt welds for lapped and strapped joints, and of the elimination of flanges from stiffeners, and of connecting angles. The reason for the different attitude in these respects adopted in Germany lies in the different valuation placed there upon experimental results and in the different view taken of the nature and objects of welded connections; an attitude proved right by the favourable performance which up to now has followed upon arc welding in that country. Similar generalisations are true in regard to the choice of electrodes in ship welding, these having scarcely altered during the course of development except for improvements in their quality, whereas in other countries the bare or lightly covered electrodes favoured in German shipbuilding are replaced by thickly covered ones. A brief critical consideration will now be made of these apparent differences of view as to the scope of the various types of electrodes.

A comparison between the different electrodes —such as between the bare and the covered types— in their application to shipbuilding cannot be based merely upon tests and experience of isolated welds; it must take account of all the circumstances liable to attend the execution of every application of welding, the requirements and working conditions imposed upon the performance of welded work, the capacities of the available welders, the kinds and shapes of the required joints, the difficulties involved, certain results of welding such as shrinkage effects, the loading of the welded connections, and considerations of economy. It may well happen that a type of electrode used with entire success in one field of application is useless in another.

There are a number of important differences between arc welding with bare and with thickly covered electrodes. Using the first-mentioned, only a limited amount of slag is formed, which has little effect on the welding process if the electrode is properly applied; the welder has only to see that the arc is properly directed to ensure complete fusion of the material to be joined and is kept as short as possible. On the other hand, with covered electrodes—and of course proportionately more so with thickly covered electrodes—slag is formed which has to be driven out of the pool of weld-metal in a certain direction by the agency of a current set up by the arc (unless the seam is so positioned that the slag falls away by its own weight). The welder must, therefore, be very careful to manipulate the electrode so that the necessary flow takes place—a condition which it is not always possible to satisfy, for the molten pool may not be at the right temperature, the slag may be unsuitably constituted, or a magnetic field set up by the action of welding may interfere with the proper direction of the arc and therefore of the flow of slag. In these contingencies the slag will be imprisoned in the welded joint, if, indeed, it does not completely spoil the weld. Great skill is required for vertical or overhead welding with thickly covered electrodes, even assuming the covering to have the proper composition. But with suitable bare electrodes there is no particular difficulty in welding vertically or overhead and in depositing a uniform fillet; this may be achieved, after some practice, even by welders of average ability. Now it is precisely in shipbuilding that very many vertical and overhead welds have to be made, while, among the extraordinarily large total number of welded connections, many occur at places exposed to very powerful magnetic fields—as, for instance, in the case of the ends of fillets converging to a right angle or acute angle. Under these conditions, if thickly covered electrodes are used a large number of defectively executed welds must be reckoned with.

In ship construction preliminary tack-welds are an indispensable aid to assembly where parts of members are required to retain their accuracy of dimensions and shape when welded. These attachments can be better and more easily made by the use of bare or lightly covered electrodes which ensure a deep penetration of the heat of the arc immediately it is struck, and which thereby develop the requisite strength enabling the attachment to resist its temporary load. Bare electrodes are better, again, for tack-welding, whereby both distortion and the internal stresses in weld seams are minimised; whereas thickly covered electrodes necessitate continuity of the seams if slag inclusions are to be avoided.

In ship welding great difficulties arise through the flow of heat from the weld into the surrounding material; the more the latter is heated the greater is its distortion, so that in some circumstances the weld may be torn away or the parts in question may suffer such pronounced distortion that welding cannot be carried out at all. In welding together the components of ships the necessity therefore arises to limit the spreading of the heat to a minimum, and this purpose, as already stated, is favoured by the adoption of a suitable procedure and by making the welding intermittent. Further, it is greatly influenced by the amount of heat coming from the arc itself, which is much larger with covered electrodes than with bare electrodes of the same thickness, because of the greater consumption of energy in the former and the chemical reactions occurring between the substances contained in the covering. In this respect also, then, the adoption of bare electrodes entails fewer difficulties.

On the other hand, welds made with bare electrodes are less perfect than those resulting from the use, under favourable conditions, of the thickly covered type. A joint welded with bare electrodes is characterised by the presence of innumerable minute bubbles of gas and of a lesser number of small slag inclusions. The loss of density from this cause, and the brittleness due to absorption of nitrogen and oxygen from the atmosphere, have as their consequence a lowering of the ductility of the weld-metal. A weld made with thickly covered electrodes possesses, on the contrary, great compactness of structure and fineness of grain, resulting in a high ductility provided that no slag inclusions due to unfavourable influences and conditions are present in the joint.

Despite the possibility of making a welded joint having properties nearly identical with those of the parent metal, the bare electrode has hitherto been employed in German shipyards owing to the fact that the difficulties inherent in the use of thickly covered electrodes cannot easily be mastered by welders of average ability. Moreover, there are conditions in ship work where the use of thickly covered electrodes would be quite impossible, and the tendency is to be satisfied with welded joints the properties of which may indeed be at a low level, but which do not fall very much below this level when executed under difficult conditions. There is the further point that in the assembly of a ship harmful secondary effects from the welding are less common where bare electrodes are used.

The experience that has now been gained of great numbers of welds in shipbuilding, whether in partial applications or in completely welded vessels, has shown that properly executed work with bare electrodes fully satisfies all requirements arising from the operation of ships, at sea, amid ice, and in harbour. In particular it has been shown in cases of collision, imposing heavy loads on the seams, that the risk of breakage of the brittle welds, which laboratory tests on simple specimens would lead one to anticipate, has not materialised, doubtless because in the completed vessel the stresses resulting from the shock are quite differently distributed.

The contractions and distortions which attend the execution of welding attain great importance in a structure composed of such complex and numerous parts as a ship, and lead to insuperable difficulties unless they are taken into consideration in the design, and unless the procedure of assembly is fully correlated with the shrinkage effects. In other words, plans must be available, showing the order in which welds are to be undertaken in completing individual major parts of the ship, and the order in which those parts are to be assembled by welding into the whole. This in itself implies a departure from the practice that is customary in riveted construction.

Several systems of welded construction have already been evolved, all, however, having for their basic principle the avoidance of cumulative shrinkage effects which might result in a lifting of the bow or stern, or even in giving a twist to the entire hull. Large contractions also cause stresses which, when combined with those due to service loads, may entail fracture of the connections of the constructional material. Because of the cumulative nature of the contractions, the erection and welding of component parts must not, as has hitherto been the practice, proceed in the sequence of their positions, but each set of components must first be welded together independently so that these effects can take place unhindered; the assembled series of parts is then so welded to its neighbours that the consequent shrinkages again all occur in one direction. Thus, in the construction of the shell or decks, all butts of each strake should, if possible, be completed before the welding of the longitudinal seam is undertaken. It is very important to minimise the heating of the parts and the resulting shrinkage effects by making no weld thicker than is necessary to give it the strength required for meeting all possible demands that may be made upon it.

Doubtless the possibilities of building up welded ships will undergo further vigorous development in the future, and ships' lines will tend to alter by improved adaptation to the lighter type of construction which is favoured by welding. Experiments in this direction have already been made with very encouraging results in small vessels differing in form from the usual design, and operating experience with these welded ships has been satisfactory in every respect.

# INSTITUTE NOTES.

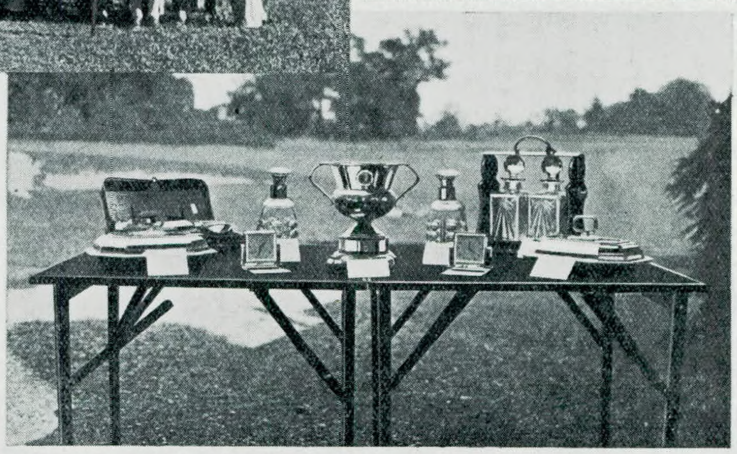
## FIFTH ANNUAL GOLF COMPETITION.

In perfect weather conditions the Fifth Annual Golf Competition was held at Shirley Park, East Croydon, on Friday, June 21st, 1935, by kind permission of the Shirley Park Golf Club Committee.

The competition for the Institute Cup, presented in 1931 by Mr. John Weir, took place in the morning, 28 players taking part. The Cup was won by Mr. E. F. J. Baugh (Associate) with a net score of 74. The second and third prizes, presented by Mr. John H. Silley, O.B.E., Past President, were won by Messrs. F. P. Bell and G. F. O'Riordan (Members), who tied with a net score of 76. A prize for the best scratch score, presented by Mr. F. M. Burgis, was awarded to Major W. H. Dick (Companion).

In the afternoon a four ball bogey competition was held. The two first prizes, presented by Mr. W. C. Warwick, were won by Messrs. G. F. O'Riordan and J. H. Rhynas (Members); the second prizes, presented by Mr. T. C. Riddell, were secured by Messrs. A. J. Walker and J. H.

THE PLAYERS AND PRIZES



THE PRIZES

THE WINNER OF THE CUP
E.F.J. BAUGH

SOME MEMBERS OF THE COMMITTEE

THE FIFTH ANNUAL GOLF COMPETITION.

Williams (Members); whilst the third prizes, presented by Mr. John Macmillan, went to Messrs. R. N. Orren (Associate) and T. C. Riddell (Member).

The prizes were presented by Mr. A. Robertson, C.C., Convener of the Social Events Committee, who subsequently presided at a dinner which was held at the Club, when it was arranged to hold a further Competition in September in view of the continued success of these meetings. Mr. A. E. Crighton expressed the Committee's regret that Mr. John Silley had been prevented from being present through illness, and their best wishes for his early recovery. To him (Mr. Silley) and to the other donors of the handsome prizes which had been presented that evening the Committee accorded grateful thanks. (Applause).

On the proposal of Mr. R. Rainie, seconded by Mr. A. R. Langton, votes of thanks were also accorded amid enthusiasm to Messrs. A. Robertson (Convener) and B. C. Curling (Secretary) for their successful arrangement of the day's programme.

The following participated in or were present during the competitions and subsequent events:—Messrs. E. F. J. Baugh, F. P. Bell, F. M. Burgis, Eng. Capt. R. D. Cox, A. E. Crighton, T. A. Crompton, B. C. Curling, I. Davis, Major W. H. Dick, J. M. Edmiston, R. M. Gillies, J. Alan Goddard, S. G. Gordon, H. S. Humphreys, E. B. Irwin, Walter C. Jones, A. R. Langton, L. J. Le Mesurier, J. T. London, E. E. Mees, W. Morralee, O. H. Moseley, G. F. O'Riordan, R. N. Orren, S. Pearson, R. Rainie, J. A. Rhynas, T. C. Riddell, A. Robertson, J. Robinson, H. J. Savage, C. C. Speechly, A. J. Walker and J. H. Williams.

## ELECTION OF MEMBERS.

List of those elected at Council Meeting held on Monday, July 15th, 1935.

**Members.**

John Bennet, 5, First Avenue, Netherlee, Glasgow.

Wilfred Brown, The Poplars, Front Street, Whitburn, Co. Durham.

Edgar George Buckwell, 93, Priory Avenue, Hastings, Sussex.

William Denny, Longbarn, Cardross, Dumbartonshire.

Thomas Halbert Hutton, Barassie Bank, Barassie, Near Troon, Ayrshire.

James Alexander Leslie, 2, Hayswell Road, Arbroath, Scotland.

George McPherson Logie, 22, Exeter Drive, Partick, Glasgow.

Thomas Richard Nelson, 179, Liverpool Road, Crosby, Liverpool 23.

Charles Christopher Parkin, Fawdington, Helperby, York.

James Parkinson, Canadian National Steamships Co., 384, St. James Street, Montreal, P.Q., Canada.

John Pattie, Tavistock Road, Sketty, Swansea.

John Patrick, 2, West View, Beech, Sowerby Bridge, Yorks.

George Scott, 40, Wickham Avenue, Shirley, E. Croydon.

John William Sharp, 153, Stanhope Road, South Shields.

John Blake Thomson, c/o McIlwraith McEacharn, Ltd., Scottish House, William Street, Melbourne.

John George Wilson, 34, Exeter Road, Bootle, Lancs.

John Wyndham Witts, 42, Shirley Road, Liverpool 19.

**Companion.**

James Wallis Goodyear, 18, Stephen Court, Park Street, Calcutta.

**Associate Members.**

Thomas Reginald Bradley, Ballaquane Cottage, Dalby, Near Peel, Isle of Man.

James Dolan, 95, Lanehouse Road, Thornaby-on-Tees.

Robert Eugene Gueroult, 5, Rue Gabrielle d'Estreés-Vanves (Seine), Paris.

Harold G. B. Perry, 94, Canton Road, Shanghai.

**Transfer from Associate Member to Member.**

Bryan Ord Gibbs, 23, Vaughan Gardens, Ilford, Essex.

Adolphus John Daniel, 167, Downend Road, Downend, Bristol.

William Robert Harding, St. Helen's, 13, Woodmancote Road, Milton, Southsea, Hants.

Edward Shaw, 272, Footscray Road, New Eltham, S.E.9.

Richard Renyard Strachan, Croxholm, Homestead Road, Chelsfield.

**Transfer from Associate to Member.**

Edmund Ernest Burrage, Havenlea, 32, Clandon Close, Ewell, Surrey.

**Transfer from Student to Member.**

Leo Kellett Donaldson Wood, Lieut. (E.), R.N., H.M.S. "Shropshire", c/o G.P.O., London.

## ADDITIONS TO THE LIBRARY.

Purchased.

"Machinery and Pipe Arrangement on Shipboard", by C. C. Pounder. Emmott & Co., Ltd., 1922, 17s. 6d. net.

Presented by the Publishers.

"Science in Parliament". Parliamentary Science Committee.

"Steam Traps and Strainers", by Lea, and "The Welding of Monel Metal and Nickel". Henry Wiggin & Co., Ltd.

The British Electrical and Allied Industries Research Association. Sub-Committee J/E: Joint Committee: Steels for High Temperatures. The creep properties at 550° C. of the material of two alloy steel superheater tubes, by H. J. Tapsell and L. E. Prosser, with an appendix on the metallurgical examination of the materials by C. H. M. Jenkins,

C. A. Bristow and E. H. Bucknall. The creep properties at 550° C. of the material of two alloy steel superheater tubes after heat treatment, by H. J. Tapsell and G. Conway, with an appendix on the metallurgical examination of the low chromium-molybdenum steel, by C. H. M. Jenkins and E. H. Bucknall.

"Electric Wiring", by W. S. Ibbetson, B.Sc., E. & F. N. Spon, Ltd., 4th edn., 253pp., illus., 6s. net.

This book is the fourth edition of a work which has now become well known amongst contractors, wiremen and others engaged in the wiring of electrical installations. It is essentially for those engaged in shore practice, but many of the matters with which it deals are of interest and practical value to marine engineers whose work brings them into contact with the electrical side, more especially as electricity is gradually becoming very important in ships.

The new Wiring Regulations of The Institution of Electrical Engineers have been embodied throughout, but for marine practice such information as is given, to be of complete utility, would have to be supplemented by the Ships' Electrical Equipment Regulations issued by the same Institution and the regulations of the various registration societies and other interested bodies.

"Chemistry in Relation to Fire Risk and Fire Extinction", by A. M. Cameron, B.Sc. Sir Isaac Pitman & Sons, Ltd., 278pp., 7s. 6d. net.

The object of the Author has been to produce a text book on chemistry dealing with the theory of combustion, and its relation to fire risk, with an explanation of the principles of fire extinction. The result is a practical text book eminently suitable and useful, particularly for the examinations of the Chartered Insurance Institute and the Institution of Fire Engineers.

The material has been carefully selected and clearly presented, and embodies sufficient to make it interesting and intelligible to those whose training has included elementary chemistry on fundamentally sound lines. A reference book only may be dangerous in such circumstances, and a pure text book on chemistry is so comprehensive as to be bewildering. Here, however, we have the essentials in a really presentable form for the insurance official and the fire engineer.

Equally important also is the value of a work of this kind in the wider sphere of industrial executives. The chemist, the safety engineer and the manager, will all find in it agreeable and profitable study. The facilities thus given for a wider dissemination of knowledge appertaining to fire is the path leading to greater safety, and must inevitably aid the work of the insurance official and fire engineer. In this broader sense a treatise which tends to the advancement of fire knowledge is to be welcomed, because it must inevitably be followed by the development of the principles of fire prevention, which should be the basis of fire protection.

The author has made an able attempt within the space of two chapters to discuss fire hazards in industry. It was obviously impossible to include many industrial processes, but the excellent method of selection ensures a sound basis for the reader to solve the problems he may meet.

The subject matter of fire extinction is well treated, and both the merits and limitations of all the usual fire extinguishing media are given. The complicated problem of possible toxic effects arising from the use of certain halogen derivatives is treated with an excellent reserve consistent with all the uncertainties of the whole question.

This book should be very successful for the purpose which the author had in mind.

"Principles of Electric Power Transmission by Alternating Currents", by H. Waddicor, B.Sc. Chapman & Hall, Ltd., 3rd edn., 449pp. illus., 21s. net.

In the present (third) edition of this work, the principal alterations have been made to the chapters on underground cables. These chapters have been completely re-written in order to deal with modern developments in the design and manufacture of cables for transmission purposes.

The book deals essentially with the fundamentals and principles of power transmission by alternating currents and is pre-eminently suited to the requirements of advanced students and transmission engineers who are concerned with the design of transmission networks. Sufficient general information on transmission practice is given to make the book useful to the general electrical engineer as well as to the transmission specialist.

The theory and calculation of short and long transmission lines is dealt with by both approximate and rigorous methods, and is supplemented by worked examples, the working being given in detail so that all steps can be readily followed. Alternative graphical methods of solution by vectors and complex quantities are also given.

A special chapter is devoted to "phase modifiers" and the important problems connected with voltage regulation, power-factor control, and the interchange of power between interconnected stations. Theoretical treatment is given for long lines, and worked examples by analytical and graphical methods are included. The principal protective systems in use are discussed briefly from the point of view of their principles of operation. The final chapter deals with the power limits of transmission systems. Analytical discussions are given for short and long lines, and worked examples are included.

The book can be highly recommended to those who are interested in the subject and have the mathematical ability to follow the analytical treatment, which is, however, set out so clearly that it at once inspires the confidence of the reader.

"Practical Solution of Torsional Vibration Problems", by W. Ker Wilson, M.Sc., Wh.Ex. Chapman & Hall, Ltd., 438pp., illus., 25s. net.

The author of this volume set himself a most difficult task when he introduced the word "Practical" into his title, for though the mathematics of torsional vibration is by no means so complex as is generally believed, the explanation of the subject in simple language is by no means easy. There is a grave danger in practical mathematics that results are stated to the student without the argument that leads up to them, so that while he may be able to work out a problem he does not understand the real meaning of the formulæ or methods by which he arrives at his solution. In the volume under review Mr. Wilson has to some extent avoided this danger, but in places falls into the trap himself and works from incorrect assumptions due to accepting an idea without first investigating its derivation.

In the first three chapters the author deals with the usual methods of calculation for the determination of the natural frequency of systems having various numbers of masses connected by a torsionally flexible shaft. These three chapters are clearly written and should enable the student to follow readily the methods, so that he should quickly be able to make calculations for normal systems. Geared and other more complex systems are briefly treated, but this section could with advantage have been dealt with in greater detail.

The fourth chapter deals with the determination of stresses at non-resonant speeds and here the author, in common with many other writers on the subject, has gone astray in working from the assumption that for any vibrating system the node of a forced vibration is in the same position as the node of free natural vibration.

The following chapter dealing with the stresses at resonance is interesting, but, in the present state of knowledge of the question of damping, is rather too academic for a work of a practical nature. Up to the present time, practical experience obtained from measurements of vibration is the only real guide to the values that may be expected in any case for the damping factor at resonance. The remaining chapters dealing with measurement of torsional vibration, with damping devices and with the dynamic characteristics of internal combustion engine generating sets are interesting and valuable.

On the whole this volume is a valuable addition to the literature of the subject; the solution of problems is amply illustrated by worked-out examples, and the indexing has been carefully arranged so that it is of value both to the student who wishes to study the whole subject and to those engineers who wish only to have a work of reference.

"Motorships", by A. C. Hardy, B.Sc. Chapman & Hall, Ltd., 317pp., illus., 7s. 6d. net.

"Motorshipping", by A. C. Hardy, B.Sc. Chapman & Hall, Ltd., 166pp., illus., 7s. 6d. net.

First published in 1925 and 1928 respectively, these two books from the pen of Mr. Hardy have met with such approval from the motorshipping world that the publishers have been encouraged to re-issue them in cheap editions.

For the information of those who have not had an opportunity to peruse these useful books, "Motorships" is a comprehensive investigation into the characteristics of mercantile vessels propelled by internal-combustion engines, whilst "Motorshipping" is a valuable study of the Diesel-engined ship in relation to present-day shipping showing something of the newest era in sea transport.

The wide circulation of these books almost makes it unnecessary to add that they are recommended to those studying the subjects which they set out to cover.

"Petroleum. Twenty-five Years' Retrospect. 1910-1935". The Institution of Petroleum Technologists, 219pp., illus., 7s. 6d.

It is common knowledge that the petroleum industry has expanded enormously during the past twenty-five years. The extent of the development and the method by which it has been achieved can be appreciated after reading this book. The information given in the first chapter conveys the magnitude of this development. It is stated that in 1910, the world production of petroleum was 44,000,000 tons which had increased in 1934 to 208,500,000 tons; in the same period the tonnage of oil-burning steamers increased from 500,000 tons to nearly 20,000,000 tons and, in 1934, there were also over 10,500,000 tons of motor ships.

The progress of development is described in a number of articles by eminent authorities who deal with each phase in the development, from the finding of the oil to the distribution of the finished product.

Methods of oil finding and oil drilling are described showing the improvements effected during the period under review. In a similar fashion, chapters deal with progress and development in the transportation of oil by land and by sea, in oil storage installations, in refining and treatment processes, distillation, cracking, testing, etc.

The last two chapters of the book describe developments in the Scotch Shale Industry and in the production of oil from coal, including a brief description of the latest hydrogenation process.

It is not a text book but, nevertheless, contains a mass of information which cannot fail to be of interest to marine engineers and others who have to deal so extensively with important products of petroleum, comprising furnace and Diesel fuels and lubricating oil.

