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President : The Hon. ALEXANDER SHAW.

*Oxy-Acetylene Welding and Cutting in Shipbuilding and Ship Repairing.

(Prepared by the British Acetylene Association).

A REVIEW of the application of the oxy-acetylene flame in the building and repairing of ships and their machinery naturally falls under two principal headings—the extent to which it has been and is used, and that to which it may be developed. The oxy-acetylene blowpipe is no modern innovation in the shipyard, either for welding or cutting but, although it still stands unrivalled in its latter capacity, and its value is realised continually and increasingly, it has never been very extensively used for purposes of welding, except in repair work where in certain circumstances and for certain materials it still proves the best and sometimes the only tool by which a satisfactory repair can be made. Its use for the welding of structural steel has so far been limited to the repair of the shell plating and of marine boilers, and in recent years it has had to compete with arc welding in these fields.

In the past, lack of knowledge of the physical properties of weld metal of any type and of the value of welded joints in the materials used in ship construction had restrained the authorities from permitting its use in ships, except where failure of the joint could not have much effect on the efficiency of the part, or where it was laid down that a weld should not be made in such circumstances that it would be liable to tensile stress, and where exceptions were permitted they were subject to such requirements as made the extensive development of structural welding uneconomical. This attitude has now changed, and the only requirement which welding now has to meet is that it shall prove a means of enabling the shipbuilder or repairer to do his work more efficiently and cheaply than the methods to which he has been accustomed for so many years. The development of welding in ship construction has been largely due to the efforts of the protagonists of arc welding which process is finding a valuable ally in oxy-acetylene cutting and may well find another in oxy-acetylene welding since the latter process has now received the official blessing of those who control the construction of ships.

Although oxy-acetylene welding has been applied to steel structures and sufficient information is available to give its users every confidence

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that structural steel could be joined by welds which were themselves of sufficient strength and had the physical properties to develop those of the parent metal, it was necessary, before oxy-acetylene welding could be applied to shipbuilding in this country, that a complete series of tests on various thicknesses of plating should be made in order to satisfy the requirements of the Board of Trade and the Classification Societies.

Tests of Welded Joints.

It is proposed to describe these tests in some detail in the hope that the information may be of interest as showing not only the results which can be achieved by the processes, but the requirements which have been formulated by the authorities in this country and which are applicable to welding by both oxy-acetylene and electric arc. The following general conditions governing the tests were laid down :—

(1) Test pieces are to be made and tests to be carried out in the presence of a surveyor.

(2) The steel used in the tests specified hereafter shall be mild steel of a tensile strength of 28-32 tons per square inch.

(3) Filler rods shall be selected by the surveyor from an identified stock of at least twice the quantity required for the tests.

(4) Test pieces shall be made under such conditions and in such positions as are considered by the surveyor to be representative of practical conditions.

It will be noted that the steel used has a tensile strength of 28-32 tons per square inch. This quality of steel is easily obtainable in this country as it conforms to the British Standard Specification which is adopted for steel work in buildings. It also covers the requirements of the British Corporation Register for steel to be used in the construction of ships, although the requirements of Lloyd's Register are that steel for this purpose should have a tensile strength between 26 tons per square inch and 32 tons per square inch, while the requirements of the Board of Trade correspond to those of the International Loadline Convention for the Safety of Life at Sea—also 26-32 tons per square inch. The ductility of steel plates in use for shipbuilding varies between 16 per cent. for thin plates below ·375in. in thickness to 20 per cent. for the heavier plates.