"Bibliography of Literature on Spectrum Analysis", by D. M. Smith, A.R.C.S., B.Sc., D.I.C. British Non-Ferrous Metals Research Association, Regnart Buildings, Euston Street, London, N.W.1, 20pp., 1s. 6d. post free.

In 1934, the British Non-Ferrous Metals Research Association published, as its Research Monograph No. 2, a book entitled "Metallurgical Analysis by the Spectrograph", by D. M. Smith, A.R.C.S., B.Sc., D.I.C. (114pp., price 10s. 6d.). This publication embodied the results of work carried out by the author for the Association over a period of some eight years, and included a bibliography of the literature of the subject.

Even in the short time which has elapsed since publication of the book, many new papers bearing on the subject have appeared. The author has therefore incorporated references to these in the bibliography (up to March, 1935) and the revised bibliography is now issued by the British Non-Ferrous Metals Research Association as a Supplement to the book, under the title "Bibliography of Literature on Spectrum Analysis"

Presented by Mr. H. S. Humphreys.

"Fuel Consumption and Maintenance Costs of Steam- and Diesel-Engined Vessels", by L. J. Le Mesurier and H. S. Humphreys. Paper read before the North East Coast Institution of Engineers and Shipbuilders.

# ABSTRACTS.

*The Council are indebted to the respective Journals for permission to reprint the following abstracts and for the loan of the various blocks.*

## BOARD OF TRADE EXAMINATIONS.

List of Candidates who are reported as having passed examinations for certificates of competency as Sea-Going Engineers under the provisions of the Merchant Shipping Acts.

**For week ended 6th June, 1935:—**

| Name. | Grade. | Port of Examination. |
|---|---|---|
| Strachan, Richard R. ... | 1.C.M. | London |
| Hunter, Alan ... ... ... | 1.C. | Dublin |
| Bainbridge, Robert W. C. ... | 1.C. | Newcastle |
| Edmundson, Harry ... ... | 1.C. | " |
| Heseltine, Herbert ... ... | 1.C. | " |
| Tuck, Edward A. ... ... | 1.C. | " |
| Wilkinson, Eric T. ... ... | 1.C. | " |
| Drury, George V. ... ... | 1.C. | Liverpool |
| Michael, George H. ... ... | 1.C. | " |
| Park, Alfred ... ... ... | 1.C. | " |
| Walley, Alfred ... ... | 1.C. | " |
| MacDonald, Raymond F. ... | 1.C.M. | " |
| Aitchison, Donald ... ... | 1.C. | Glasgow |
| Condie, Alexander ... ... | 1.C. | " |
| Fleming, Alexander R. ... | 1.C. | " |
| McLean, John A. ... ... | 1.C. | " |
| Robson, Kenneth ... ... | 1.C. | " |
| Scott, Archibald J. ... ... | 1.C. | " |
| Joyce, John J. ... ... | 1.C.M. | " |
| Watson, Peter H. ... ... | 1.C.M. | " |
| Guy, Thomas G. ... ... | 1.C.E. | London |
| Martin, John E. ... ... | 1.C.M.E. | Newcastle |
| Gent, William ... ... | 1.C.M.E. | " |
| Marsh, Cyril ... ... ... | 1.C.M.E. | " |
| Hagedorn, Cecil C. ... ... | 1.C.M.E. | London |
| King, Kenneth S. ... ... | 1.C.M.E. | " |
| Scott, Howard P. ... ... | 1.C.M.E. | Newcastle |
| Smith, Albert ... ... ... | 1.C.E. | Liverpool |
| Watson, George A. ... ... | 1.C.M.E. | Glasgow |

**For week ended 13th June, 1935:—**

| Name. | Grade. | Port of Examination. |
|---|---|---|
| Reed, Robt. C. H. ... ... | 2.C. | Cardiff |
| Marshall, David ... ... | 2.C. | Glasgow |
| McDonald, Daniel J. ... | 2.C.M. | " |
| Pierce, John A. ... ... | 2.C. | Liverpool |
| Rea, James H. ... ... | 2.C. | " |
| Spence. Arthur R. ... ... | 2.C. | " |
| King, Robert H. ... ... | 2.C. | London |
| Maddox, Eric F. ... ... | 2.C. | " |
| Ellis, William L. ... ... | 2.C.M. | " |
| Ridley, Arthur ... ... | 2.C. | Newcastle |
| Stephenson, Edward M. ... | 2.C. | " |
| Copeman, George ... ... | 2.C.M. | " |
| Thompson, Wilfred... ... | 2.C.M. | " |

**For week ended 20th June, 1935:—**

| Name. | Grade. | Port of Examination. |
|---|---|---|
| Gardener, Thomas ... ... | 1.C. | Newcastle |
| Nicol, William ... ... | 1.C. | " |
| Starkey, Frederick A. ... | 1.C. | " |
| Robson, Joseph ... ... | 1.C.M. | " |
| Lyon, James ... ... ... | 1.C.M.E. | " |
| Day, Reginald Sydney ... | 1.C.M.E. | London |
| Rossiter, Frederick H. ... | 1.C.M.E. | " |
| Currie, Henry Philip ... | 1.C.S.E. | Liverpool |
| Tate, John T. R. ... ... | 1.C.S.E. | " |
| Higginson, John F. ... ... | 1.C.M.E. | " |
| Tait, David ... ... ... | 1.C.M.E. | Glasgow |
| Carr, John S. ... ... | 1.C.M.E. | " |
| Ramsay, Gilbert C. ... ... | 1.C.M.E. | Newcastle |
| Smith, William H. ... ... | 1.C.S.E. | " |
| McRoberts, Thomas... ... | 1.C.M. | " |
| Wood, William C. ... ... | 1.C. | Cardiff |
| Daniel, Adolphus J. ... | 1.C. | London |
| Swanbrow, Charles J. ... | 1.C.M. | " |
| Brice, William H. ... ... | 1.C. | Liverpool |
| Deakin, Leslie ... ... | 1.C. | " |
| Martin, Elliott G. ... ... | 1.C. | " |
| McNaught, Matthew ... | 1.C. | " |
| Gillespie, David ... ... | 1.C. | Glasgow |
| Robertson, James Bowie ... | 1.C. | " |
| Scott, Alan D. ... ... | 1.C. | " |
| Stewart, William ... ... | 1.C. | " |
| Thomson, Thomas C. ... | 1.C. | " |
| Dale, Stanley ... ... ... | 1.C. | Newcastle |
| Forbes, Alexander P. ... | 1.C. | " |
| Gamlen, Denys ... ... | 1.C. | " |

**For week ended 27th June, 1935:—**

| Name. | Grade. | Port of Examination. |
|---|---|---|
| Tanner, Charles F. D. ... | 1.C. | Glasgow |
| Coates, Thomas ... ... | 2.C.M. | Dublin |
| Lush, Leonard E. C. ... | 2.C. | London |
| McIntyre, Robert G. ... | 2.C. | " |
| Waterman, Denis F. ... | 2.C. | " |
| Hendry, William F. ... | 2.C. | Glasgow |
| MacLeod, Kenneth ... ... | 2.C. | " |
| Small, John ... ... ... | 2.C. | " |
| Smyth, Thomas W. ... ... | 2.C. | " |
| Watson. Oswald ... ... | 2.C. | " |
| Fenwick, Frederick E. ... | 2.C. | Newcastle |
| Rooke, Stanley B. ... ... | 2.C. | " |
| Smith, Arnold ... ... | 2.C. | " |
| Turnbull, J. F. W. ... ... | 2.C. | " |
| Walker, James W. ... ... | 2.C.M. | " |
| Fairclough, Harold ... ... | 2.C. | Liverpool |
| Fidele, John F. ... ... | 2.C. | " |
| Walsh, Roland ... ... | 2.C.M.E. | " |

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## Tests of a 7,000 b.h.p. Engine.

Fuel Consumption Under 0.33lb. per B.H.P.-hour with a Double-acting Two-stroke B. & W. Diesel Motor.

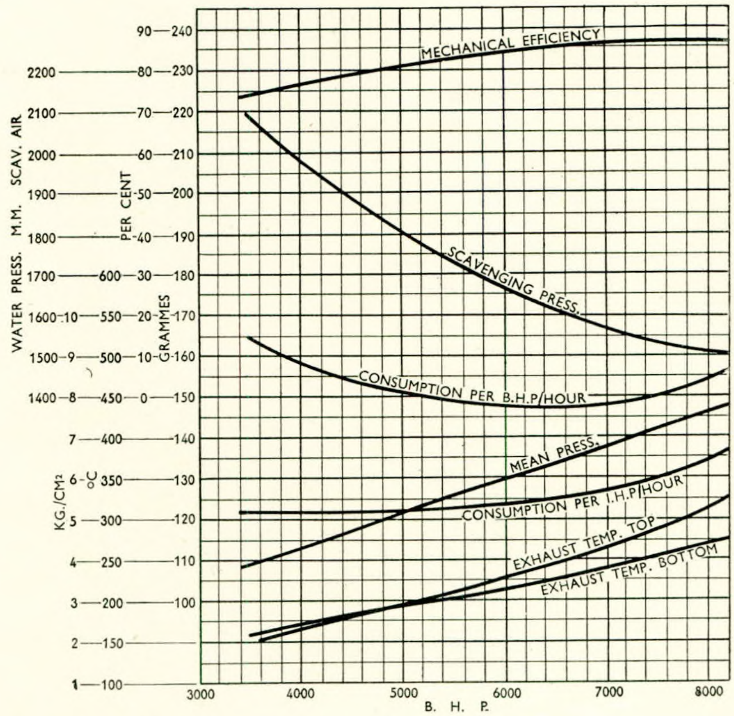
By Dr. H. H. BLACHE.

"The Motor Ship", June, 1935.

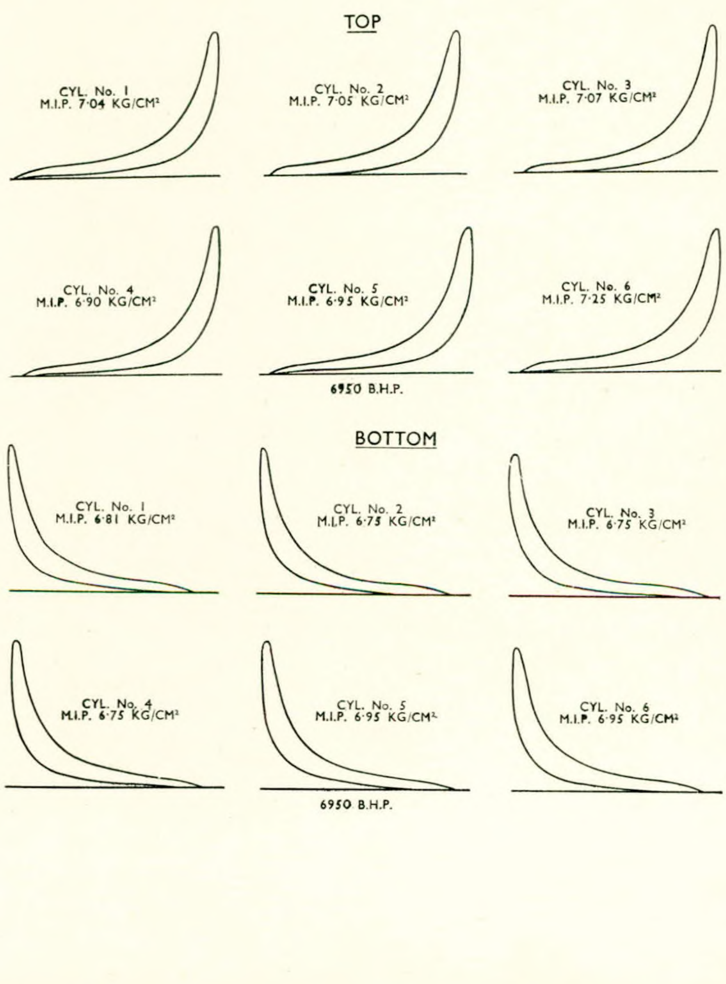
A short time ago, Burmeister and Wain were able to complete the engine for the "Canada", a sister ship to the m.s. "Amerika" and m.s. "Europa" for the East Asiatic Co. in ample time for a thorough trial to be carried out before the vessel was launched. The opportunity was taken, therefore, to carry out a number of tests with varying powers, in addition to the usual full-powered runs, and it is now possible to publish the complete results. The particulars represent the first complete details of the tests of a Burmeister and Wain double-acting two-stroke engine.

The unit in question is a standard six-cylinder two-cycle airless-injection double-acting plant with cylinders 620 mm. in diameter, the piston stroke being 1,400 mm. This is a size similar to that of the engines in the "Amerika" and "Europa", also those built by Harland & Wolff and installed in the cargo liners "Rothesay Castle" and "Roslin Castle", except that the number of cylinders is different.

The designed output is 7,000 b.h.p. at 105 r.p.m., and the mechanical efficiency at this load is 85·8 per cent., the corresponding indicated power being 8,150. The mean pressure is 6·75 kg. per sq. cm., or 96lb. per sq. in., referred to the total




Curves showing test results of a 7,000 b.h.p. double-acting two-stroke B. and W. engine. Below are reproductions of the indicator cards.




stroke volume of the main piston and the exhaust valve cylinder, and 7·43 kg. per sq. cm., or 103·5lb. per sq. in., referred to the stroke volume of the main cylinder.

The consumption per b.h.p.-hour at the load mentioned is 0·1485 kg., or 0·332lb. The most economical running of the engine is obtained when it is developing 6,400 b.h.p., the consumption then being 0·148 kg. per b.h.p.-hour, or 0·325lb. per b.h.p.-hour. Even at 10 per cent. overload the fuel consumption is only 2½ per cent. higher.

The tests were carried out with a constant number of revolutions, but with varying loads.

The problem which the marine engine designer has to solve is the production of an engine which, whilst being of robust construction and built without unnecessary expense, develops the greatest horse power possible with the lowest weight and the smallest size. This means an engine which operates with the maximum mean pressure, consistent with reliability of running and economy of fuel consumption. The test results attained with the engines under consideration show that these conditions are fulfilled at the rated full power of 7,000 b.h.p., since the saving in fuel consumption when the engine develops less than 7,000 b.h.p. is so small that it is without importance.

The engine was built with a tuned exhaust pipe arrangement, for the purpose of utilizing the energy of the air oscillations in the exhaust pipe and thereby improving the scavenging.

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## Cylinder-liner Wear in Service.

Detailed Results with four Ships over six years Running. Reasons for satisfactory Performance.

By A. E. Ash, M.I.N.A.
(Supt. Engineer, The Lancashire Shipping Co.)

"The Motor Ship", July, 1935.

The following data refer to experience with the cylinder liners of four twin-screw motor ships owned by the Lancashire Shipping Co., which have been in continuous service for over six and seven years respectively, during which period careful records were kept of the cylinder gaugings. The vessels in question are two sister ships, the "Greystoke Castle" and "Muncaster Castle" (fully described in "The Motor Ship" of April, 1928), and a second pair of sister ships, the "Thurland Castle" and "Penrith Castle" (of which an account appeared in "The Motor Ship" of August, 1929). The single-screw Diesel-engined vessel "Raby Castle", of the same fleet, will be dealt with later in this article.

The propelling machinery in all four ships is identical. The twin screws are driven by North-Eastern Werkspoor Diesel engines with the following characteristics :—

| Type. | Four-stroke single acting-air injection. |
|---|---|
| No. of cylinders, each engine ... ... | 6 |
| Cylinder bore ... ... ... ... | 730mm. (28¾in.) |
| Piston stroke ... ... ... ... | 1,500 mm. (59⅛in.) |
| "Greystoke Castle" and "Muncaster Castle", contract engine speed ... | 103 r.p.m. |
| "Greystoke Castle" and "Muncaster Castle", contract engine power ... | 4,200 b.h.p. |
| "Thurland Castle" and "Penrith Castle", contract engine speed ... ... | 110 r.p.m. |
| "Thurland Castle" and "Penrith Castle", contract engine power ... ... | 4,480 b.h.p. |

It will suffice to say that the performance of the main engines has been exemplary and, with the exception of the stoppage of a main cooling-water pump, resulting in the failure of a number of cylinders in one ship, no major breakdown has occurred.

The vessels are all on the owners' New York, Panama, Manila, Suez, New York service, the following being performance results over typical voyages of the four ships (neglecting coasting) :—

| | "Muncaster Castle" and "Greystoke Castle". | "Thurland Castle" and "Penrith Castle". |
|---|---|---|
| Draught ... ... ... | 24ft. 6in. | 25ft. 1½in. |
| Displacement (tons) ... ... | 12,110 | 13,810 |
| Distance (nautical miles) ... | 19,681 | 22,441 |
| Speed (knots) ... ... ... | 13·31 | 13·26 |
| R.p.m. ... ... ... ... | 98·59 | 103·2 |
| I.h.p. ... ... ... ... | 5,026 | 5,145 |
| Total fuel per day (tons) ... | 16·88 | 17·65 |
| Fuel per i.h.p.-hour (lb.) ... | 0·309 | 0·316 |
| Oil coefficient ... ... ... | 73,640 | 75,950 |
| Per cent. of contract full power ... ... ... | 92 | 90 |

The coasting in Eastern waters averages about 7,000 miles each voyage, making the above round-voyage figures between 26,681 and 29,441.

Under favourable conditions the fastest voyages for each of the four ships have been 13·92 knots, 13·98 knots, 14·11 knots, 14·25 knots, and the average for the past two years has been 13·255, 13·186, 13·01 and 13·235 knots.

In view of the findings of the Institution of Automobile Engineers as to the tendency for cylinder wear to occur whilst the engine is warming up—due to condensation of the products of combustion—the following table gives the number of starts (cold and hot) per annum for one of the ships. (A cold start is assumed as such, after the engine has been standing for 40 minutes or longer).

| | |
|---|---|
| No. of days at full speed | 230 per engine per annum. |
| No. of days at reduced speed and manœuvring ... | 11 per engine per annum. |
| Total number of telegraph orders ... ... ... | 3,200 per engine per annum. |
| Total number of starts ... | 1,110 per engine per annum. |
| Total number of starts from cold ... ... ... | 303 per engine per annum. |

This gives a proportion of 55 cold starts to 1,000 hours' running—possibly only a fraction of the proportion to which a petrol engine is subject. The higher sulphur content of the Diesel fuel, however, may tend to offset the more favourable proportion of cold starts of the marine engine.

The writer has no evidence, nor any definite opinion, as to the existence of corrosion wear in marine Diesel-engine cylinders, but merely suggests that the "cold-start proportion" should be considered when investigating liner-wear problems and performances.

One point, however, which lies outside any question of opinion, is that the cylinder, its piston and rings are the most important part of a Diesel engine, and successful performance with minimum liner wear can best be obtained by ease of access to the piston, coupled with other items set out at the end of these notes. Fig. 9 shows how this is given in these North Eastern Werkspoor engines.

In the centre of the illustration to which reference is made the piston and rings are ready for inspection or adjustment. The inspection is done in 10 minutes, involving the lowering of the liner extension piece. The value of this feature is proved by a letter just received from the chief engineer of our m.v. "Penrith Castle", from Port Said :—

"5th May, 1935.
"Port Said, Egypt.

"Attention of Supt. Engineer—The 'Penrith Castle' arrived at Suez at 12.49 p.m. on 4th May, completing the run from Belawan of 4,661 miles in 14 days 6 hours 35 minutes at an average speed of 13·60 knots and with an average slip of 3·84 per cent. The machinery ran well during the passage. We had a short stay in Colombo (4 hours), and took the opportunity to examine No. 5 starboard piston, which had commenced to blow a little. The three top rings were found to be somewhat slack and the scraper ring had the taper edge worn down. These rings were removed, a ring ·650in. deep going in the top groove with a maximum clearance of ·027in. This cured the trouble . . . . . "

Is it necessary to add that, had this incipient blow in the cylinder in question continued to New York—9,000 miles—with the consequent detrimental effect on the oil film on the liner wall, a serious increase in the cylinder wear would have been inevitable?

The illustration shows how the cylinder walls can be subjected to a spotlight all round, with the engines either standing or running. This affords the opportunity of a squirt of oil from a syringe to any cylinder where dryness appears. It is specially valuable when starting up from cold. The latter feature has a bearing on the cold-start "corrosion" theory.

In making the statement above that the cylinders, pistons and rings are the first essentials in successful Diesel-engine work, the writer is influenced by the excellent performance of the running gear and parts of these particular engines, which operate at speeds and pressures considered prohibitive only a few years ago.

The chief engineer of the "Penrith Castle" also wrote us from Belawan, dated April 18th, on his way to Port Said, and I give an extract from his letter relating to Lloyd's Survey:—

"Lloyd's Survey—The starboard main bearings and crankshaft journals were examined and passed. (Kobe, 12th March, 1935). The wear down gauge was tried on all these bearings and showed less than ·002in. wear compared with the original readings and the white metal and bearing surfaces were in excellent condition".

This ship is six years old and her condition is indicative of the fleet. The shaft wear-down ranges from a bare 2/1,000ths to 7/1,000ths in the worst case, and only in one ship has any re-metalling been done, and that due to the ship having been ashore.

Out of all the other running-gear parts, i.e., guide shoes, bottom ends and top ends, only two bottom halves of crosshead brasses have been remetalled up to the present time.

The performance of the machinery is outstanding and reflects the highest credit on the builders and the personnel who have run the jobs.

Fig. 1 is a section of a cylinder on which are shown the standard gauging positions, and it will be noted that position "A" is in line with the top ring travel, i.e., maximum wear. Hence, the wear referred to herein is always the maximum, that is, on the diameter of the cylinder at position "A". It is given in thousandths of an inch and is the mean of the fore-and-aft and athwartship wear. In Table I are shown the overall wear rates per 1,000 hours' running of the engines, and in the ovality column the figures give the difference between fore-and-aft and athwartship gaugings.

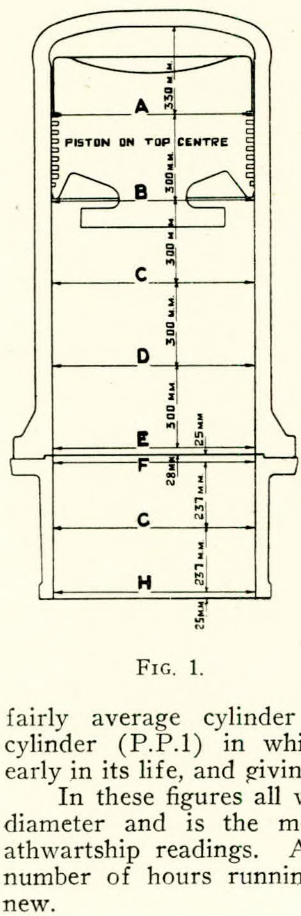


Fig. 1.

In Fig. 2 are shown successive gaugings of the cylinder (G.P.3) in the ship with the highest wear rate; in Fig. 3 a fairly average cylinder (M.P.2); in Fig. 4 a cylinder (P.P.1) in which gaugings were taken early in its life, and giving data over this period.

In these figures all wear shown is that on the diameter and is the mean of fore-and-aft and athwartship readings. Against each curve is the number of hours running since the cylinder was new.

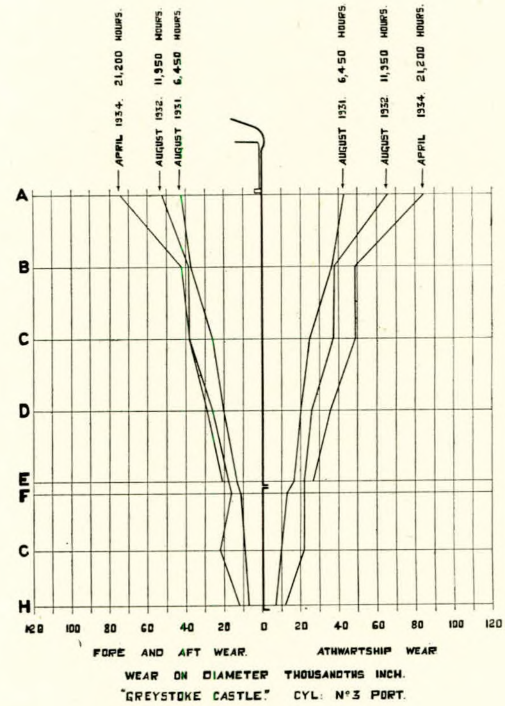


Fig. 2.

Table I.—*Liner Wear in Thousandths of an Inch.*

| Ship. | Wear at A per 1,000 hours. Best Cyl. | Worst Cyl. | Mean of 12 Cyls. | Ovality at A. Max. Athwartship. | Max. Fore and Aft. | Mean of 12 Cyls. | Hours Running. |
|---|---|---|---|---|---|---|---|
| "Greystoke Castle" | 2·76 | 3·76 | 3·29 | 14 | 6 | 7 Athwartship | 21,160 |
| "Muncaster Castle" | 2·60 | 3·47 | 2·94 | 22 | 12 | 2·5 Athwartship | 37,500 |
| "Thurland Castle" | 2·43 | 3·47 | 3·02 | 10 | 10 | 0 | 31,300 |
| "Penrith Castle" | 1·53 | 2·66 | 2·10 | 10 | 8 | 0 | 29,900 |

In Fig. 5 are shown for all 12 cylinders of ship "G" the amount of wear at position "A" plotted against the number of hours running, and through them has been drawn the curve (a) of wear. From this curve has been deduced curve (b), which gives approximately the rate of wear at any particular period.

Figs. 6, 7 and 8 are similar curves for the other three ships. It will be noted that, in every case, the wear rate seems gradually to fall until, after about 10,000 hours, it has reached a steady rate in the four ships, as follows:—

| | | |
|---|---|---|
| Ship "G" | ... | About 2·2 thousandths per 1,000 hours. |
| Ship "M" | ... | About 2·4 thousandths per 1,000 hours. |
| Ship "T" | ... | About 2·4 thousandths per 1,000 hours. |
| Ship "P" | ... | About 1·7 thousandths per 1,000 hours. |

This point is of importance, as one is inclined to think at first sight that, in the beginning, some

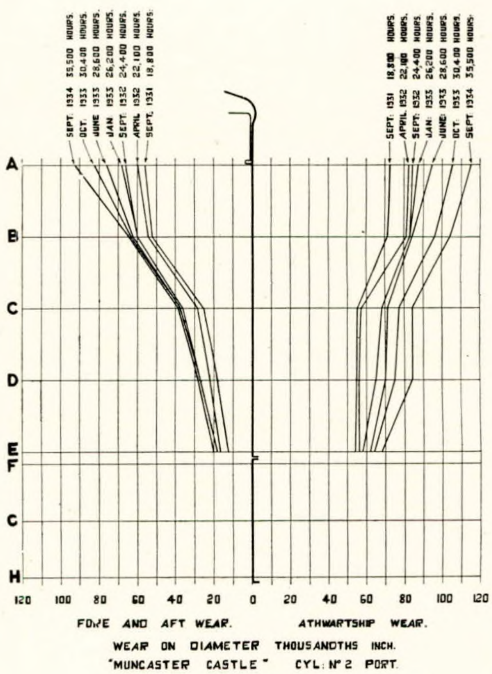


FIG. 3.

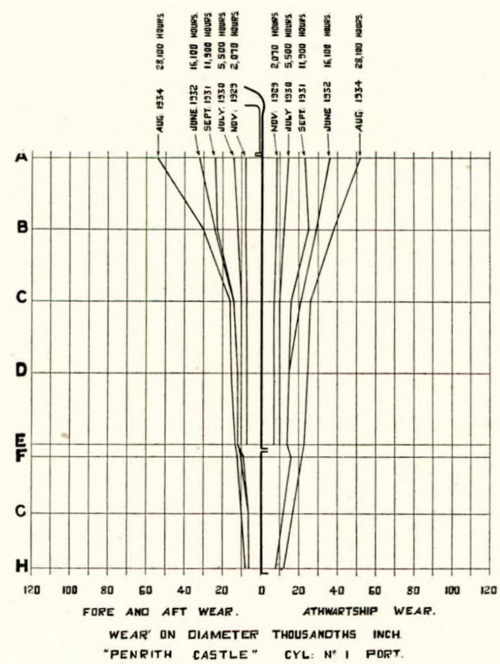


FIG. 4.

unfavourable factor has been present, or favourable factor absent, and that this was removed, or appeared, after the first few thousand hours. This is not the place for a discussion on this feature, but the writer inclines to the view that the reduced wear rate only occurs at position "A", and that if we had corresponding gaugings in line with the second and third rings from the top we should find that their wear rate tended to increase as that of the first ring decreased. That is to say, that, with parts of accurate manufacture, the top ring in the beginning holds up all the gas pressure with resultant extra local wear. As it gets worn the lower rings take up some of the load and so shift the wear lower down.

If this reasoning be correct it is possible that, in cases of serious liner wear, the conditions might be improved by intentionally spreading the load over a greater number of rings, i.e., by encouraging a gradual step down in pressure. One cannot be dogmatic on this question; there are many possible reasons for the decreasing wear rate—for instance, it may be that as time goes on the metal absorbs oil, which improves its wearing properties under the arduous conditions.

Liner Wear in the "Raby Castle".

In the case of a fifth ship (the single-screw M.S. "Raby Castle"), liner-wear records are also available, but they are not so complete as for the later twin-screw ships.

The ship and machinery were fully described in "The Motor Ship" of May, 1925, and the engine is of the same general design as those in the twin-screw ships, but has eight cylinders of rather shorter stroke and lower speed.

This ship has been in service for over 10 years; six and a half years ago the engines were converted to work on the Büchi system of exhaust-turbo charging. This represented the first continuously supercharged installation, and during this period they have developed continuously a 25 per cent. increase of power, 30 per cent. being the limit on the existing shaft and rudder post. Six of the original eight liners are still in use. One cylinder of the two replaced had the flange fractured in very heavy weather in the Atlantic two years ago, and the other through a crack developing in the exhaust-valve seating after seven and a half years' service. The worst liner is now worn 130 thousandths, and the best 104 thousandths (both on diameter at position "A") giving wear rates of 2·55 thousandths

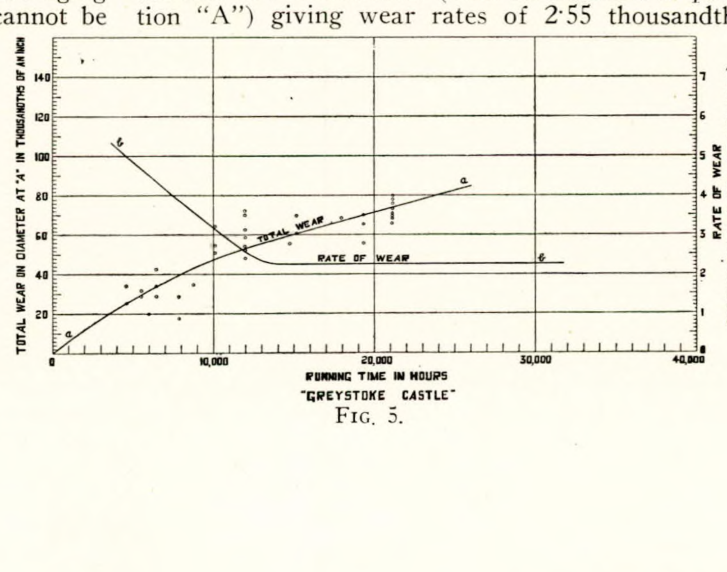


FIG. 5.

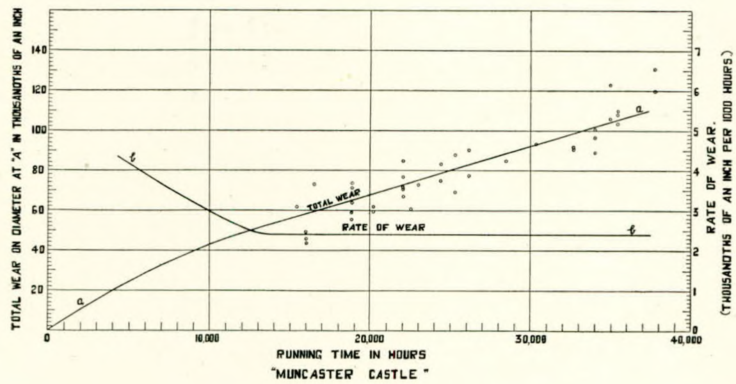


FIG. 6.

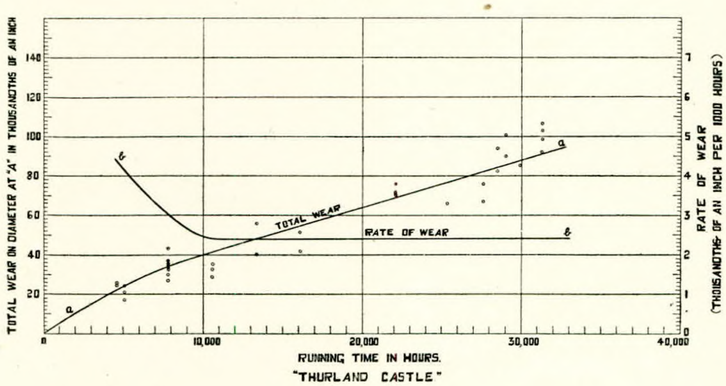


FIG. 7.

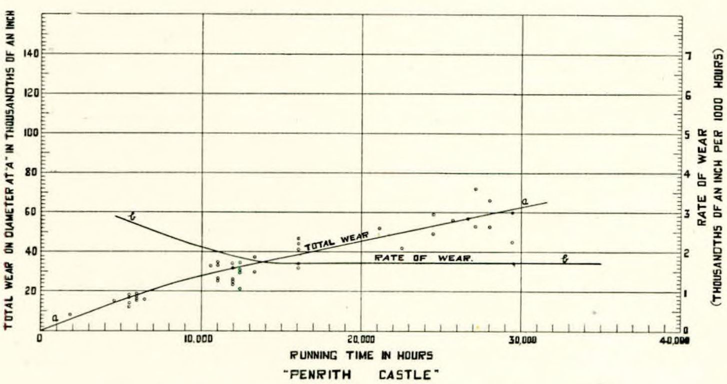


FIG. 8.

and 1·95 thousandths per 1,000 hours. So far as can be detected from the records, the increased power after supercharging has not caused any increase of liner wear (indeed, possibly a reduction), or of any other parts.

As a result of the above-mentioned increase in power the ship shows an average increase of speed since supercharging of ·73 knots.

The fuel oil used on all ships has been of Diesel quality, mostly bunkered at San Pedro, U.S., together with smaller quantities of Anglo-Persian, Borneo and Tarakan bunkered on passage. Its properties have varied as follows:—

Characteristics of Fuel used.

| | |
|---|---|
| Specific gravity ... | ·86 to ·938. |
| Viscosity ... ... | 50 to 68 Saybolt universal at 100° F. |
| Calorific value ... | 19,050 to 19,500 B.T.U.s |
| Sulphur content ... | ·2 to ·994 per cent. |
| Carbon residue (Conradson) ... ... | 1·5 to 2·0. |
| Pour point ... ... | 30 to 35° F. |
| Water and sediment | 0·10 per cent. |
| Ash ... ... ... | 0·01 to 0·03 per cent. |

Very much has been written on the subject of liner wear, but all of it, and the writer's own experience, seems to boil down to the fact that marine Diesel-engine conditions are such that the maintenance of an oil film between the upper rings and liner becomes very difficult, especially when the ship is rolling and pitching in a heavy sea. An engine designed and operated so as to give the oil film most chance of existence, and with metals of a quality well adapted to stand up to the severe and poorly lubricated conditions, will give the best results.

In all articles on liner wear hitherto the problem has been tackled on the assumption that excessive wear is present. In this case, however, all the engines under the writer's supervision give what is thought to be a highly satisfactory wear rate. In general, it seems that, until the age is over 10 to 12 years, no question of liner replacement or boring-out may arise. Once reboring has been carried out and new pistons fitted, from my experience as set out, I think it is not too much to expect that this replacement will outlast the normal life of the ship.

The writer advances the following reasons for what is a satisfactory state of affairs; it is with some trepidation that he takes this course, as he did not build the engines, and may even find himself at variance with the engine builders. If so, he can only ask to be let off lightly.

The items conducive to the satisfactory performance of liners are thought to be:—

(1) Excellence and consistency of the metal of which liners, pistons and rings are made. The metal is Lanz Perlit cast-iron, the rings having a Brinell hardness some 10 to 20 degrees less than the liners; the structure of the metal, especially as regards the disposition of the graphite, is particularly suitable for the arduous conditions.

(2) The top piston ring is well down from the piston crown, and in a thoroughly cooled position.

(3) Cylinder oil is introduced in a satisfactory manner, and the quantity is not stinted. Three quarts are allowed per day for each cylinder, i.e.,

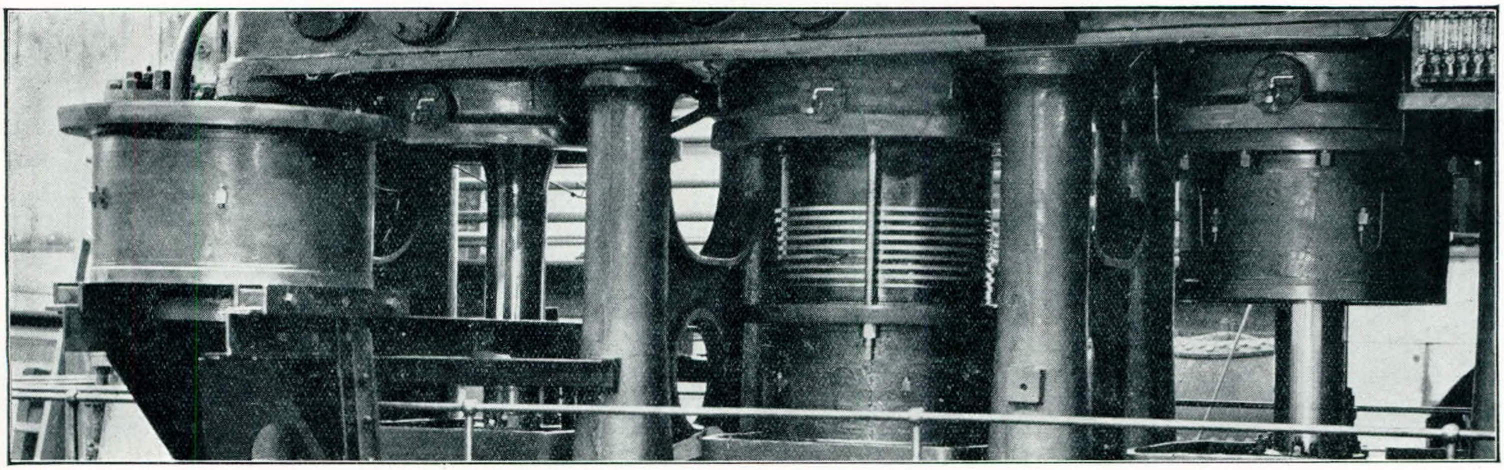

FIG. 9.—Showing the method of access to the pistons in the North-Eastern Werkspoor engine.

9 gallons per day per ship. The cylinders are 28¾in. bore, and the piston speed 1,000ft. per minute.

(4) All fuel oil is centrifuged before use.

(5) The pistons are extremely accessible—possibly one of the most important factors; in fact, a piston can be exposed for examination in 10 minutes. This means that they get regular examination, and there is no need to wait for trouble to develop before the rings are examined.

(6) The engines are accurately erected in the first case, to ensure that the piston travels truly in the cylinder bore.

---

**The "Empress of Britain" as a Twin-Screw Ship.**

"The Engineer", 7th June, 1935.

On Thursday, 30th May, we were invited to inspect the "Empress of Britain" in dry dock at Southampton. The vessel returned to that port on 28th May from her fourth successive round-the-world cruise, having travelled a total distance of 37,500 miles, at an average speed of approximately 18·5 knots. On the cruise and on the Atlantic passages to and from New York she was operated as a twin-screw vessel, her outer propellers having been removed prior to leaving Southampton. That arrangement has again proved to be most economical in fuel consumption, while the use of one funnel only conduced to a clean ship. The vessel was, at the time of our visit, in dry dock to receive her outer propellers and a new pair of inner propellers. She begins her 1935 Atlantic season on Saturday, 8th June. We were impressed by the well-kept clean engine-room and by the fact that after such a long voyage no repairs or renewals were necessary other than a few routine replacements of boiler brickwork.

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**Turbo-electric Propulsion in Germany.**

"The Engineer", 7th June, 1935.

The "Gneisenau", the second of the Norddeutscher Lloyd Company's three express liners for its Far East services, recently launched at the Deschimag Yard, Bremen, is an 18,000-ton ship with a Maierform hull, and will be propelled by geared turbine machinery. Her sister ship, the "Scharnhorst", is propelled by A.E.G. turbo-electric machinery with Wagner-Deschimag water-tube boilers, and is now on her maiden voyage to the Far East. She is equipped with two 10,000 kW. A.E.G. turbo-generators running at 3,120 r.p.m., which supply 3,120 volt A.C. to the two 13,000 h.p. propelling motors. The water-tube boilers are four in number and each has a heating surface of 650 square metres. Steam is supplied to the turbines at a pressure of 710lb. per sq. in. and a temperature of about 880° F. The auxiliary machinery includes four 220 volt D.C. turbo-generator sets. The ship, after undergoing successful trials, left with a full complement of 120 first-class and 150 tourist-class passengers. The third liner, the "Potsdam" which is being built to Hamburg-America Line account by Blohm and Voss, at Hamburg, will be engined with Siemens-Schuckert turbo-electric machinery and high-pressure Benson boilers. She is to make her maiden voyage early in July. The competitive performances of these three high-speed liners with varied hull and propelling machinery equipments will be watched with interest by all marine engineers.

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**The Union Steamship Company's New Vessel.**

"The Engineer", 21st June, 1935.

The Union Steamship Company has under construction at the yard of Vickers-Armstrongs, Ltd., at Barrow, a new passenger liner. She is of 14,000 gross tons, and will have a speed of about 23 knots, She is destined for service between Australia and New Zealand, and she represents the answer to identical declarations made by the Premiers of Australia and New Zealand last September with regard to their proposed actions to safeguard the shipping interests of their countries. The Union Steamship Company immediately called for tenders for a steamer to "excel in service and speed all foreign competing vessels". The new liner is to be

544ft. long overall, with a beam of 74ft.; her displacement will be 15,000 tons. Her five accommodation decks will be connected by electric passenger lifts; 400 first-class, 160 tourist, and a limited number of steerage passengers will be carried. The forward end of the promenade deck is to be screened to form an observation space. On each side of the smoking-room will be club-rooms, one for men and the other for women. Mechanical ventilation and talking picture equipment are to be installed. The ship will be propelled by Parsons single-reduction geared turbines. Oil-fired, forced draught water-tube boilers are to be used, and she should maintain a 2½-day passage between Sydney and New Zealand. A wireless direction finder, electric submerged log, gyro compass, and a recording echo-sounding machine are to be fitted, while an electric ship's progress indicator will be installed in the main vestibule. The stowage space provided will include 50,000 cubic feet for the carriage of refrigerated cargo.

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## The National Physical Laboratory.

"The Engineer", 28th June, 1935.

The National Physical Laboratory official inspection by the General Board took place at Teddington on Tuesday, 25th June. There was a large gathering of engineers and scientists, and the party was received by Sir F. Gowland Hopkins, President of the Royal Society, and Chairman of the General Board; Lord Rayleigh, the Chairman of the Executive Committee, and Sir Joseph Petavel, Director of the Laboratory. Considerable interest was shown in the work going on in the William Froude Laboratory, where the Lithgow propeller-testing tunnel was demonstrated, and experiments on the reduction of pitching and heaving in ships were illustrated. The new wind tunnel in the aerodynamics department, designed for a wind speed of 650 miles per hour, was shown working, and other experiments in this department dealt with apparatus for recording atmospheric gusts, and research work on high-pitch airscrews. In the engineering department, among other new items, were new fluid-pressure cupping tests for sheet metal, and the demonstration of stability of construction in thin sheet metal panels. Work of special interest to engineers included research on the maintenance of the tightness of steam pipe flanges. For this investigation two lengths of 8in. steam pipe, on which the test flanges are mounted, are employed. The whole assembly is heated to 1,000° F. and steam up to a pressure of 1,400lb., generated in an electrically heated boiler, can be admitted to the test pipes. The deformation of the flanges and the creep of the bolts are carefully measured. In the metallurgy department the whole subject of magnesium alloys is being investigated with the object of developing light alloys stronger than those at present available for use at ordinary and high temperatures, such alloys being demanded by aircraft constructors.

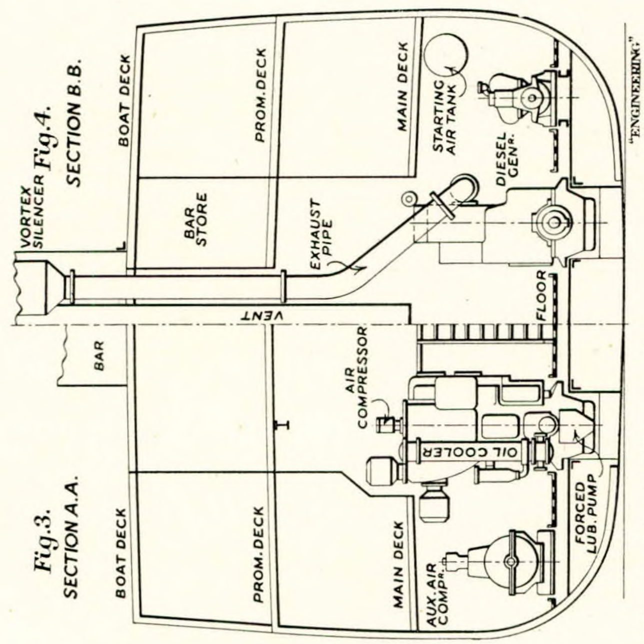
## Cross-Channel Motorship "Queen of the Channel".