The first batch of tests made dealt with the physical characteristics of the metal as deposited, uninfluenced by any effect of the parent metal in a joint. The test pieces were made by using a small flame to deposit a run of weld metal on the surface of a fairly heavy plate. This run was then gradually built up by the addition of further runs, the test piece being continually turned so that the original run was kept approximately in the centre. When sufficient material was deposited for a test piece for the size required to meet British Standard Specification No. 18, the deposited metal was machined to the dimensions of this standard, as shown in the accompany sketch :—

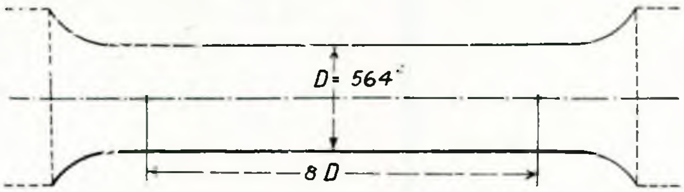


Fig. 1.

This procedure was repeated for the remaining tensile and bend specimens and for the Izod test pieces, which latter were machined to the dimensions shown in Fig. 2.

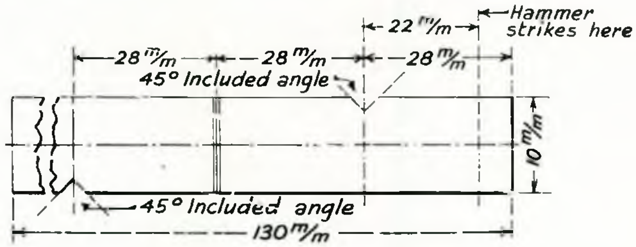


Fig. 2.

Throughout the tests the rightward method of welding was used, and as has been indicated, the deposited metal was laid rather slowly by means of a small flame. In these tests the British Oxygen "B" grade rod was used, although in a later series another rod was developed.

Certain preliminary experiments were made with a view to determining the best method of laying down the deposited metal for these test pieces, and it was found, as might be expected, that metal laid down comparatively slowly by the use of a small flame gave somewhat better results, due to the annealing effect being greater in proportion to the time taken as compared with the use of a larger flame and a more rapid deposition of metal.

The detailed requirements for these tests were decided upon as follows :—

Tensile Test.

(1) Filler metal is to be deposited to permit a test piece of ·564 diameter being cut from it. The test piece, which is to conform to the requirements of the *British Standard* (See B.S.S. No. 18) shall not be annealed or subjected to any form of mechanical or heat treatment.

(2) The tensile breaking strength of the test piece shall be not less than 26 tons per square inch and the elongation not less than 18 per cent. on a length 8 times the diameter.

(3) For each type or make of filler rod used, two test bars shall be made. If either

fails two more pieces are to be made, and acceptance of the test requires that three out of the four shall be satisfactory.

Bend Test.

A sample of the deposited material is to be capable of being bent without fracture through an angle of 120 deg. over a bar having a diameter of 2in., the sectional area of the test piece being not less than ·25 square inch.

Izod Impact Test.

Two specimens consisting of deposited metal, each not less than 130 mm. in length and machined to 10 mm. square in section, are to be submitted to impact test by the Izod method.

The average value for each specimen is to be not less than 20 foot pounds.

The following table gives the detailed results of the tensile tests, which, both as regards the ultimate strength and the elongation, are very satisfactory, and the accompanying Figure No. 3 shows test pieces after fracture :—

shown in Fig. 3 indicate the quality of the specimens tested.

The results of the Izod tests are also satisfactory, and the fact that one of these is somewhat on the low side is not perhaps of great importance in view of the variations which are liable to occur in this form of test however carefully carried out.

A characteristic of the test pieces and the breaks was the absolute homogeniety and cleanliness of the deposited metal. No trace of gas or inclusions of foreign matter was found, and these results in themselves seem to indicate that the weld metal itself had excellent characteristics, whatever might be its value in a joint between two portions of plate.

Several forms of connection commonly used in shipbuilding were tested, perhaps the most important of these being the ordinary butt joint between plates of various thicknesses, and the requirements laid down for this test were as follows :—

Butt Welds.