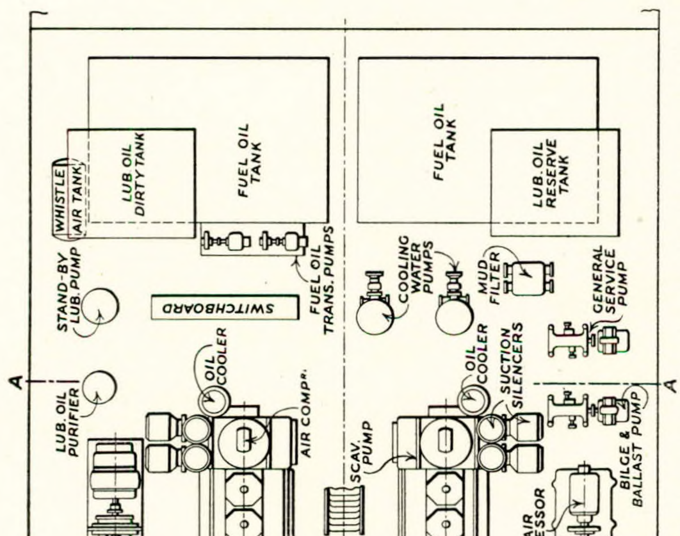
"Engineering", 21st June, 1935.

The first British motorship for cross-Channel work, "Queen of the Channel", will be put into commission on Saturday, 22nd June. Thereafter a daily service will be run, embracing Ostend, Calais and Boulogne, in connection with the Gravesend, Tilbury, Southend and Margate Continental service. The vessel has been constructed by Messrs. William Denny and Brothers, Limited, Dumbarton, for Messrs. London and Southend Continental Shipping Company, Limited, 5, St. Helen's Place, London, E.C.3, and, we understand, during her two-days acceptance trials gave very satisfactory results, the contract speed of 19 knots being well maintained. The absence of vibration from the propelling machinery and auxiliaries during the trials was the subject of general comment from those present, and it is stated that the vessel ran as smoothly and quietly as a turbine-driven steamer.

The vessel is 255ft. long by 34ft. broad by 11ft. 6in. deep to the main deck. The mean draught is about 7ft. 6in. There are twin screws situated well forward of a balanced rudder. There is also a rudder at the bow. This latter is hand-operated. The steering gear for the main rudder is situated underneath the quarter deck and is electrically driven. The warping capstan on the quarter deck and the windlass forward on the promenade deck are also electrically driven. Control is, of course, from the navigating bridge, and as there are docking telegraphs to both ends of the vessel the smoothness of handling necessary for a passenger vessel of this type should be readily secured.

A brief account may be given of the machinery, the lay-out of which will be clear from the engine-room plan and cross-sections reproduced in Figs. 2, 3 and 4. The two main engines are of eight-cylinder two-stroke cycle compression-ignition Sulzer type. One set was made by Messrs. William Denny and Brothers, Limited, at Dumbarton, and the other by Messrs. Sulzer at their Winterthur works. The cylinders are 360mm. (14·17in.) in diameter by 600mm. (23·62in.) stroke, the full-power speed being about 320 r.p.m. The scavenge air is supplied by a tandem reciprocating-type pump, driven by a separate crank, at the forward end of each engine. This pump is surmounted by an air compressor for charging the starting receivers. A pump of the geared type driven from the forward end of each crankshaft supplies forced lubrication, through filters and a Serck oil cooler to the main bearings, and crank-pin and gudgeon-pin bearings. The small bearings are fed by a mechanical type lubricator. The pistons are oil-cooled by circulation from the forced-lubrication pump, the cylinders being cooled by sea water supplied by a motor-driven Drysdale centrifugal pump, which is duplicated to provide a stand-by. The same makers are also responsible for a motor-driven




fresh-water pump and a motor-driven stand-by forced-lubrication pump.

There are four receivers for the starting air, which is maintained at a pressure of 600lb. per sq. in. by a motor-driven Reavell air compressor. The fuel oil is stored in two large tanks in the forward part of the engine room, from which tanks it is transferred to the daily service tanks by two pumps made by Messrs. Hamworthy Engineering Company, Limited, Poole, one being a stand-by set. The lubricating oil is purified, on the continuous system, by a purifier made by Messrs. Alfa-Laval Company, Limited, London. Motor-driven pumps for bilge and ballast duty and for general service and sanitary duty have been supplied by Messrs. Dawson and Downie, Limited, Glasgow. Current is supplied for the various pumps, steering gear, cooking apparatus, lighting, etc., by three generating sets driven by compression-ignition engines made by Messrs. Gleniffer Engines, Limited, Glasgow, the dynamos being supplied by Messrs. Laurence, Scott and Electromotors, Limited, Norwich, the same firm supplying the pump and air-compressor motors. The motor starters were supplied by Messrs. E. N. Bray, Limited, Walthamstow The telegraph system was installed by Messrs. Mechans, Limited, Glasgow. The silencers for the exhaust gases from the main and auxiliary engines are combined with dust collectors of Alexander's Vortex type. The machinery is made to Board of Trade requirements.

As regards the safety provisions of the vessel, there are 10 water-tight bulkheads, and fire-resisting curtains are arranged to close the alleyways on each side of the main deck amidships. The fire-fighting equipment is in accordance with the latest Board of Trade regulations and includes "Phomene" type fire extinguishers in the engine room.

## The 150th Anniversary of Messrs. J. & E. Hall, Limited, Dartford.

"Engineering", 28th June, 1935.

The celebration of anniversaries is a habit which in these days of publicity tends if anything to grow, and we have even been requested lately to find room for recording functions dealing with twenty-five years of existence. While it is true that in these times of constant change, of dissolution and absorption, there is something to be proud of in even a quarter of a century of existence, how much more pride and satisfaction is to be felt in a successful record of a century and a half? The claim of Messrs. J. & E. Hall of Dartford to some notice in our columns is, therefore, somewhat exceptional, especially since, although not at all times in the past equally prosperous, the firm has enjoyed an exceptional record in this respect and has been associated with some of the most interesting phases of engineering history. The celebrations, which attracted a large company, were held on the company's sports ground on Princes Road, overlooking Dartford Heath. Guests were received by Mr. Everard Hesketh, M.Inst.C.E., past-chairman, and Mrs. Hesketh, and by Lord Dudley Gordon, managing director, Mr. H. J. Ward, the present chairman, being unfortunately absent through illness. A full programme was arranged for the afternoon and evening, but the main interest to our readers lay in the speeches delivered after tea, of which that by Mr. Hesketh dealt with the historical aspect of the occasion.

Before Mr. Hesketh's speech, Lord Dudley Gordon, who presided in the absence of Mr. Ward, mentioned that they had received innumerable congratulations on the event, and from Messrs. Carl Flohr A.-G. of Berlin, with whom they were associated in the manufacture of escalators, they had received a very kindly letter and a gilt loving cup. Mr. Hesketh, who himself joined the firm in 1878, and therefore has 57 years' service to his credit, was naturally able to review developments from personal knowledge over quite a long period, while for many years he has made a study of the firm's past history. Although tradition suggested a romantic commencement for the firm, in reality, Mr. Hesketh said, this seemed to be of a prosaic character, the founder, John Hall, seeking employment in the district, with which his father had been acquainted some years before. There were many mills in the district and he was so successful in finding work that he was induced to start a business on his own account, with premises in Lowfield Street. Not long after, a move was made to Hythe Street, this site still being included in the present works. At first the works were driven by windmill and later by water power. After John Hall's death, the works were carried on by the two sons, John and Edward, the latter, however, conducting affairs alone for 25 years after the death of his brother in 1850. Edward Hall died in 1877, and two years later the control passed into the hands of Mr. Hesketh, who had joined the firm in the previous year.

As is well known, Richard Trevithick had been connected with the works, and a letter of his explained how refrigeration could be effected by mechanical means, anticipating developments of 50 years later. He also tried steam turbines in mills in the neighbourhood. Another famous name connected with the firm was that of Bryan Donkin, who in 1800 was associated with John Hall in the production of the first continuous paper-making machine by which that industry was revolutionised. In this connection, too, reference might be made to the fact that the two Bertrams were at the works prior to starting the now well-known firm in Edinburgh. Hall's early took up canning, but were best known as makers of refrigerating plant, having taken up the first Giffard system after the Paris Exhibition of 1877. Later the $CO_2$ machine came on the scene, and to-day Lloyd's Register showed that the firm had been responsible for some 61 per cent. of the refrigerating plant afloat.

Mr. Hesketh concluded with reference to past celebrations and to the social side of the works, the firm being strong believers in cultivating a happy spirit among their staff and in the result of this on team work. All, Mr. Hesketh said, were comrades indeed, and he thanked everybody for their loyal and efficient service.

Mr. Alexander Ramsay, who spoke subsequently, said he conveyed to the firm the congratulations of the whole industry for there was no doubt much which it was legitimate to feel proud of in what Mr. Hesketh had said. And if they carried the mind a little further, it would be found that at the back of everything around us to-day stood the engineer—making this indeed a calling to be proud of. We did not, however, get things always in the right perspective. Refrigerators, for example, were not merely so much metal. Through the efforts of salesmen, they were put into ships, by which the products of New Zealand and Australia were brought to us, thus fulfilling services to farmers and all our people abroad, as well as to ourselves. Many generations in Hall's had passed on the torch, and it was for those in the firm to-day to continue the good work and to go on from strength to strength, making for the solidarity and security of our far-reaching Empire.

The programme very fittingly included speeches by representatives of the office and works, and presentations to two veterans of 50 years' service. At the present time the firm has on its books a staff of 2,500, the highest number, and the works cover a greater area than ever before.

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## The Diesel-Electric Paddle Vessel "Talisman".

"Engineering", 28th June, 1935.

The Diesel-electric paddle vessel "Talisman", which is shortly to be added to the London and North Eastern Railway Company's passenger fleet on the Firth of Clyde, is stated to be the largest of its kind in the world. The hull, which was built by Messrs. A. & J. Inglis, Limited, Penthouse, under the supervision of Mr. J. A. Rodger, marine superintendent for the Southern Scottish Area of the railway, is 215ft. long between the perpendiculars, the breadth moulded being 27ft. 6in. and the depth moulded to the promenade deck being 16ft. 6in.

The propelling equipment consists of four 400 h.p. Diesel engines, which supply a single 1,300 h.p. propulsion motor with a normal speed of 50 r.p.m., or equivalent to 17 knots. Power for the deck services and for lighting and heating is supplied from the main generators, which, like the engines, the propulsion motor, the exciters and auxiliary electrical equipment, were manufactured by Messrs. The English Electric Company, Limited. The design is such that it has been possible to install the complete generating plant below the main deck in spite of the shallow draught and the small moulded depth of the vessel. The propulsion equipment can be controlled either direct from the bridge or from a control deck in the motor-room, and is so arranged that overloading of the engines or paddles is impossible. It is essential for paddle boats, the use of which is still necessary for certain duties, that the prime mover must have a reasonable fuel consumption and occupy a small space. It is claimed that these conditions can best be fulfilled by using a Diesel engine and that the electric drive forms the most suitable connection between it and the paddle owing to the absence of heavy and expensive gearing. Control is also facilitated.

The vessel is provided with accommodation for both first-class and third-class passengers, the former being forward and consisting of a covered shelter on the main deck with a restaurant and lounge below. Third-class passengers have a small shelter on the main deck with a lounge on the lower deck, and ample provision is made for both the officers and crew.

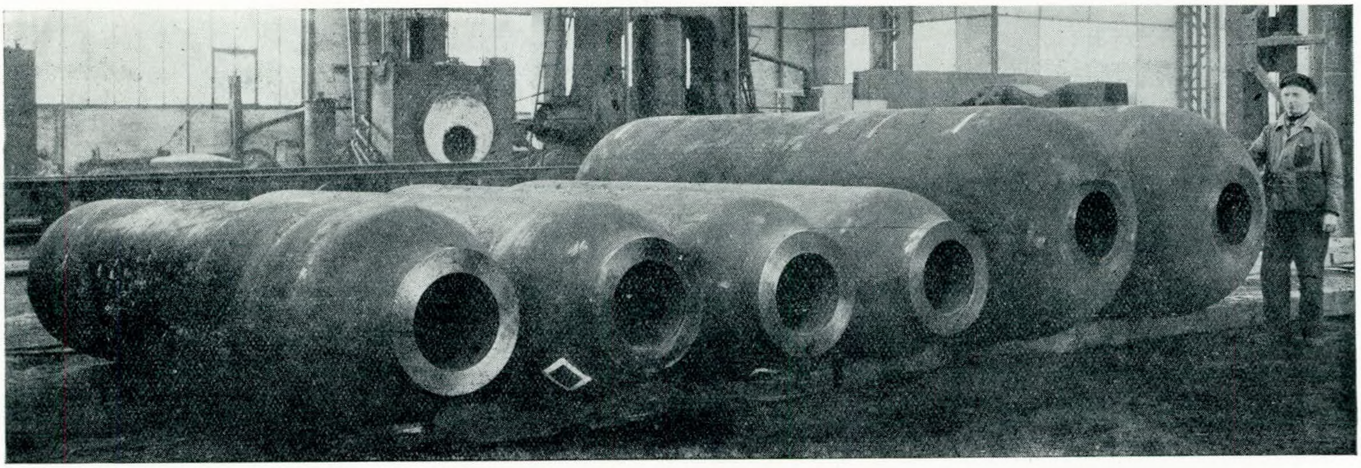
## Water-Gas Welded Drums for Marine Boilers.

"The Marine Engineer", July, 1935.

On one or two occasions we have commented upon the progress which has been made on the Continent with the water-gas roller-lap welded type of water-tube boiler drum. It may surprise many of our readers to know that considerably more than a thousand such drums have been supplied for land boiler work according to the Thyssen process of manufacture. Up to comparatively recently, however, this type of drum has not been looked upon with favour by the marine classification societies. It is particularly interesting to have to record, therefore, that the large steam drums in the Wagner-Bauer boilers of the turbo-electric liner "Scharnhorst", which we described on page 157 of our last issue, have been manufactured according to this process by the Thyssen work at Mulheim (Ruhr) of the Deutsche Röhrenwerke A.G., the German tube combine, whose headquarters are at Dusseldorf. *Mr. W. Hamilton Martin, N.W.3, has done much good work in breaking down prejudices against such drums in this country.

The steam conditions in the boilers of the "Scharnhorst", moreover, are quite the most severe yet adopted in marine practice, utilising ordinary drum-type boilers. The boiler steam pressure, it may be recalled, is 710lb. per sq. in., and the final steam temperature at the boiler, 878° F. It is thus abundantly clear that both the Norddeutscher Lloyd and the Germanischer Lloyd are satisfied as to the general reliability of this type of drum construction for the most arduous marine conditions. Two of the four large steam drums manufactured for the "Scharnhorst" are shown at the right of the accompanying illustration. These drums are 10ft. 2¼in. long by 4ft. 5in. in external diameter and have a weld thickness of 2⅝in. It may be mentioned that machining of the drums is not necessary beyond facing of the end apertures, as can be seen in the illustration. The material is a special Thyssen steel, known as TH 10B, which has a tensile strength of 26/32 tons per sq. in. Space does not allow of our describing the manufacturing process which has been developed by the Thyssen works in connection with these drums, but it may be stated that the strength of the weld is 96 per cent. of that of the material of the drum and in no case, we believe, where such drums have been tested to destruction, has fracture occurred in the weld. We have had the opportunity of examining etched specimens of work of this class, and the appearance of the material and the weld is remarkable; it is, in fact, difficult to detect the point where the two ends of the rolled plate meet one another.

The drums illustrated, it is interesting to note, were tested to a pressure of 1,140lb. per sq. in., and then subjected to heat treatment. The smaller water drums seen to the left of the steam drums are made according to a newer and even more interesting manufacturing process which the Thyssen works have evolved. These are seamless hot radial rolled drums, and are manufactured



* M.I.Mar.E.

from a hollow billet of TH 10B steel in a special form of expanding radial roller mill, which the Thyssen concern have also developed. The whole process of manufacture is completed in one heat, and it is possible to make drums of considerable length and diameter and of a comparatively small thickness. The drums shown are 10ft. 6¾in. long by 2ft. 11½in. external diameter, and have a wall thickness of 2in. As in the case of the water-gas welded drums the only machining operation required is the facing of the ends of the drums. The boiler tubes, superheater tubes, heat-resisting soot blower bodies and superheater element supports for this vessel are all made of special Thyssen steel, the tubes being made by a cold drawn process.

Apart from the technical interest attaching to high-pressure boiler drums manufactured according to the processes described, it is important that both the water-gas welding and radial rolling processes are materially cheaper than the solid forged drum which is generally employed in this country. The water-gas welded drum, other things being equal, is the cheapest, although the radial rolled drum is very little more expensive, we understand. In the case of the sister ship "Gneisenau", at present building, in which geared turbine machinery will be employed, two of her four boilers will have seamless hot rolled steam and water drums, while the other two will have water-gas lap welded steam drums and seamless hot rolled water drums.

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## Output and Regulation Tests on Velox Steam Generator.

"The Marine Engineer", July, 1935.

The general arrangement of the Velox "superboiler" is now well known (it has already been described in "The Marine Engineer"), but the diagrams (Figs. 1 and 2) will be of additional interest as illustrating some of the details of this remarkable boiler. The tests discussed were carried out on August 2nd, 1934, by Prof. A. Stodola on a Velox steam generator arranged in the Baden works of Brown, Boveri & Co., the dimensions of the boiler being shown in the table on this page.

Before calculating efficiencies from the foregoing results it was necessary to allow for the fact that, owing to the small cross-sectional area of the flue outlet pipe and many bends, the exhaust back pressure on the flue gases amounted to 15·2—14·0, i.e., 1·2lb. per sq. in. (33in. of water column) instead of about 2·4in., which experience on other boiler plants indicates should be encountered. This has been done, and the following results arrived at are shown in the table on page 108.

Regulation Tests.

During the tests the boiler was supplying steam to the works system, the pressure in the mains being 150lb. per sq. in. gauge. The load on the boiler was varied by opening and closing a throttle valve in the main steam pipe; this valve could not, in

| | |
|---|---|
| Heating surface of evaporator (radiation) ... ... ... ... ... | 227 sq. ft. |
| Heating surface of evaporator (contact) ... ... ... ... ... | 339 sq. ft. |
| Heating surface of superheater ... ... ... ... ... ... ... | 1,025 sq. ft. |
| Heating surface of preheater ... ... ... ... ... ... ... | 1,960 sq. ft. |
| Total heating surface ... ... ... ... ... ... ... ... | 3,551 sq. ft. |
| Combustion chamber volume ... ... ... ... ... ... ... | 134 cub. ft. |
| Steam production, maximum rate ... ... ... ... ... ... | 75,000lb. per hour. |

| | | | |
|---|---|---|---|
| Fuel analysis:—Carbon ... | 84·7 per cent. | Nitrogen plus Oxygen | 1· 3 per cent. |
| Hydrogen... | 10·8 per cent. | Water ... ... ... | 1·14 per cent. |
| Sulphur ... | 1·9 per cent. | Ash ... ... ... | 0·14 per cent. |

Lower Calorific Value: 17,150 B.Th.U.'s per lb.

| | |
|---|---|
| Flue gas analysis—$CO_2$ ... ... ... ... ... ... | 14·8 per cent. by volume. |
| Excess air above theoretical ... ... ... ... ... | 5·3 to 6·3 per cent. |

The results of the output tests were as follows:—

*Pressures and temperature—*

| | |
|---|---|
| Barometer ... ... ... ... ... ... ... ... | 28·5in. |
| Air pressure after compressor ... ... ... ... ... | 36·7lb. per sq. in. abs. |
| Gas pressure before gas turbine ... ... ... ... ... | 32·8lb. per sq. in. abs. |
| Gas pressure after gas turbine ... ... ... ... ... | 16·6lb. per sq. in. abs. |
| Air pressure after feed heater ... ... ... ... ... | 15·2lb. per sq. in. abs. |
| Feed water pressure before feed heater ... ... ... | 463lb. per sq. in. abs. |
| Steam pressure after superheater ... ... ... ... | 400lb. per sq. in. abs. |
| Fuel pressure at nozzle ... ... ... ... ... ... | 335lb. per sq. in. abs. |
| Air temperature before blower ... ... ... ... ... | 28·9° C. |
| Gas temperature before turbine ... ... ... ... ... | 533·7° C. |
| Gas temperature after turbine ... ... ... ... ... | 427·0° C. |
| Gas temperature after feedheater ... ... ... ... ... | 128·7° C. |
| Feed water temperature entering feed heater ... ... | 55·4° C. |
| Feed water temperature leaving feed heater ... ... | 176·4° C. |
| Steam temperature leaving superheater ... ... ... ... | 461·8° C. |
| Fuel temperature before heating ... ... ... ... ... | 28·9° C. |
| Fuel temperature after heating ... ... ... ... ... | 104·0° C. |

*Quantities and heat contents—*

| | |
|---|---|
| Air consumption $G_L$ ... ... ... ... ... | 89,300lb. per hour. |
| Fuel consumption B ... ... ... ... ... | 6,220lb. per hour. |
| Combustion gases $G_g$ ... ... ... ... ... | 95,520lb. per hour. |
| Steam production D ... ... ... ... ... | 74,000lb. per hour. |
| Heat content of superheated steam $i_D$ ... | 1,450 B.Th.U.'s per lb. |
| Heat content of feed water $i_s$ ... ... | 100 B.Th.U.'s per lb. |
| Heat put into steam $Q_D$ ... ... ... ... | $100{\cdot}2\times10^6$ B.Th.U.'s per hour. |
| Heat in fuel $Q'_B$ ... ... ... ... ... | $107{\cdot}2\times10^6$ B.Th.U.'s per hour. |
| Heat put into fuel by preheating $Q_V$ ... | $0{\cdot}43\times10^6$ B.Th.U.'s per hour. |
| Heat total given out by fuel $Q'B+Q_V$ ... | $107{\cdot}63\times10^6$ B.Th.U.'s per hour. |
| Steam production, specific, on steam producing surface ... ... ... ... | 131lb./sq. ft./hour. |
| Steam production, specific, on total heating surface ... ... ... ... ... | 21lb./sq. ft./hour. |
| Combustion chamber loading ... ... | 800,000 B.Th.U.'s per cub. ft. per hour. |

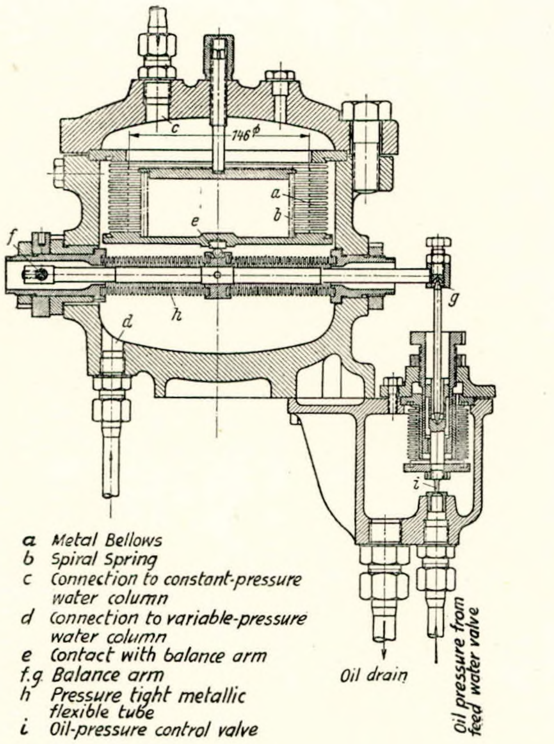



FIG. 1.

practice, be moved through its range in less than about 40 or 60 seconds. Figs. 3 and 4 represent the variation of the steam pressure, the rate of steam flow, and the speed of the blower during the process of loading and unloading the boiler. In the former case the steam pressure varied by 57lb. per sq. in. from the usual 400, whilst in unloading the steam pressure varied by 88lb. per sq. in. These variations in steam pressure, of course, bear no relation to the speed variation of any turbine supplied by such a boiler because the turbine would have its own governor. The unloading from a steaming rate of 75,000lb. per hour down to 12,000lb. per hour takes about 40 seconds, the load-

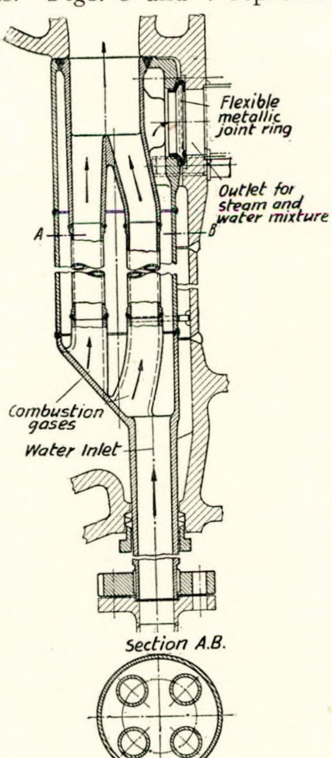



FIG. 2.

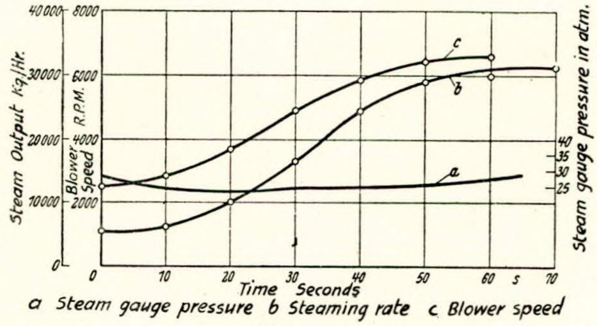



FIG. 3.

ing from 12,000lb. to 68,000lb. per hour takes 60 seconds. During the loading period a slight amount of smoke is produced resulting from the fact that the air supply control is given a small advance relative to that of the fuel feed. In a plant where the flue resistance is more normal than in this case these regulation times could be shortened considerably. On other Velox boiler installations, figures of 12 - 15 seconds for output

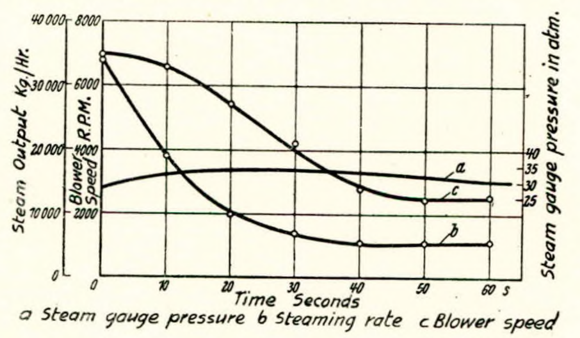



FIG. 4.

increases of from 1/5 normal to 20 per cent. overload have been obtained. The absence of any periodic oscillation in the curves in Figs. 3 and 4 is noticeable, and speaks well for the stability of the control system.

Smoke Limits.

Since all the controls are independently workable by hand it is possible, when steady conditions have been reached, to reduce or increase the quantity of air without altering the fuel feed. In the former case shortage of air quickly produces smoke; in the latter the weaker mixture burns more slowly, and the flame is extinguished as a result of the rapid cooling in the steam generating

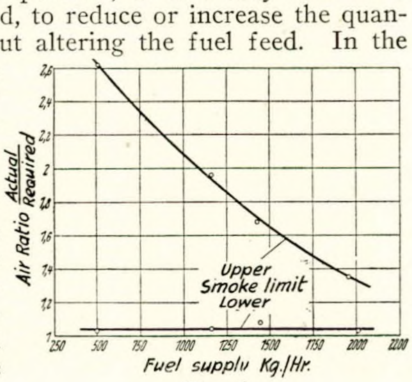



FIG. 5.

Thermal efficiency.

| | | As Measured. | Converted Figures. |
|---|---|---|---|
| 1. | Flue back pressure in. of water column ... | 33 | 2·4 |
| 2. | Effective power given by circulating pump motor ... ... ... ... kW. | 20 | 20 |
| 3. | Ditto by auxiliary motor ... ... kW. | 130·5 | —5·2 |
| 4. | Total power given to boiler ... ... kW. | 150·5 | 14·8 |
| 5. | Heat supplied through auxiliary motors B.Th.U.'s per hour ... | 510,000 | 50,000 |
| 6. | Heat supplied through fuel heating B.Th.U.'s per hour ... | 424,000 | 424,000 |
| 7. | Fuel×lower calorific value B.Th.U.'s per hour ... | 107,200,000 | 107,200,000 |
| 8. | Total heat supplied (5+6+7) B.Th.U.'s per hour ... | 108,134,000 | 107,674,000 |
| 9. | Heat obtained in steam B.Th.U.'s. per hour ... | 100,200,000 | 100,200,000 |
| 10. | Thermal efficiency (9÷8) per cent. ... ... | 92·90 | 93·33 |

Heat Balance Sheet—

| Flue back pressure ... ... | As measured 33in. water. | | Converted figures 2·4in. water. | |
|---|---|---|---|---|
| | B.Th.U.'s per hour. | % | B.Th.U.'s per hour. | % |
| Useful heat in steam ... | 100,200,000 | 92·90 | 100,200,000 | 93·30 |
| Exhaust gas loss ... ... | 4,534,000 | 3·95 | 4,534,000 | 3·97 |
| Radiation and unaccounted... | 3,400,000 | 3·15 | 2,940,000 | 2·73 |
| Heat from fuel and motor | 108,134,000 | 100·00 | 107,674,000 | 100·00 |

tubes. This produces a yellow-brown smoke, a mixture of a little soot and a large amount of half-burnt particles. Fig. 5 illustrates the smoke limits for various loads; ordinates are the ratios of actual air to theoretical air required. As can be seen the lower limit is a figure of 1·04.

"Cold starting" of Boiler.

As, during the present tests, the boiler was under steam all the time a start-from-cold test could not be made, but the accompanying diagram, Fig. 6, shows the results obtained on earlier tests on a 44,000lb. per hour boiler, carried out by Prof. H. Quiby as Prof. Stodola's representative. It will be seen from Fig. 6 that at 90 seconds after the start the maximum firing rate was reached; full speed of the blower was attained after two minutes, the lag of the blower behind the fuel rate resulting in smoke.

In 4min. 10sec. full steam pressure was reached, and in 4min. 50sec. the full rate of steam was being drawn from the boiler. By converting these times in the inverse ratio of the water contents of the two boilers and allowing for differences in the rates of fuel and air feeds it can be calculated that the boiler which is the subject of the present report could reach full steaming rate in 3min. 52sec. By cutting out the separator drum from the circulating system during the starting period, this time could be further reduced to 3min. 20sec.

Of course, this shortening means a sacrifice in the shape of an increase in output of the auxiliary motor which has to supply the energy for the rapid acceleration of the blower and turbine rotating masses. The manufacturers reckon the requirement to be about 25 kW. divided by the minutes for starting for each 2,200lb. per hour of maximum boiler output. For the boiler of 75,000lb. per hour required to reach full output in 3 minutes, the auxiliary motor would need to deliver 25×34÷3 =283 kW. This output would only be needed in exceptional cases.

"Warm-Start" Test.

The steam pressure was dropped to 80lb. per sq. in. and then this test was carried out; the results are shown in Fig. 7. From starting the auxiliaries to lighting up took one minute. Although

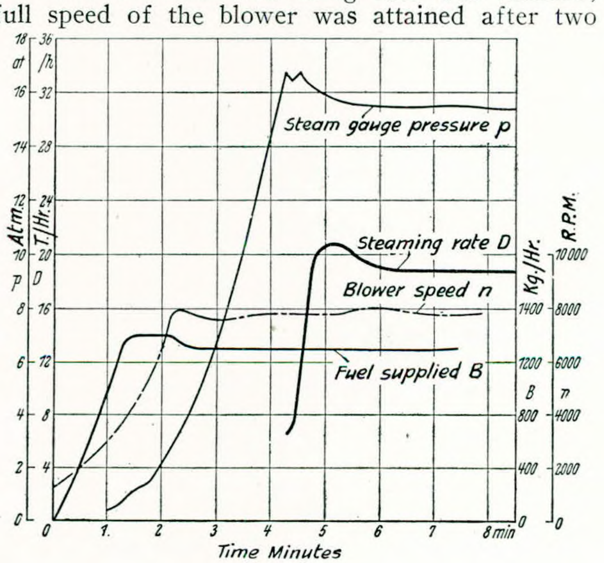
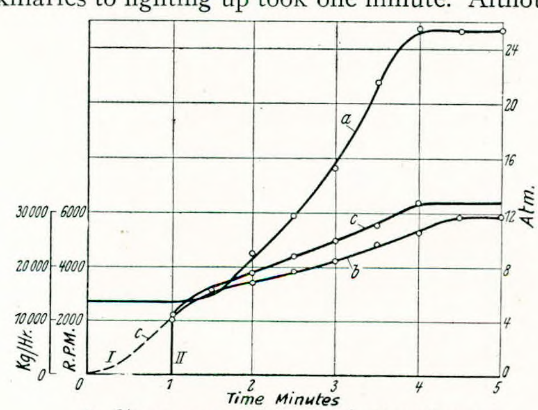



FIG. 6.

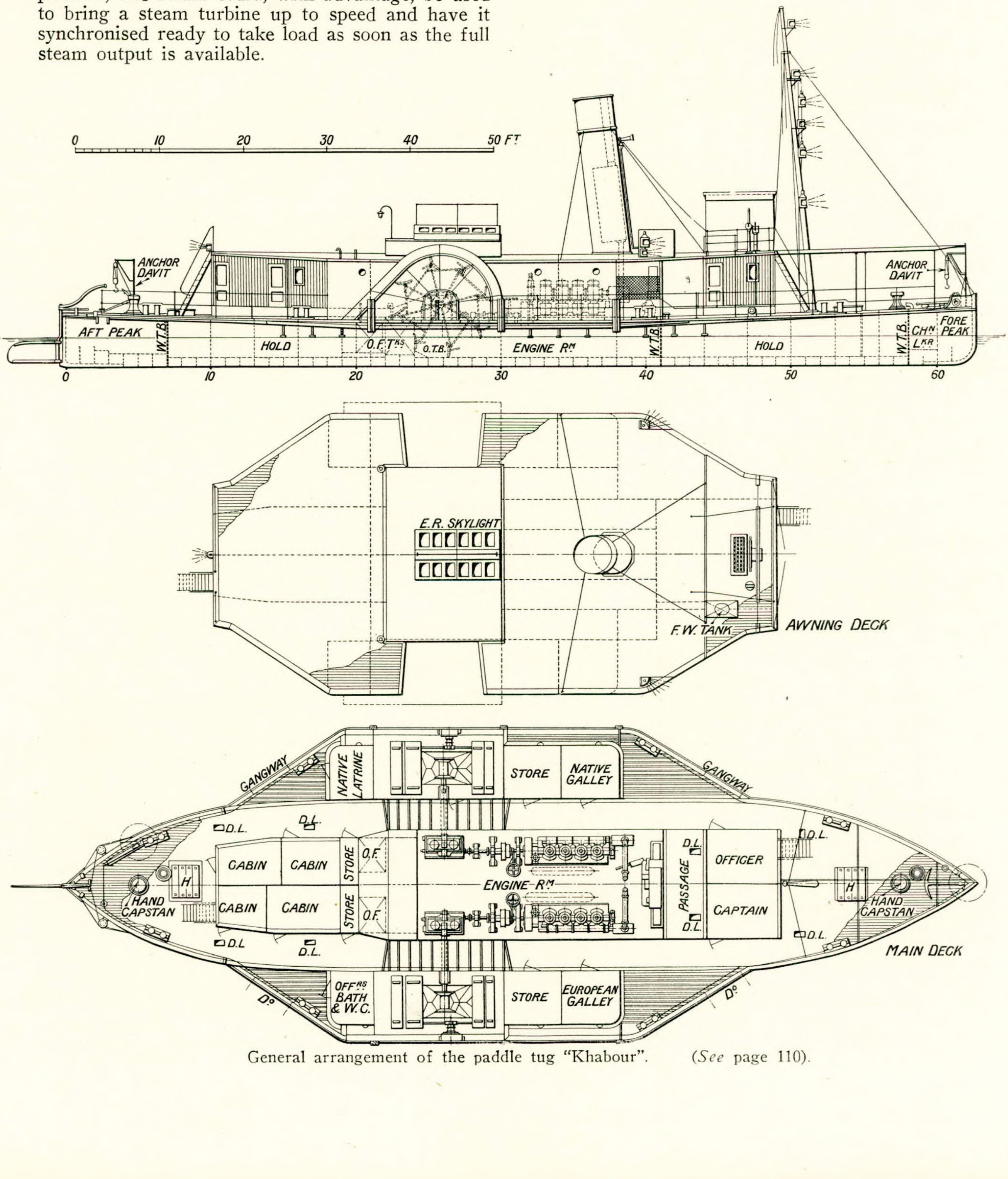



*a Steam gauge pressure b Steaming rate*
*c Blower speed I Starting-up of auxiliaries*
*II Lighting-up*

FIG. 7.

the turbine output was adversely influenced by the high flue resistance, and the auxiliary motor could only take 250 kW. at maximum speed, the steam pressure and steaming rate increased to normal in 3 minutes. With the superheater empty, as it was at the beginning of this test, steam had to be drawn immediately the fuel was lit in order to avoid burning of the superheater. In practice, this steam could, with advantage, be used to bring a steam turbine up to speed and have it synchronised ready to take load as soon as the full steam output is available.

Because of the very small radiation loss from the boiler, the steam pressure (when the boiler is shut down) remains for hours sufficiently high to permit of reaching full output in an exceptionally short time.—*Prof. A. Stodola. Z. V. D. I.*, April 6th, 1935.




General arrangement of the paddle tug "Khabour". (*See* page 110).

### The Geared Diesel Paddle Tug "Khabour".

"Shipbuilding and Shipping Record", July 4th, 1935.

The first paddle tug to be built in this country embodying mechanically-geared Diesel drive to the paddle wheels ran trials recently on the Clyde, prior to being partly dismantled for shipment to the East, where she will operate in the service of the Euphrates & Tigris Steam Navigation Company. The "Khabour", as she is called, has been built by Ardrossan Dockyard Limited.

The vessel is designed for shallow draught river work, her load draught with full deadweight being limited to 3ft. 4½in., and the principal dimensions are :—

| | |
|---|---|
| Length ... ... ... ... | 110ft. |
| Breadth, moulded ... ... | 21ft. |
| Breadth, over sponsons ... | 37ft. 6in. |
| Depth, moulded ... ... | 5ft. 6in. |

The vessel has a straight stem and stern and a single-plate rudder aft of the stern, with stock led up above the main deck level and fitted with tillers. The hull is subdivided by three watertight and two oiltight bulkheads into six compartments, comprising the after peak, after cargo hold, oil fuel cross bunker, engine room, forward cargo hold and fore peak. Each cargo hold is served by a hatchway measuring 4ft. by 3ft. 4in. The main deck is laid with 1¼in. teak, and a substantial elm belting extends for the full length of the vessel along the main deck and round the sponsons.

The machinery is situated amidships and consists of two Diesel engines driving two independent paddle wheels through reduction gears, and an auxiliary engine driving an air compressor and a dynamo. The main engines comprise two Gardner cold starting airless-injection 4.J.7 two-stroke cycle vertical engines, each developing 120 b.h.p. at 340 r.p.m. Each engine has four cylinders 10in. in diameter by 12in. piston stroke. Aft of the main engines are two reduction gears of Stone's K.2.R. type coupled to the main engines by forged steel shafts with Cooper-Benz clutches at the engine end and Wellman Bibby couplings at the reduction gear end. The paddle shafts are of forged steel with Wellman Bibby couplings to the reduction gear.

Cast iron paddle centres are keyed to the paddle shafts and take the forged steel arms of the paddle wheels. The cast steel float brackets are connected to feathering gears, the floats being of American elm. The auxiliary set is placed at the forward end of the engine room and consists of a Gardner 1.L.2. engine, driving a Gardner air compressor and a Crompton Parkinson 5/5½ kW. 100/110 volt generator.

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### Oil Fuel for Big Ships.

"Shipbuilding and Shipping Record", July 4th, 1935.

The opinion that without the progress made in the use of oil as fuel it would be almost impossible to build and run on an economical basis such large and powerful ships as the "Normandie", was expressed by M. de Malglaive, managing director in London for the Cie. Générale Transatlantique, in an address before the Oil Industries Club in London on Tuesday.

"I foresee that the boiler of the near future", he said, "will be related to its turbine more in the line of the carburettor to an oil engine, than the Scotch boilers of 20 years ago to their reciprocating engines. The modern trend of steam production points definitely in that direction.

"I feel sure that in the near future we will find apparatus which will still be called boilers by habit, but will be only transformers directly attached to their turbines, where water will be instantaneously transformed into very high-pressure superheated steam, expanded in specially-designed turbines and condensed in a few seconds".

M. de Malglaive said that under full power, when developing about 160,000 h.p., the oil consumption of the "Normandie" was about 57 to 60 tons an hour.

If coal, instead of oil, had to be used, more than 150 tons an hour would have to be carried into the stokehold and fed into the boilers. An army of trimmers and firemen would be required to dispose of 10 to 12 tons of ashes and clinker.

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### Fuel Oil Prices in America.

"Shipbuilding and Shipping Record", July 4th, 1935.

A conference was held last week at New York between operators of private shipping lines and officials of the Shipping Board services at which steps to obtain reductions in the price of fuel oil and a proposal to draw the Government's attention to the rapid increase in the price of fuel oil in the last three years were discussed, reports Reuter's Trade Service from New York.

Two or three years ago, when fuel oil was obtainable at about $0·60 a barrel at North Atlantic ports, practically all passenger and many freight vessels were transformed into oil-burners, which resulted in great operating economies and vastly superior results. Most ship operators were so enthusiastic about the advantages of oil that, in making the change from coal to oil, they scrapped their coal-burning equipment entirely although a few left their original coal bunkers in.

Now the picture has changed completely. With fuel oil at $1·20 a barrel it would be definitely cheaper to operate on coal, and a return to coal is now receiving serious consideration. Ship owners, however, do not want to go to the expense of re-equipping their vessels if there is any possibility of being able to buy fuel oil at a lower price in the immediate future, hence the present agitation.

The oil companies realise that the shipping lines are in a dilemma and are sitting back awaiting developments. They are not going to reduce fuel-oil prices if they can help it, since it is asserted that even now these prices only represent a fair margin of profit considering the high price of crude oil. They also realise that shipowners, apart from the expense, do not want to go back to the disadvantages of coal. The oil companies have at present the upper hand and, although it is possible that a slight reduction may be made in fuel-oil prices, very substantial concessions do not appear an immediate probability.

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**Express Transatlantic Shipping.**

"The Shipbuilder and Marine Engine-Builder", July, 1935.

By crossing the North Atlantic from east to west at an average speed of 29·98 knots, and by returning at an average speed of 30·35 knots on the eastward passage, the French quadruple-screw turbo-electric North Atlantic liner "Normandie" on her maiden voyage has not only broken all previous speed records, but has recovered for France the Blue Riband after an interval of nearly half a century. The manner of her achievement—accomplished as it was despite a compulsory slowing down westbound due to a broken condenser tube—clearly suggests that the great ship has within her potential speed and power reserves still not fully revealed.

This outstanding performance—and, in fact, the "Normandie" as a whole—serves to emphasise the hazard and uncertainty attendant upon prophetic tendencies relative to transatlantic shipping; for it will be recalled that less than 10 years ago there were few who thought other than that prewar speed rivalry was unlikely to be revived for some substantial time ahead, and that the 1,000ft. ship would continue an unrealised dream. With regard to speed, the record held for some 22 years by the Cunard liner "Mauretania" passed to the Norddeutscher Lloyd liner "Bremen" in 1929 with the new records of 27·83 knots westward and 27·9 knots eastward. Despite a very gallant attempt on the part of the "Mauretania" in August, 1929, to recover her lost laurels, she was unable to equal the "Bremen's" figures, although she attained then, at 22 years of age, her highest average speed of 27·22 knots—a remarkable tribute alike to her builders and owners. In 1930, the "Bremen's" westbound record was improved upon by the "Europa", which clipped off 36 minutes, only to see the record again revert to the "Bremen". The last-named vessel in 1933 was the only merchant ship which had averaged a speed in excess of 28 knots across the Western Ocean. From Germany, the record passed to Italy in August, 1933, when the "Rex" crossed from Gibraltar to New York at the high average speed of 28·92 knots—an east to west record which only the "Normandie" has been able to improve upon. That the "Normandie's" figures will be hard to beat is perhaps best illustrated by recording that, on her first homeward voyage, her best daily run was 711 miles and her highest speed 32·3 knots.

Performances such as the foregoing leave no doubt as to the enormous progress which has been accomplished in naval architecture and marine engineering during the past few years. Without the benefits which flow from the practical application of modern experiment-tank researches, records of the foregoing character would have been unattainable. How far the special Yourkevitch underwater hull form may prove advantageous for any given ship is a matter on which divided opinions may be held, but its success in the "Normandie" would seem to have been clearly demonstrated. Above water, no less than below, the hull and superstructure of the "Normandie" have been designed according to the latest technique in streamlining. In no previous large liner, it is safe to say, has so much care and thought been devoted to the elimination of air resistance, and it can hardly be doubted that such attention has made some material contribution towards speed.

As to the machinery, although higher powers and speeds were developed some 10 years ago in the United States naval aircraft-carriers "Lexington" and "Saratoga"—210,000 s.h.p. and 33 knots were then recorded—with broadly similar turbo-electric drive on quadruple screws, it says much for the general design and robustness of the "Normandie's" electrical machinery that it should have stood up so well to what must have been severe demands upon it before it was fully run in. In this respect, it would appear that electric propelling machinery is in no wise more frail or requires more nursing than steam geared-turbine drive. With regard to the boiler plant, it is here that marked progress has been made; and whereas but a few years ago the problem of powering a large liner was very largely the problem of how many boilers could be squeezed in, to-day modern steam generators of many dependable types are available. In the "Normandie", the Penhoët water-tube boilers—29 in number—were adequate to all demands made upon them.

From the technical standpoint— the interesting question which presents itself is how long will the "Normandie" records—outstanding as they undoubtedly are—be allowed to remain unchallenged? At the time of writing, information is not yet available as to the aggregate power developed by the "Normandie", but her designed power is stated to be 160,000 s.h.p. The first potential challenger is the Cunard White Star liner "Queen Mary", now being fitted out afloat at Clydebank; and since her engine power is unofficially, but no doubt correctly, recorded as being above the "Normandie's" figure, it appears probable that the "Queen Mary"—assuming her hull form to be favourable—will prove to be a successful challenger early next year. The "Queen Mary" apart, there is no other challenger immediately in the offing, and none appears likely to be built for some time, having regard to the present trend of passenger traffic as well as to the prohibitive cost of such a ship. Germany and Italy have already the "Bremen" and "Europa", and

"Rex" and "Conte di Savoia", respectively—all Blue Riband-class ships—and it has been suggested that, if these vessels were re-engined, they could equal the performance of any new record-holder. It has also been freely suggested that in due course the "Normandie's" owners will proceed with the re-engining of the "Ile de France", since her speed is now low in comparison with her later consort; and if this should be confirmed, it will prove once again that balanced liner services are the ultimate objective of experienced operators. A further and material factor in favour of speeding up the "Ile de France" is to be found in the fact that, at 23½ knots, her present fuel consumption is practically equal to that of the much more powerfully-engined "Normandie" at about 29 knots—a wonderful tribute to modern engineering progress.

While it has not been the policy of the Cunard White Star Line, in laying down the "Queen Mary", to regard the ship primarily as an aspirant for the Blue Riband of the North Atlantic, it hardly calls for emphasis in stating that, unless the British ship in due course is able to prove herself a faster vessel than the "Normandie", then a definite loss of prestige will have been suffered by her owners and builders, if not, in fact, also in a wider national sense; such is the great significance of these enormous undertakings to-day. It will doubtless be found that, in due course, as and when the need arises, the "Normandie" will raise still higher her already high average crossing speed; so that it would appear necessary for the "Queen Mary" to prove herself capable of averaging as much as 32 knots if the trophy is to be recovered and held. While the target to be shot at is high, there is no sort of reason to anticipate that the "Queen Mary" will not achieve all and more than is now expected of her. No better guarantee of that need be sought than the wide experience and efficiency of her owners and builders—the Cunard White Star Line and Messrs. John Brown & Co., Ltd.

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## The Turbo-electric Liner "Scharnhorst"

The Largest Ship so far constructed on the Maierform Principle.

"The Shipbuilder and Marine Engine-Builder", July, 1935.

Main Propelling and Auxiliary Machinery—General Considerations.

The "Scharnhorst" is among the first fast German-built liners having the turbo-electric form of propulsion. This twin-screw vessel is intended for the Far East service, and consequently has long stretches to steam at reduced speed.

The governing gear of the turbo-generators is illustrated in the perspective drawing reproduced in Fig. 2. The high pressure of the steam used makes it essential for the governor to have accurate control over small volumes of steam. The operation of the governor is such that all speeds between 750 and 3,360 r.p.m. can be adjusted from the manœuvring platform. The oil-control apparatus enables the position of the camshaft controlling the opening of the regulating valves to be adjusted either by the governor or the control lever. When running at low speeds, the controlling force of the governor is small, and an oil-pressure intensifier is fitted to ensure the maintenance of accurate governing. In order further to protect the turbine against over-speeding, an eccentric-ring type governor is fitted to the turbine shaft. This governor, through the medium of a trip gear and rods, operates the quick-closing stop and emergency valve. The gear is also tripped by excessive rise in the condenser pressure, stoppage in the condenser cooling-water supply, and oil-pressure failure. The stop and emergency valve is fitted with hand gear to close it when there is no oil pressure.

As previously stated, oil pressure is maintained by a spur-wheeled oil pump driven through worm gearing off the forward end of the turbine shaft. The pump supplies the distribution valve which is connected to the governor relay system, and through a pressure reducing valve to the turbine lubricating circuit.

Incorporated in the oil circuit is a double-filter oil strainer and a tubular oil-cooler of contraflow pattern. Each oil-cooler has a cooling surface of about 270 sq. ft., and, with a cooling-water temperature of 90° F., cools the oil from 140° F. to 122° F. With a sea-water temperature of 75° F. one cooler can serve both main engines when they are running at full load.

The main alternators are of the usual A.E.G. type, and are shown in sectional elevation in Fig. 1. They are totally enclosed, and special attention has been paid to the air-cooling. Cold air is sucked in by fans mounted on the rotor, and is first forced from both ends through axial grooves and then through radial spaces in the stator windings, being finally led by ducts into the air-cooler. This consists of finned tubes through which sea water is circulated, the sea water being tapped from the condenser circulating circuit. The cooler is made up of four sections, which can be separately shut down and cleaned while the plant is running. The tubes are of aluminium brass and are expanded into the tube-plates at both ends.

The rotor is machined from a single forging and is slotted to carry the field windings, the latter being held in position by non-magnetic steel end-caps and wedges. Copper damping strips are also fitted in the slots, and are short-circuited to the rotor. Mica and micanite are used for the insulation throughout. The excitation current is provided by generators fed from the ship's lighting circuit. The current is led through carbon brushes into the steel slip rings, which are shrunk on to mica insulation rings.

Special precautions have been taken to prevent dirt, oil vapour and water vapour entering the machine through the passage for the shaft in the end shields, while the brush gear is provided with a vapour-tight hinged inspection cover.

Main Propulsion Motors.

The two main propulsion motors are of the totally-enclosed, three-phase, salient-pole, synchronous type. The current is led from the switchgear through high-tension, paper-insulated lead-covered cables, the supply voltage being 3,120 volts. Each motor develops normally 13,000 s.h.p. at 130 r.p.m. and has a maximum output of 16,200 s.h.p. at about 137 r.p.m.

The frames and end shields of the propulsion motors are of some interest, being fabricated from steel plates welded together. Great rigidity combined with saving in weight is claimed for the system.

The armature, in addition to the d.c. windings, carries the short-circuited coils to provide the high starting and reversing torques required. Unlike the closed-air circuit employed in the generators, that used for the motors is an open circuit, two fans attached to the main framing of each machine being used to circulate the cooled air through the windings. These fans suck air from the motor-room, special precautions being taken to prevent water and water

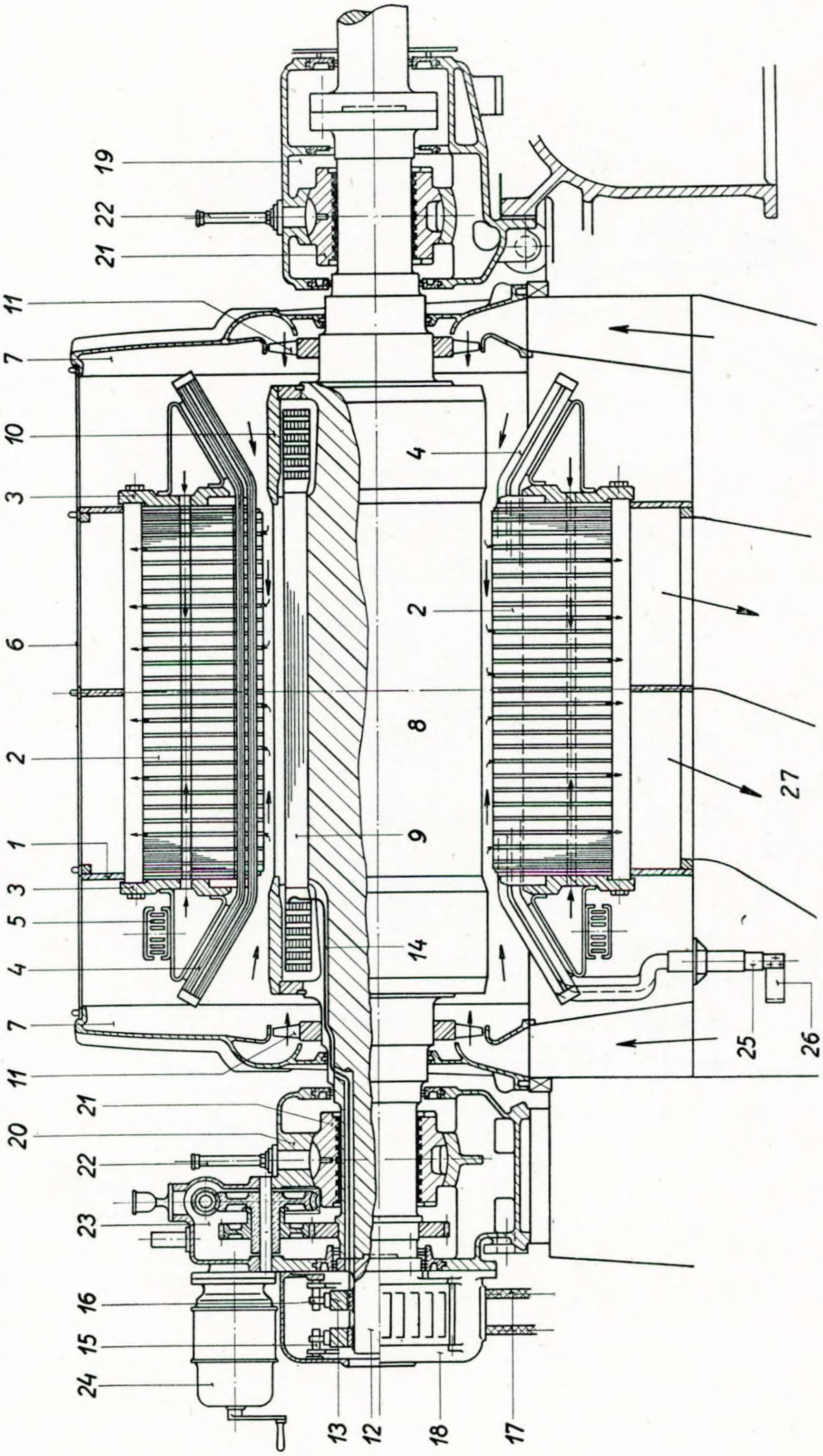

Fig. 1.—Section through main alternator.

1—Shell.
2—Laminated core.
3—End plates.
4—End connections.
5—Ring connection.
6—Enclosing plates.
7—End shields.
8—Rotor shaft.
9—Rotor coils.
10—End caps.
11—Air fans.
12—Slip-ring end of shaft.
13—Slip rings.
14—Slip-ring cables.
15—Brush gear.
16—Brush holders.
17—D.C. supply cables.
18—Inspection cover.
19—Bearing at exhaust end of turbine.
20—After bearing.
21—Bearing bush.
22—Thermometer.
23—Rotor-turning gear.
24—Motor for turning gear.
25—Main A.C. cables.
26—Neutral cable connection.
27—Warm-air duct.

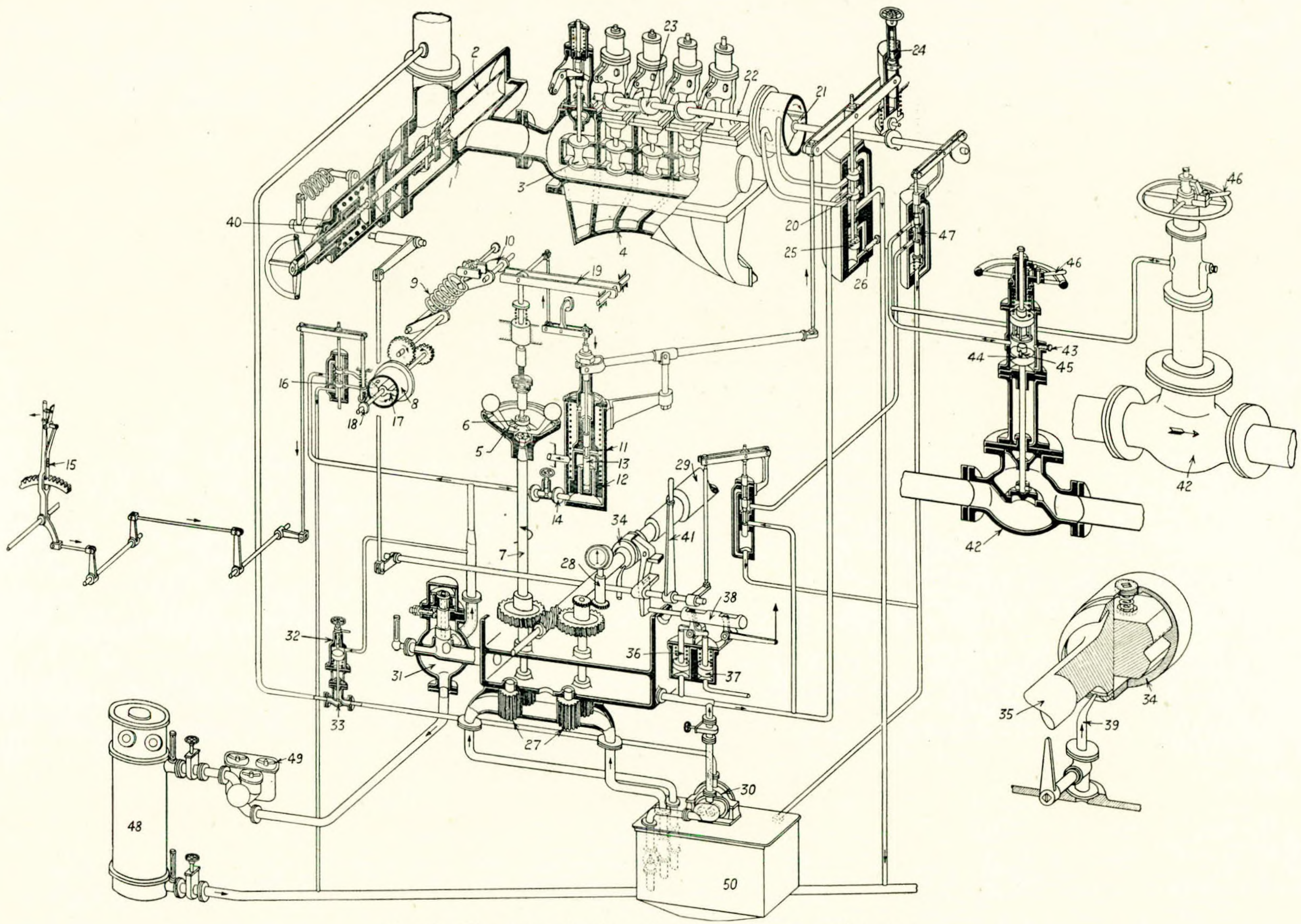

FIG. 2.—Diagrammatic view of main-turbine governing gear.

1—Quick-closing, stop and emergency valve.
2—Strainer.
3—Main regulating valves.
4—Nozzle-group distribution box.
5—Governor.
6—Governor sleeve.
7—Governor spindle.
8—Relay cylinder for governor.
9—Main spring.
10—Cam.
11—Pressure intensifier.
12—Plunger of intensifier.
13—Governor-operated plunger.
14—Throttle valve.
15—Hand-control lever at manœuvring platform.
16—Pilot valve.
17—Diaphragm.
18—Cam.
19—Governor-operated lever.
20—Pilot valve on cam-shaft relay.
21—Diaphragm.
22—Cam-shaft.
23—Cams operating regulating valves
24—Overload adjustment.
25—Dashpot.
26—Adjusting screw.
27—Main oil pump.
28—Tachometer.
29—Turbine shaft.
30—Auxiliary turbo-driven oil pump.
31—Oil-distributing valve.
32—Oil-pressure regulating valve.
33—Steam-supply valve to auxiliary oil pump.
34—Emergency governor.
35—Shaft to governor-driving gear
36—Arrangement for tripping when oil pressure fails.
37—Arrangement for tripping when pressure in condenser rises excessively.
38—Trip gear.
39—Lubricating-oil pipe to emergency governor.
40—Valve-closing mechanism.
41—Hand-lever to operate quick-closing valve mechanism.
42—Steam-supply valve.
43—Adjusting screw.
44—Damping piston.
45—Spring-loaded valve.
46—Locking pin.
47—Pilot valve.
48—Oil cooler.
49—Oil filter.
50—Oil tank.

vapour entering the machine, and the heated air is discharged into the same compartment through a sea-water circulated tubular air-cooler similar to that described for the generators.

Electric-control System.

The multiplicity of running combinations of generators and motors afforded by electric propulsion greatly enhances the reliability and freedom from breakdown of this ship-propulsion system, and to this end the electrical-control system has been carefully designed. The following running combinations are possible:—

(*a*) Starboard motor fed by the starboard generator and port motor by the port generator—full speed given.

(*b*) Either alternator feeding both motors and the other being shut down. In this latter case, the propeller speed is 104 r.p.m. and the corresponding alternator speed is about 2,500 r.p.m. The alternator is designed to give full output at this speed, and consequently the power transmitted to the propellers is 50 per cent. of the full power available with both alternators running.

The excitation current for both the motor and generator fields is taken from transformers fed from the ship's d. c. network. This is supplied at 220 volts by four d. c. auxiliary turbo-generators situated in the main engine-room. The transformers deliver the current at 110 volts to the respective field circuits. Two boosters are provided to over-excite the generator-field circuit when starting and reversing. The apparatus for controlling the generator excitation has been supplied by the A.E.G. Company, and is such as to maintain a constant generated voltage at all loads, as well as further to adjust the excitation current to suit the required speeds and outputs. The grouping of the electric-control gear and the recording and measuring instruments for the electrical equipment, in a master control board situated near the main manœuvring station, considerably simplifies the work of the engine-room personnel in adjusting the outputs of the various units to any desired load.

To ensure the safety of the plant, the system of alarms and indicators is very complete. Special precautions have been taken to protect the machinery from earths and phase faults, excessive heating in coils and bearings, and against overloading of the generators.

Boiler Installation.

Considerable interest is attached to the boiler installation, as the employment of high-pressure, high-temperature steam for marine work is a comparatively modern development. Four water-tube boilers of the Wagner-Deschimag type supply the steam for all purposes. The working pressure is 735lb. per sq. in. gauge and the temperature on leaving the superheaters is 880° F. The principal heating surfaces of each boiler are as follow:—Generating surface, 7,000 sq. ft.; superheating surface, 2,240 sq. ft.; and air-heater surface, about 11,000 sq. ft.

Each boiler has two drums, the upper having a diameter of 4ft. 5¼in. and being of welded construction, while the lower is 3ft. 3in. in diameter and solid-drawn.

The drums are connected by solid-drawn steel tubes which completely surround the combustion chamber. The nests of tubes are so arranged that the furnace gases first come into contact with uprisers, then the superheater elements, then the downcomers, and finally pass through a tubular air-heater to the funnel.

A steam-collecting box is fitted on to the top of the upper drum, and either passes the steam through the main stop valve to the lower superheater header, or through a reducing valve to the low-pressure steam mains at a pressure of about 200lb. per sq. in. Each boiler is fitted with two Deschimag-Saacke oil-burners. In this type of burner, the oil is fed into a chamber and atomised by the centrifugal action of the primary air supply, which is maintained by separate electrically-driven pumps. Further air for combustion is supplied by forced draught, the close-stokehold principle being employed. The two forced-draught fans are mounted on the upper flat in the auxiliary engine-room, and their suction is through ports in the base of the funnel.

Special attention has been paid to the boiler fittings, and the water-level regulating and indicating apparatus is unusually complete. It will be noted that the starboard battery of boilers is connected only to the starboard turbo-generator, and similarly the port battery only supplies the port live-steam mains, no interconnection being made.

The high-pressure steam mains have been tested up to 2,200lb. per sq. in. and are of Siemens-Martin steel. Bulkhead valves, with the usual water-draining apparatus, have been fitted. The whole boiler plant is characterised by the ready accessibility for inspection, cleaning and overhaul of all parts, and its performance in service will be watched with considerable interest.

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## Restoring Tool Cutting Edges.

"The Engineer", 14th June, 1935.

A firm of American welding engineers has developed a new arc-welding electrode by the use of which the cutting edge of all kinds of machine tools can be restored. This electrode, known as "Toolweld", provides a deposit which is equivalent to high-grade tool steel, and it is claimed that the deposit is of such a nature that it retains its hardness up to a temperature of approximately 1,000° Fah. The material can be used for building up the worn cutting edges of lathe tools, milling cutters, drills, bits, dies, etc., while new tools using ordinary steel in place of high-speed steel can be provided with a high-grade cutting edge. A series of tests carried out with a tool faced with "Toolweld" and another of ordinary design showed that under similar conditions the output of the former was more than twice that of the latter before regrinding was necessary. Moreover, it is estimated that the cost of the tools is about 20 to 25 per cent. less when the electrode method of construction is employed.

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### The Mariner's Compass.*

By Captain JOHN M. L. GORETT, M.S.R., C.C.A.

"The Engineer", 21st June, 1935.

It is worthy of notice and in keeping with the purpose of what I am about to write that of the many factors which have played a dominant part in the forming of our civilisation, not any other one has contributed so much nor so important constructive material as the ship.

The greatest legends of mankind have been enacted mostly upon the sea; and seamen in the early days, even as now, were and are our most beloved heroes; Danao, Ulysses, Vasco da Gama, Magellan, Captain Cook, Nelson, Captain Slocum. For it is at sea as nowhere else that man's ingenuity, dignity, and steadfastness are bred and tested.

I also hold that man's mental and spiritual progress has always followed in the wake of his mastery of the blue water of the sea, and that had not the physical venture come first as a pointing beacon of what could be achieved by trying, the social advancements may have remained but dreams of the suffering multitudes oppressed and unfortunate.

In the very beginning of history we find the boatman sailing in daytime only and never losing sight of the land; for although in possession of a craft quite strong enough to brave a measure of open water, he dared not trust himself to the uncertainty of the weather as his only source of direction lay in the visibility of astral bodies. Man's desire to see and know what was beyond the horizon, his ineradicable longing for what he did not possess sharpened his mind, and in the days of Homer we find the outward-bounder well stocked with live birds so that whenever the lay of the land was wanted a bird was released, and, by noting its direction of flight (always toward the nearest land) a bearing of some sort would be obtained. The drift of clouds associated with the quality of the wind conveyed useful information; for if the wind was cold the clouds would come from the north, and if it rained, from the east, and so forth.

Although the Mediterranean, the Red Sea, and the Persian Gulf were the entire world in those days, and voyages were short by choice, we find record of long ones which were taken by compulsion and sometimes even accomplished without better direction indicators than a dozen live crows, the sun, and the following star table, which, of course, held good only for certain and limited latitudes :—

| | |
|---|---|
| North. | Polaris. |
| N.E. | The point on the horizon where the constellation of the Ram arose. |
| E.N.E. | The point on the horizon where the constellation of Arcturus arose. |
| E. | Midway point. |
| E.S.E. | The rising of the sword of Orion. |
| S.E. | The rising of the constellation of Scorpio. |
| S.S.E. | The rising of Canopus. |
| S. | The Pole opposite Polaris. |

Stirring days those were when our earth was flat and demons and sea-serpents were very real and waiting for the adventurer, whichever way he might turn.

It is quite erroneous for a large number of writers to hold that the Chinese made use of anything like a compass at an earlier date than the Europeans did. During my investigation of the subject I have found Chinese documents, the writers of which in various epochs described their vessels with great care and a wealth of details as to the hull, the masts, and the sails, the sleeping and cooking arrangements, as well as references as to how those often large ships were handled; but I find no allusion whatever to the compass or to anything which may have served as an instrument of direction, besides birds, clouds, the sun, and various star tables. My conclusion on the subject is rendered doubly secure by the fact that those very Chinese writers from whom I have drawn my information often refer to the extraordinary power of the magnet. While obviously aware of its attractive property, they remained quite ignorant of its other, and, by far more important, characteristic of pointing to the north.

I also dismiss any possibilities as to the Arabians having had any knowledge of the compass, although they were well acquainted with the magnet, as were also the Grecians, who used it in their academies, and I find Plato speaking of it with some humour as of its being used by jealous husbands to test wifely virtue.

Marco Polo in his narratives states that on the Arabian ships he had voyaged on, there was no "Bozzolo" (Venetian for compass). He passes on to say that the vessel had four masts, only one rudder, seventy cabins for the merchants, and was navigated by the astrologer, who, sitting high and all alone with the astrolabe in his hands, and holding great thoughts, gives orders. Knowing what an accurate reporter Marco Polo was, I cannot help inferring that it would have been impossible for such a remarkable instrument as the compass, no matter in what form, to have escaped his notice; besides, the astrologer would not have sat high, probably at the masthead, had there been an instrument of direction on the ship.

It is in a volume dealing with the art of ship handling, written in Latin, title and author

*From the "Journal of the American Society of Naval Engineers".

unknown, as the title page is missing, but which I place in the third century A.D., that I find the description of what may have been a compass. I give it as I found it: "Take a number of small iron bars (needles) and paint them with a mixture of cinabro and orpimento well powdered and mixed with the blood of the crest of a rooster. Heat them well, and, after the Astrologer has carried them next to his skin for a period of a full lunation, lay them on straws floating on the water and they will point South".

Surely this is magic and not physics. Still I cannot rid myself of the thought that, perhaps, it was a bundle of magnetic needles, and that it really was physics camouflaged by magic, and the humbug of cinabro and the crest of a rooster were employed merely to hide the true nature of the needles.

Whatever it may have been, it was not adopted, for one finds nowhere any further reference to the magic process and ships continued to be navigated by the astrologer, who, sitting high with the astrolabe in his hands and great thoughts in his head, gave orders. He was probably the original look-out man, who, being aware of the earth's sphericity, knew how to hold a good job by keeping his knowledge to himself.

It is during the reign of Ludovico IX and precisely with a certain Brunetto Latini, a Florentine to whom Dante referred as "Il Maestro mio", that in his poem entitled "Tresor", and written in France in 1248 *circa,* I find mention of Norman ships being sailed with the aid of an instrument called the Mariniere, and described as follows:—"In a tub of water placed in the centre of the ship there floats the Mariniere, which is a round piece of cork with a thin hollow shaft filled with lodestone inserted through its center so that it lies parallel to the plane of the water, and the quill of a goose sealed at both ends, also inserted through the cork at right angles to the one filled with lodestone; over this there lays a bird's skin with the Fleur de Lys upon it, and even as our august King is our constant guide on the land, so does the Fleur de Lys upon the Mariniere guide the mariner by constantly pointing to Boreas (North) no matter how the ship may go".

To this very day, seven centuries later, practically every ship's compass card has a Fleur de Lys impressed upon its north joint.

Cardinal Jacques de Vitry, in 1250 *circa,* assures us that the Marinette (as it became known later) gave splendid service and we may well believe it, although Variation had not yet been spoken of.

The advent of the Marinette gave large impetus to navigation in northern waters, although it was not adopted for many years to come by the navigators "East of Suez". Voyages, however, became more frequent and speedier, and fifty years after the advent of the Marinette we find merchants cashing notes from the Indus to Normandy, and ordering goods with the time of delivery indicated for the first time in history. The astrologer was called down from aloft and installed in a small cabin erected on deck to house the Marinette and called the "Habitatus",* which in time became the Bittache and is nowadays known as the binnacle, i.e., a housing arrangement for the compass.

It is odd, but not surprising, that no mention is made anywhere of the man who discovered the north-seeking property of the magnetic needle, nor of the one who devised so clever an adaptation of this property to the requirement of navigation. Those were not the days of rugged individualism (for a consideration) and the inventor may have felt sufficiently rewarded by the knowledge that greater glory would attach to God and King for his discovery.

Useful as the Marinette turned out to be, it had the serious drawback of being thrown against the side of its container whenever the ship rolled, and in a high sea had to be taken out of it altogether to keep it from utter destruction.

To overcome this defect, Messere Flavio Gioia, an Amalfitan, devoted his knowledge of physics and mechanics, and in the year 1295 *circa* he evolved the first compass the world had ever known really worthy of the name. In place of the wooden tub filled with water in which the Marinette had floated heretofore, he employed a huge copper bowl, which, when the ship's head is swinging in Azimuth† by generating electromagnetic induction, the current of which will be in such direction as will tend to bring the needle to rest sooner than if the tub was made of wood is a decided advantage in damping the oscillations of the compass card. In the centre of the inside of the bottom of his copper bowl he secured a slender shaft on the vertical, upon the well-pointed upper end of which he balanced a compass card, showing not only the Fleur de Lys on its north point, but the other cardinal points as well, and by covering it with a glass top blown at Murano, evolved a compass which in principle, if not in details, was the same as the ones we use at present. This he called the Bussola,‡ for as the card proved to be somewhat sluggish on account of what must have been an enormous weight upon the pointed pivot with resulting retarding frictional resistance, it had to be tapped from time to time to keep it from sticking upon the pivot.

I would fain impress my reader that the facts herein stated are the result of most painstaking investigation extending over twenty years of time, and not mere hearsay.

Very little gain, however, was reaped by Flavio Gioia for his adaptation of the magnetic needle, and I rather think that of the millions who have staked their lives upon the compass or won fortunes and

* *Habitatus,* Latin for habitation or dwelling.
† *Azimuth,* from the Arabic for direction.
‡ *Bussola,* from the Italian "bussare", to tap.

everlasting fame by the aid of it, not a handful has ever given thanks to the Amalfitan who laboured not for himself, but for the future brotherhood of mankind.

In Sandres, a small town of the province of Algarves, near Cape St. Vincent in Portugal, Don Enrico, the Fifteenth Infante, in the year 1480, established the first Nautical Academy for the purpose of furthering the art of navigation. Learned men, philosophers and astrologers, shipwrights and pilots came from the Mediterranean and Northern France to confer with each other, hydrographic charts were composed, the great Gnomone which stands to this day was constructed and seventeen years after its inception the Academy had accomplished so much that on July 18th, 1497, at high noon, Vasco da Gama, in command of four vessels, sailed forth to the discovery of new lands, equipped with compasses, charts, and astrolabes of a perfection never before achieved. King Don Emmanuel was present at the sailing ceremony and marvelled much at the compasses, which in general principle and application, if not in details, were very much the same as the ones we use to-day, invented in Normandy, adapted in Italy, and perfected in Portugal. Man's advance in most fields of endeavour has ever been by leaps and bounds, and the art of compass making remained at a standstill for a long time, inasmuch as three centuries after Columbus, equipped with a not too erroneous chart of the east coast of North America, and piloted by a Guernsey sailor, had landed in San Salvador, we find the British Admiralty advocating the use of long magnetic needles in the construction of the compass card in the erroneous belief that the larger the needles the greater must be the sensitiveness of the card.

William Thompson (born in 1824, died 1907), later to be known as Lord Kelvin, for his contributions to the science of physics in its many branches, in the year 1878 revolutionised the practice of compass making and compass adjusting by proving that the shorter the needles the more satisfactory both the compass and its adjustment would be, and astonished the world by reducing the weight of the compass card from 1,600 grains to 190 grains, thereby minimising momentum due to frictional force at the pivot and achieving the most sensitive compass ever as yet devised.

It was a holosteric (free of liquid) compass, and, after most satisfactory tests, its use became well nigh universal.

In 1906 Mr. Bernard, of the Magnetic Observatory of Greenwich, patented his spherical compass, departing from the conventional by having a hemispherical glass top, which, forming with the bowl a spherical container for the card, reduced the disturbing effects of rolling and pitching that cause an unsteady card. In spite of its obvious advantages over the flat top compass, it remained a comparatively unknown instrument until 1930, when, in a much improved form, we find it to be quite a success in the U.S.A., where it has been adopted by small boats as well as ocean liners with satisfaction being expressed by its many users.

In 1920, or thereabout, Henry Hughes & Son, of London, evolved the "Dead Beat" compass, which, considered from any angle, is indeed difficult, if not impossible, to beat.

The diameter of the card has been much reduced, and its weight is the least that could be compatible with the existence of matter, for here we have precisely no more than 115 grains of weight on the pivot. The wide space existent between the sides of the bowl and the edge of the compass card prevents the same from being affected by any eddies which may exist in the liquid due to the motions of the ship. The magnets, only 2½in. long for the 10in. compass, are made of cobalt steel, which is a great improvement in itself. A special system of damping filaments has been introduced, which, coupled with the very ingenious method of suspending the compass in the binnacle by means of plungers and shock absorbing material, renders this compass so immune to the disturbing effects of vibration, rolling, pitching, or turning, as to be of an almost uncanny immobility.

Before purchasing a compass for a certain vessel two quantities should be borne in mind, as well as a number of qualities, viz., the period of roll of the ship and the period of the compass. The former is the number of seconds of time that elapse between two successive rolls of the ship, and is rather uncertain, varying for the same vessel according to the state of the sea and the metacentric height of the ship, although we may ascertain the maximum. The latter is the number of seconds employed by the compass card to return to its original position when deflected forcibly, as by a magnet, a certain number of degrees—say 40—and is a very definite quantity ruled by many factors, such as the weight of the card, the intensity of the magnetic force of the needles in it, the damping property of the material used in its construction, and the size of the compass. Without entering into a technical discussion of this very complex branch of physics, it will be obvious to anyone that if the two periods should happen to coincide they would in a seaway combine to create a wildly swinging card which would make the steering of courses an utter impossibility. This inconvenience can sometimes be overcome by altering one's course a couple of points or so, if permissible, and by reducing or increasing the speed of the ship.

I have had recourse to these expedients a number of times with entire success both under canvas and with power on small as well as large vessels.

An intelligent and honest expert (I mean expert, not would-be expert) should be consulted in this matter and be made to give a precise statement on the subject, and not uncertain and equivocal phrases which can only be used to hide his ignorance, his desire to pass off something his firm specialises in, or what he may call a bargain. I can think of very few more pathetic sights than to watch someone walk into a shop, asking for "A compass for my boat", and to see him walk out of it with one and the assurance that what he has purchased is being used by so-and-so-and-so, without a word having been spoken as to the peculiarities of the ship he is going to try to use it on.

As to where best installed, I can only say that necessity, æsthetics, and fancy should call on science to aid them in choosing a place for the compass on your ship.

Many things can and often do happen to a compass in the course of time that you may never be aware of, but which nevertheless will cause the loss of a race or the making of landfalls a few miles from where you expected to make it, and, quite regardless of the nautical knowledge of owner or sailing master, compasses should be inspected both as to mechanical defects and deviation every year, by an accredited and competent (which is not the same thing by far) compass adjuster.

It is, however, regrettable that our laws which compel a plumber to possess a certificate of competency before he is allowed to repair our kitchen sink, will permit anybody to tamper with a compass while posing as an adjuster with results that are often regrettable and have at times been known to lead to disaster.

Do not place a loud-speaker or engine-room tools nor harpoons or other hardware within 10ft. of the compass. Do not carry a knife or keys when near it.

Do not let the sun beat down upon it, as it is not made of stone, but of very delicate parts.

It is not my purpose to give here a treatise on magnetism, but merely to suggest that a compass be accorded the care which your eyes receive, for the compass is indeed the mariner's eye; it sees in the dark, and leads us all in all sorts of weather to high adventure, romance and independence, which we may never have known but for a Norman, about whom all is known is that he was a Norman, an Amalfitan, whose very resting place is as much a matter of conjecture as anything can be, and a Scotchman, who, by refusing to accept the practice of his contemporary as final, made it possible for the present navigator to place his vessel within her own length from a distance of 800 and even more miles, regardless of fair weather or foul.

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**The Achievements of Science.**

"Engineering", 7th June, 1935.

The advance of science during the past twenty-five years has covered so wide a field that the task of summarising it has appeared too formidable for some to attempt it, and Sir Frank E. Smith is to be congratulated therefore on the clear and succinct manner in which he attacked the subject at the Jubilee Luncheon of the Society of Engineers.

Sir Frank Smith's interesting summary commenced with something in the way of a broad review touching upon some of the developments likely to impress most strongly the average person, such as, in the case of women, the introduction of artificial silk and the application of plastics to various purposes; and in the case of men, the great changes which had been brought about in all components of the motor car, in which practically everything had been transformed during the past twenty-five years. The greater part of the address, however, was focussed on four "pictures", one of which was biological in aspect, while the second was concerned with food, the third with cutting tools and the fourth with the atom.

Dealing with the first, Sir Frank pointed out that among all the crowds who had enjoyed the Jubilee celebrations, thousands would have been dead, but for the advances made in the past twenty-five years. The application of knowledge gained in the spheres of medicine, engineering and chemistry had been directly responsible for an increase of life of 10 per cent. in the period named. This change had not resulted from taking better care of ourselves, but from such things as better water supplies, improved hygiene, and greater skill in surgery. From our knowledge of vitamins, a word not coined when His Majesty came to the throne, it was possible now to order diet so that the most suitable food values could be assured and applied to the prevention of disease. It had now been definitely asserted that rickets was no longer incapable of prevention and cure.

In his "picture" relating to food, Sir Frank referred to the pre-war trade in Chile nitrates and reminded his audience of the fears which then existed that in relatively few years these would have become exhausted at the rate at which they were then being consumed. To-day the situation had been completely changed by the work of the chemical engineer, and more fertilisers than we can use can be produced from the air. In the process of production it was necessary to employ a catalyst, an agent about which knowledge was still incomplete, and as an interesting sidelight on the labour involved in having on account of this fact to proceed by trial and error, Sir Frank stated that something like 20,000 substances had been tried out as catalysts before commercial success had been achieved. Incidentally in connection with food supplies it was worthy of note that by the process of breeding and selection two improved wheats had been produced in 1912 which were now employed for about one-third of the wheat grown in the world.

The improvement in cutting tools had been responsible for the great advance in production processes of every kind. The old carbon steels removed steel at the rate of about ¼lb. per minute. By 1910, alloy steels had brought the rate up to 3lb.

Then tungsten-chromium steels had raised it to 5lb., and with cobalt added this had been doubled. Finally we had the carbides, which increased the rate to 17lb. and were so hard that glass, porcelain, hardened steel, etc., could be dealt with. In the production of drawing dies these materials were invaluable and the output during the life of dies had increased 100 fold. The effect was felt all through production, and while engineering processes had reduced labour, they had so cheapened the product as to result in vastly increased consumption.

The last topic was the discovery of the electron, and the work of Sir J. J. Thomson and Lord Rutherford and others on the structure of the atom, and the results that had flowed from this. Sir Frank referred to the introduction of the thermionic valve and recalled the fact that in 1910 there was not a single "listener-in", whereas to-day there were 7,000,000 licensed receivers in this country alone, and that one man had been able on Jubilee day to speak to hundreds of millions of people all over the world. The radio industry, which did not exist in 1910, had last year a turnover estimated at over 20 millions sterling. With a reference to television and talkies, Sir Frank passed finally to the subject of illumination and pointed out that if to-day we insisted on having the present standards of lighting, but had only the old methods at our disposal, our bill would amount to some 10 million pounds more per annum.

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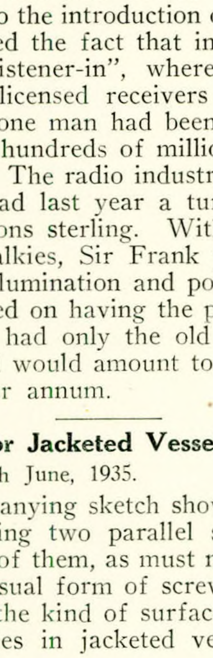
### Tubular Stay for Jacketed Vessels.

"Engineering", 28th June, 1935.

The accompanying sketch shows an interesting method of staying two parallel surfaces without perforating one of them, as must necessarily be the case when the usual form of screwed stay is used. An example of the kind of surfaces which may be thus stiffened lies in jacketed vessels of various




kinds. The jacket in such cases usually contains steam under pressure and it is often important that no leakage should take place into the interior vessel in which some chemical or manufacturing process, likely to be interfered with by such leakage, is being carried on. Conversely leakage of the contents of the vessel into the steam space must be guarded against where the internal pressure is greater than that of the jacketing steam. The device illustrated, which has been developed by Messrs. Ashmore, Benson, Pease & Company, Stockton-on-Tees, employs welding instead of screwing as the mode of securing the stay to the surfaces. The stay itself consists of a short piece of tube welded internally to the exterior of the inner vessel which is, in consequence, not perforated, and welded externally to the jacket shell. Any leakage from the steam space or defect in the stay itself is, of course, visible, whilst the method, as it does not involve the drilling and tapping of two holes in line, effects considerable economies in construction. Messrs. Ashmore have adopted this form of stay in such jacketed vessels as those used for chemical reactions. These vessels may be of cylindrical shape and of large dimensions, one recently constructed being 12ft. 3in. in diameter by 18ft. long. To avoid excessive thickness in the shells of both container and jacket, these, though cylindrical, are stayed in the manner shown. The tubular stay is, clearly, of equal value for flat surfaces, and has been applied to such. We are informed that it is covered by a British patent and that foreign patents are pending.

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### Government by Council.

*(For Members of Council and Vice-Presidents only!)*

"Engineering", 28th June, 1935.

And it was so that in the course of years there grew up side by side, both in the literal and metaphorical meaning of the words, two great bodies representing in whole and in part the profession to which the people mainly owe their continued existence on the earth; and the part was in some respects greater than the whole. Now the one body combined a little sociability with its dignity, and the other a little dignity with its sociabilty; and in the one the fellowship of those promoted to act as Fathers in Israel and to sit in the seats of the mighty became lost to the commonalty, and they were as beings translated to another world, while in the other they managed to mix continually with the crowd promoting thereby a very goodly feeling of comradeship.

And it happened that as time went on the rules and regulations approved by the great King for the governance of these bodies became somewhat antiquated and unsuited to the proper conduct of their respective affairs, and the task fell to the Fathers of considering in each case the changes necessary to adjust their institutions to the times. But the great King, in his wisdom, had laid down that alterations so made should be assented to by the commonalty, and there were regulations directing how this consent should be secured.

In the one, therefore, when the time came, the people were called and thronged to a vast conclave to deliberate on the subject line by line. It happened in those days that among the Fathers were two, spiritual twins, who though they had not been able to occupy the chair of high office simultaneously, had done so in succession, and the second officiating on this occasion, took charge of the proceedings. After the usual formalities by the herald, the first new rule was considered, and various alterations were suggested as commended themselves to different individuals in the conclave. Upon this, Castor or Pollux, whichever it may have been —let us say Pollux—in the chair of high office, amiably admitted that there was much truth in what had been said, and that the contentions were very reasonable, but it should be considered that the Fathers had laboured for many years to find the best phraseology to meet the new facts, and that the sifting of proposals had been most carefully performed. The body of Fathers had met together not once but many times, and a sub-body had been elected together with sub-sub-bodies, so that each word might be weighed in the balance, and if found wanting a substitute sought for it; the matters had been bandied to and fro between the Fathers in full body and in parts, and in parts of those parts, until they were convinced that they had arrived at the very best words possible, and he would ask his twin, Castor, further to explain matters. Thereupon the twin, in his notably urbane manner, reviewed how the body of Fathers had met together not once, but many times, and a sub-body had been elected, together with sub-sub-bodies, so that each word might be weighed in the balance and if found wanting a substitute be sought for it; the matters had been bandied to and fro between the Fathers in full body and in parts and in parts of those parts until they were convinced that they had arrived at the very best words possible—after which lucid and friendly communications those in the throng who thought they knew better were quite convinced that no change could possibly be made except for the worse, and the wording proposed was on all hands acclaimed as the very best the language could produce to attain the objects in view, the rule being adopted.

Now when the second rule came to be considered the same procedure was found equally to serve. Proposals were made with a view to its improvement, and Pollux, from the chair of high office, again admitted in the most winsome manner, that there was much truth in what had been said, that the contentions were very reasonable, but it should be remembered that the Fathers had laboured for many years to find the best phraseology to meet the new facts, and that the sifting of the proposals had been most carefully performed. The body of Fathers had met together not once, but many times, and a sub-body had been appointed, together with sub-sub-bodies, so that each word might be weighed in the . . . and so on and so forth . . . and he would ask his twin further to explain matters. Thereupon the twin, in his engaging confidential manner reviewed how the body of Fathers had met together not once but many times, and a sub-body had been elected together with sub-sub-bodies, so that each word might be weighed in the . . . and so on, easily convincing the assemblage that any change could only be for the worse, whereupon the proposal was acclaimed on all hands to be the very best the language could produce to attain the object in view, and was forthwith adopted.

When the third rule came to be considered, the same procedure was found to be satisfactory, and much the same with the fourth. By about this stage of the proceedings, the concourse at large was satisfied that everything possible had been done in every instance to word the new rules in the very best phraseological terms possible, and matters could then be so expedited that in all the remaining cases the rules were read out and at once acclaimed as being in the very best style, and the business of the meeting was brought rapidly to a close; after which the Fathers, fraternising with the throng, drank coffee with them, or with them repaired to a more substantial repast, as they were moved, and everything ended in a very friendly and convivial manner.

But in the neighbouring body so simple a procedure was not followed. Discussions took place and meetings were called, much time being occupied for little progress. Time was spent debating whether obtaining the consent of the commonalty really meant what certain words seemed to say, or whether this should be made a formality of no real import, and that the Fathers in Council, having been appointed to govern, the people had only to accept what they put forward as best for them. One sportsman drew analogies from India, but among those present were some who considered the affairs of that country were in too distracted a state to serve as much of a guide. It did not seem to occur to anyone that if government by the Council were to be taken as rendering reference to the commonalty unnecessary, or a formality, as changes were being made, a simple alteration of the regulations could make this clear, when all other rules would be superfluous—procedure could be vastly simplified and special meetings and postal ballots avoided. As has been said at the end of lengthy deliberations, the position was, in the phrase of men-at-arms, "as you were", and the conclave broke up, many regretting that the main result had been a waste of time—and, when the ballot forms were sent out through the King's posts later, undoubtedly many of them were confined to the waste-paper basket with the remark "What's the good!"

**The "Normandie".—The "Shipbuilder" Supplement, June, 1935.**

The Institute has received a copy of a "Special Souvenir Number" of "The Shipbuilder and Marine Engine Builder" describing the "Normandie". The issue collates all the published material which exists and contains additional fully descriptive and illustrative matter relating to every aspect of the design, construction and multitudinous other details of the ship. The subjects dealt with are too numerous to indicate here and it might suffice to give some general particulars of the volume, which contains some seventeen chapters totalling 160 pages.

The necessity for and the considerations governing the extension of the port facilities and the construction of the new Dock-Lock at St. Nazaire are fully described, followed by a discussion of the various problems involved in the design and construction of the vessel, the building of the hull and the final completion for service. A chapter on the general equipment covers such items as ventilation, heating, refrigeration, steering, etc., and the solution of the many problems is of great interest. The main propelling machinery, which is turbo-electric, the auxiliary generating plant and the general auxiliary machinery occupy six chapters, which are of considerable interest to every marine engineer whether afloat or ashore. The last four chapters include descriptions of the accommodation for passengers, officers and crew and the various passenger services, arrangements for protection against fire, and the trial trip and maiden voyage of the vessel.

The volume is profusely illustrated and contains numerous plates, diagrams and other illustrations. It seems to answer almost any question of general interest to members of the profession.

The book is being permanently retained in the Library and will be available for reference by members.

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**The "Normandie's" Achievement.**

"The Marine Engineer", July, 1935.

It was an almost foregone conclusion that the French Line's new express liner "Normandie" would gain for herself the Blue Riband of the Atlantic, even if not on her maiden voyage. That the record crossing of the Italian liner "Rex", with an average speed of 28·92 knots was broken on the first Transatlantic run of the new ship is a testimony to the design of the hull and the machinery installation of the "Normandie", as well as to the confidence of her engineers in charge. Apart from one or two minor mishaps, which, according to reports, included a faulty condenser tube, the vessel proceeded on normal routine at well over the anticipated speed of 28 knots without any serious trouble accruing. There is little doubt from what we ourselves gathered by personal experience of the ship during her initial run from Havre to Cowes Roads that the officials of the French Line have every reason to be satisfied with the results so far obtained. Undue emphasis has been laid in some quarters on a persistent vibration on certain superstructure decks aft. The important point is that it cannot be connected in any way with the propulsive machinery, and there is every likelihood that it will be reduced sufficiently by suitable stiffening of the deck structure in the affected locality so as to avoid any real inconvenience to passengers or excessive maintenance costs.

The average speed of the "Normandie" on the outward run from Bishop's Rock to Ambrose Light was 30·10 knots, the ship taking 4 days 3 hours 2 minutes to cover 2,980 miles. The highest daily average on this trip was 32 knots (on the fourth day), which was better than on any of the other three days by over 2 knots. On the return passage, when this excellent performance was improved upon, the distance traversed from Ambrose Light to Bishop's Rock was 3,015 miles, the time taken for the voyage being 4 days 3 hours 25 minutes, giving the record speed for the Atlantic crossing of 30·31 knots. This is indeed a fine achievement, and one in which French citizens must take a justifiable pride, although it is fairly certain that the figure will be exceeded before many more trips have been made. The task before the "Queen Mary" is thus by no means an easy one.

In spite of the enthusiasm which records of this nature evoke, a far more important consideration is the normal average speed which the vessel is capable of maintaining over a long period of service without overstressing the machinery or hull, or incurring wasteful fuel consumption at the higher ranges of speed. The question of service speed is inevitably one to be largely decided by policy, taking into account such factors as attraction to passengers, fuel consumption and speed-power curves, schedule of sailings, and time required at terminal ports. Nevertheless, it is useful to compare the relative performance of a ship of the size of the "Normandie" with other Atlantic liner types, in order to discover the bearing of size and speed. Taking as a basis of comparison the $\frac{V}{\sqrt{L}}$ factor, it is found, for instance, that if the normal service speed of the "Mauretania" is taken as 26 knots, the equivalent speed of a vessel of the size of the "Normandie" would be approximately 29·5 knots, which clearly indicates the advantage to be gained by increase in size. In his extremely interesting paper entitled "Liverpool and the Atlantic Ferry", read before the Institution of Mechanical Engineers in June of last year, Mr. J. Austin, chief superintendent engineer of the Cunard White Star Line, in speaking of the policy envisaged by the Cunard White Star Line of a weekly two-ship service said, "Apart from the economies to be effected by a two-ship service instead of three-ship service, the large liner of the present day is only possible because of the relatively easier propulsion of a long ship and the high efficiency of modern propelling machinery, which enable one to build a vessel of about twice the tonnage of the "Mauretania", which consumes approximately the same quantity of oil fuel for the passage between Europe and America under similar conditions. The large ship is also less affected by weather, which, as well as enabling the vessel to maintain a better average speed, makes for a ship which is more comfortable for passengers". The results already obtained with the "Normandie", as recorded in the last issue of "The Marine Engineer", go far to confirm this statement. It will be recalled that we quoted a performance on trials of 32·2 knots on a displacement of around 68,000 tons, the power being about 165,000 s.h.p., with an hourly all-purposes fuel-oil consumption of 52 tons. Also, it was stated that at 28·7 knots her consumption was approximately that of the "Ile de France" at 24 knots (viz., 38 tons), a vessel of little more than half the size of the "Normandie", while at 24 knots it was only 24 tons per hour. It is interesting to compare these figures with the daily consumption of the "Mauretania", which has been given as 33 tons of fuel oil per hour at the service speed of 26·25 knots. This was accomplished on a power of 72,000 s.h.p., giving a consumption of 1·02lb. per s.h.p. per hour. The specific consumption of the "Normandie" on the figures quoted was 0·7lb. per s.h.p. per hour for all purposes.

An analysis of increase of size *per se* can be seen by comparing vessels such as the "Normandie" and "Mauretania". Since on the Admiralty constant formula the propulsive power varies as the displacement to the two-thirds power, a ship of the size of the "Normandie" would require to have machinery developing a horse-power 1·52 times that of the "Mauretania" for the same service speed, although the displacement would have increased 186 times (assuming the "Mauretania's" displacement to be 36,500 tons).

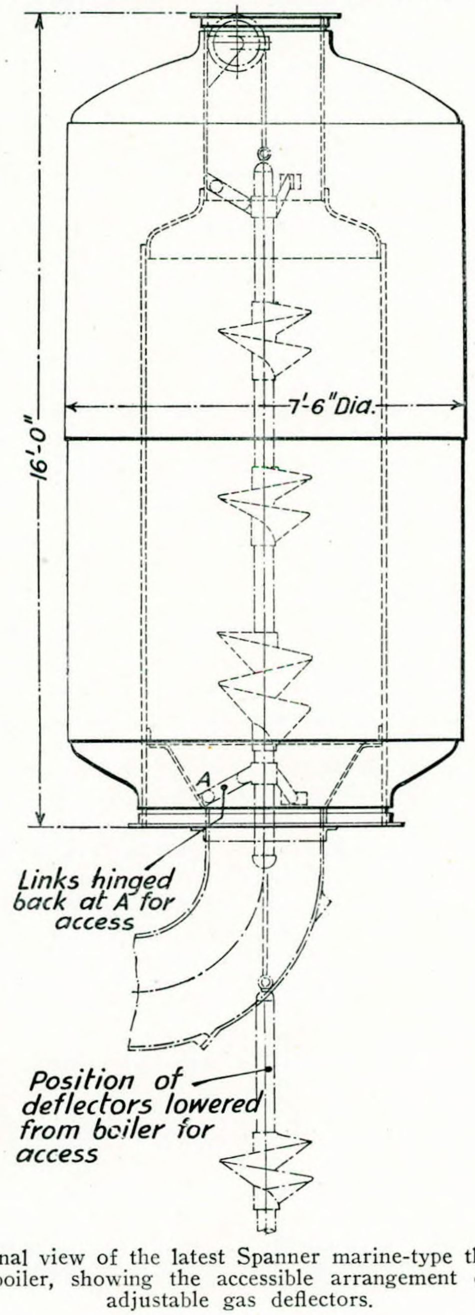
## Spanner Thimble-tube Waste-heat Boilers.

"The Marine Engineer", July, 1935.

The accompanying *illustrations show two Spanner thimble-tube boilers in course of construction to the order of Richardsons, Westgarth & Co., Ltd., Hartlepool. These boilers, which are to be fitted in the "Silverlarch" and "Silverpine", respectively, are each designed to work in conjunction with a two-stroke double-acting Richardsons-Westgarth oil engine of 4,000 b.h.p. normal output, and to produce 3,800lb. of steam per hour at a pressure of 120lb. per sq. in. when the engine is developing this power.

Attention may be directed to the regular spacing of the holes in the tube nest, as seen in one of the views, one of the features of Spanner boilers being that a progressive proportioning of the area of the gas passage is obtainable, through the tube nest in the boiler, without complicating the drilling of the tube plate. In these particular boilers a considerable variation of the cross-sectional area is obtained simply by varying the effective length of the tapered thimble tubes from just over 14in. to about 16in. In early designs of thimble-tube boiler considerable effort was made to secure a spiral flow through the tube nest, and several patents were taken out by the late Mr. Thomas Clarkson in the effort to secure such a desirable objective. In these Spanner boilers a spiral flow of gas through the tube nest is secured automatically, simply by tubing the boiler so that tubes of the same length lie along diagonal lines. It is easy to see, from the illustration of the tube plate, that the multi-spiral path formed by the tubes tends to turn the gas through about half a complete turn as it passes through the boiler.

The spiral flow is also assisted by the use of




Sectional view of the latest Spanner marine-type thimble-tube boiler, showing the accessible arrangement of the adjustable gas deflectors.

* One drawing only reproduced.—EDITOR.

spiralled deflectors which are mounted on an adjustable member running through the centre of the boiler as shown in the drawing. These deflectors provide easy and gradually divergent guides for the gases, forcing the gases out into the tube nest in a positive and controllable manner. The several spiral elements are separately constructed and mounted along the length of the supporting tube in a semi-permanent manner, affording opportunity for a fairly wide adjustment when the boiler is being finally adjusted to suit the engine. Satisfaction achieved in this direction, it still remains possible to vary the position of the deflectors as a whole while the engine is running. This permits of the output of steam being varied to suit the demand.

The drawing also shows, diagrammatically, the lead of the exhaust pipe to the boiler and the manner in which provision is made for lowering the complete deflector, with its supporting tube, right down clear through the access hole in the exhaust-pipe connection. The lower steadying links can be unpinned and thrown back clear of the centre member before it is lowered, so that the entire central space is then left free of obstruction. The boiler is provided with about 16in. of clear width in the water space, the maximum size of the tubes being 2½in. outside diameter. The whole boiler unit is very compact, a total effective water-tube steam-raising surface of nearly 1,300 sq. ft. being provided on maximum dimensions of 16ft. overall height and 7ft. 6in. maximum diameter. The boilers are being built by J. Samuel White & Co., Ltd., of East Cowes.

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**Mercantile and Naval Boilers.**

"Shipbuilding and Shipping Record", 20th June, 1935.

Although it might be described as of comparatively recent introduction, the water-tube boiler has become firmly established as a reliable and efficient type of steam generator for almost every class of merchant steamship. For naval vessels, of course, the water-tube boiler has been almost exclusively employed ever since the earliest years of the present century. Its adoption by marine engineers for steamers in the merchant service does not, however, imply that the two services—naval and mercantile—are now in the same position as regards current practice in the design of water-tube boilers, the peculiar conditions governing the operation of the propelling machinery still being responsible for many notable differences between naval water-tube boilers and those used on merchant ships. These differences were clearly indicated in a paper, entitled "Marine and Naval Boilers", by Captain C. A. Jones and Lieut.-Commander T. A. Solberg, both of the U.S. Navy, which was read at the recent annual meetings of the American Society of Naval Architects and Marine Engineers. The particulars given refer necessarily to American practice, but they are of interest not merely as indicating the differences which exist but as suggesting the possibilities of further development in the design and construction of water-tube boilers for use on merchant ships.

The authors give, in tabular form, test and operating data of 10 typical boilers, one of which is a land boiler, the others being either naval or mercantile boilers. Some remarkable differences are shown as regards heat-release rates and furnace volumes, the maximum heat release in mercantile practice rarely exceeding 50,000 B.Th.U. per hour (the average being only 18,000 B.Th.U. per hour) whereas 200,000 B.Th.U. per hour is not an unusual figure for naval water-tube boilers. Higher steaming capacities are now obtained in naval practice with units of less weight, occupying less space, and, except in special vessels, eight is the largest number of boilers fitted in U.S. naval ships. There is a definite trend towards operating at higher ratings, a maximum fuel rate of 1·1lb. of oil per hour per sq. ft. of heating surface having been adopted after recent tests in place of the former maximum of 1lb. The specification also requires a 20 per cent. overload or 1·32lb. per hour. As regards size, for modern naval units the maximum heating surface approximates to 11,720 sq. ft., with a maximum evaporation of 16lb. per sq. ft., while in mercantile practice, the size ranges up to 10,000 sq. ft. of heating surface with an evaporation of 10 to 12lb. per sq. ft. The authors express the opinion that the steam pressure and temperature adopted afloat can never approach that now used in shore plants, and they suggest a pressure limit of 600lb. per sq. in. and a temperature limit of 750° F. for naval purposes. In the merchant service the higher final steam temperature of 850° F. is suggested as the vessels normally operate under constant conditions with but few of the complications found in naval practice.

American naval practice has hitherto been against the adoption of waste heat recovery by the fitting of economisers and air heaters, largely on account of the extra weight involved. With the increase in steam pressure it was felt that some form of waste heat recovery was desirable and boilers of the three-drum type for use on destroyers have been designed with an economiser in each uptake. Employing aluminium gill rings, it has been satisfactorily demonstrated that economisers are feasible in all types of naval vessel, as the handicaps of space and weight are a maximum in destroyers. On merchant ships, their use is highly desirable in all boilers where the pressure is 400lb. per sq. in. or more, except where the use of air heaters is a more attractive proposition. Air heaters are practically unknown on naval ships, although it is suggested that their use may become desirable or even imperative with the increase in the use of heavily-cracked fuel oil, the rate of combustion of which is comparatively slow. An interesting sidelight on the problem of circulation in water-tube boilers of the three-drum types is given by a reference to the discovery of marks indicating a water level in the water drums. Further examination showed heavy pitting below the tube ends, which was found to be caused by radiant heat absorption through an exposed area of the drum. Gauge glasses fitted at the ends of the water drums showed that there was a water level caused by a steam pocket, although this would be eliminated by covering the exposed part of the drums or by fitting external downcomers. The paper also contains an interesting comparison between boilers of the sectional-header type as fitted on the United States Line steamships "Manhattan" and "Washington", and the three-drum type as fitted on the Grace Line steamers "Santa Elena" and "Santa Paula".

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**Metallurgy.**

By Sir H. C. Harold Carpenter, F.R.S.

"Engineering". May 3rd, 1935. Silver Jubilee Supplement.

The most striking feature of metallurgy during the last twenty-five years has been the scientific development of alloys, and this is true for the three main divisions, viz., Steels, Cast-Irons, and Non-Ferrous Metals. It is proposed in the following survey to review some of the chief advances made. All alloy steels contain at least three elements, namely, iron, carbon, and one alloying element. Some are more complex, and contain three, four or five alloying metals. The best-known examples of these are found among high-speed cutting tools which may contain chromium, tungsten, vanadium, cobalt and molybdenum, and heat-resisting steels which may contain chromium, nickel, tungsten, and silicon. The most widely used of the alloying elements has proved to be chromium, and if it so happened that only one element was available, more could be done by alloying chromium with iron and carbon, in suitable proportions, than by the employment of any other element.

Plain chromium steels were some of the earliest alloy steels to be made, and they date from about the year 1880. They were used for a variety of purposes in all of which hardness was the important property. Steels containing from 0·8 per cent. to 0·9 per cent. of carbon, and from 0·4 per cent. to 0·5 per cent. of chromium, are used for stamp shoes and dies for crushing gold and silver ores. Toughness, as well as hardness, is required, and some annealing is essential in their heat treatment. It is very remarkable that an entirely new use for chromium steels was discovered more than thirty years after they had been widely used. The discovery that when suitably treated, such steels were remarkably resistant to corrosion, was made by Mr. H. Brearley in 1913. Some of the modern stainless steels contain nickel, as well as chromium, but all of them, without exception, contain chromium in considerable amounts, and it is this element which confers the corrosion-resisting properties on steel. The discovery of stainless steel is one of the major inventions not only of this century, but of all time, and the great variety of its applications is even now only beginning to be realised. The range of properties which can be obtained by suitably varying the composition and heat treatment is so great that it is no longer correct to regard stainless steel as a particular kind of steel, but rather as a modified form of it in which most of the mechanical properties of ordinary steels may be obtained in addition to high resistance to corrosion. The addition of nickel to a chromium steel extends the range of resistance to corrosive conditions. "Staybrite" contains 18 per cent. of chromium and from 8 per cent. to 9 per cent. of nickel. Other varieties of this type are "Anka" and "V2A". These alloys are ductile, and can be worked into almost any form, and "Staybrite" can also be welded. It cannot be hardened by quenching, although a certain amount of hardening can be produced by cold work.

Silicon, nickel and chromium have proved to be, so far, the most important alloying elements of cast-irons. The alloy known as "Silal" is a grey cast-iron having a fine graphite structure, and containing about 2·5 per cent. of total carbon and 5 per cent. of silicon. This high silicon content greatly increases the resistance to oxidation, and this alloy gives much better service than any low-silicon iron for purposes such as fire bars, furnace parts, etc., at temperatures of about 850° C. The high-silicon content, however, makes the iron brittle and low in impact strength and ductility at temperatures below a black heat, though at higher temperatures it is quite ductile and does not crack. The iron is easily machineable, and has a tensile strength of about 20 tons per sq. in., with a total-carbon content of 2·5 per cent., a composition which can easily be made in a cupola from ferro-silicon and steel scrap. This carbon content gives the best union of properties for light castings, but a lower total-carbon content gives greater heat resistance and strength. It increases the liquid shrinkage, lowers the fluidity, and increases the tendency to mottle on thin sections. For heavier castings the total-carbon content should be lowered, in order to obtain as fine a graphite structure and as high a strength as possible. "Nicrosilal" is an austenitic grey cast-iron containing about 2 per cent. total carbon, 5 per cent. silicon, 1 per cent. manganese, 18 per cent. nickel, and from 2 per cent. to 5 per cent. of chromium. This iron is extremely tough and ductile, in spite of its high silicon content, which increases the resistance to oxidation. as in the case of Silal. The resistance is further increased by the chromium content, so that even at 950° C. scaling only proceeds very slowly, and growth is practically nil. The iron is easily machineable, and takes a very fine finish. Certain compositions may be cast white and malleableised by heating for half an hour at 950° C. Others may be hardened by tempering at about 600° C. These irons can be produced in the cupola and cast well, having good fluidity. The Silal and Nicrosilal heat-resisting cast-irons have been developed under the auspices of the British Cast-Iron Research Association, and are based on the research work carried out by A. L. Norbury and E. Morgan, to whom I am indebted for the above information.

The problem of improving the qualities of cast-iron consists essentially in preparing a material based mainly on pearlite with deposited graphite. A cast-iron of this kind would certainly be superior in properties to any of the ordinary varieties, and it may be expected to exhibit mechanical properties approximating to those of pearlitic steel which would be influenced only by graphite. Numerous tests carried out by different investigators bear out this view. Diefenthäler and Sipp were able to devise a process to enable this structure to be obtained regularly. It was patented in 1916. It has been improved upon, and has finally led to definite rules for achieving the desired properties. The properties claimed for these irons are: (1) High transverse and tensile strengths and toughness; (2) high resistance to impact stresses; (3) moderate hardness when properly treated; (4) only a slight tendency to the formation of "pipes", and hence the possibility of making complicated castings; (5) great resistance to friction (abrasion); and (6) fine and dense structure, the structure being unaffected by temperature changes.

Probably the most important advances in non-ferrous metallurgy centre round the discovery of the so-called "age-hardening" alloys. In this category come the "precipitation-hardening", "dispersion-hardening", and "temper-hardening" alloys. All of these depend upon changes of solid solubility in an alloy system, and their importance depends on the fact that they are influenced by the rate of cooling.

The changes in solid solubility of copper and $Mg_2Si$ in aluminium are utilised in the heat treatment of light aluminium alloys such as those of the Duralumin type. At the eutectic temperature, 548° C., aluminium dissolves 5·65 per cent. of copper. The solubility decreases rapidly as the temperature falls, and is only 0·5 per cent. at 200° C. By quenching, the formation of $CuAl_2$ may be prevented, and thus, depending on the quenching temperature, alloys containing up to 5·5 per cent. of copper can be retained at atmospheric temperature as solid solutions. The same applies to those containing $Mg_2Si$. After quenching, pure aluminium-copper alloys, and such other alloys as contain $Mg_2Si$, undergo a change at atmospheric temperatures which results in an increase of strength and hardness. This is the process of age-hardening. On heating, it proceeds more rapidly, and is known as accelerated age-hardening. If, however, the time of heating is sufficiently prolonged or the temperature sufficiently high, the hardness reaches a maximum and then begins to decrease.

In explanation of these changes, Merica, Waltenberg and Scott advanced the "dispersion hypothesis", which attributed the increase in hardness to the precipitation of $CuAl_2$ or $Mg_2SI$ in the form of sub-microscopic particles and the subsequent softening to their coalescence. This hypothesis was widely, but not universally, accepted, and more recent work has shown that the change is more complicated than was originally supposed. As a result of this hypothesis, the terms precipitation and dispersion hardening came into use, and temper hardening is also employed in the case of alloys such as those of copper and beryllium, copper aluminium and silicon, copper aluminium and nickel, which require to be heated to promote the changes in question.