Test pieces not less than 2in. in width and 8in. in length over the parallel portion are to be pre-

Type.	In Diar.	Area. Sq. in.	Yield Point. Tons per sq. in.	Ult. Strength. Tons per sq. in.	Elongation. 1in. 8in.	Remarks.
Tensile	·564	·25	18·16	29·44	18·9% on 8 diameters.	Good homogeneous metal. Cup and cone fracture.
,,	,,	,,	18·38	29·84	21·3%	Cup and cone fracture.
,,	,,	,,	16·8	28·08	—	Elongation took place outside marks and could not be measured.
Bend	,,	,,	—	—	—	Bent round a pin of 2″ to an included angle of 0° without sign of fracture.
,,	,,	,,	—	—	—	Bent round to an included angle of 30° without sign of fracture.
Izod	See Sketch	—	—	49·5 ft. lb.	—	Finely crystalline and silky structure.
,,	,,	—	—	43·0 ft. lb.	—	Ditto.
,,	,,	—	—	31·8 ft. lb.	—	Ditto.
,,	,,	—	—	50·0 ft. lb.	—	Ditto.
,,	,,	—	—	52·5 ft. lb.	—	Ditto.
,,	,	—	—	44·0 ft. lb.	—	Ditto.

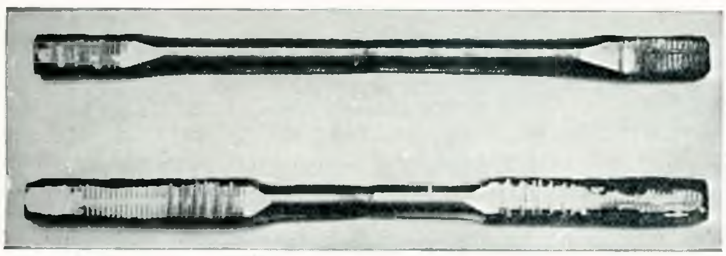


Fig. 3.

Fig. 4.

The bend tests are such that might be expected from material of the structure shown in the micrograph (not reproduced), and the examples of these

pared from plate of ¼in., ¾in. and 1in. thickness. The edges of the plates to be welded are to be cut so that the included angle shall be not less than 60 deg. and the gap between the edges shall be not less than ⅛in. The deposited metal shall be of approximately 10 per cent. greater thickness than the plate, and in the case of two out of three such test pieces prepared, the surplus shall be machined off. The machined test pieces shall have a tensile strength of not less than 26 tons per square inch, and the remaining test piece break clear of the weld.

The form of test piece adopted is shown in the accompanying illustration (Fig. 5). In this case the weld has been machined flush with the plate and the specimen has broken well clear of the weld.

stresses in the rolled plate by the rough form of heat treatment to which it is subjected.

The results of the butt welded tests have been divided between the thin and thick plating, that is, plating below and above ¾in. in thickness, because this particular series of tests was not altogether satisfactory in respect of the heavier plating. It is difficult, however, to apportion the blame because the ¾in. plate unwelded was not up to the specified standard, and the welding procedure in the case of the ¾in. and the 1in. plate was not entirely satisfactory. It must be remembered that at this stage of the investigation very little experience of welding heavy plating was available, and

FIG. 5.

In each case specimens of the unwelded plate were tested and it will be noticed from the results given below that in the case of the ¼in. plating, the plate used did not meet the requirement that it should have a tensile strength of 28 tons per square inch. The results given must therefore be referred to the lower value of the parent metal to obtain a correct estimate of the value of the joints.

bearing this in mind the results were considered to be very encouraging although they did not quite meet the specification in some cases. Tests on this heavy material were repeated as will be described later when a modified procedure and a different welding rod were used.

The next type of joint to be tested was that described as a lap weld in the following requirements. (See Fig. 6.)

BUTT TENSILE TESTS.
PLATES ¼IN AND ½IN.

WIDTH Ins.	THICK-NESS. Ins.	AREA. sq. in.	ULT. STRENGTH. T./sq. in.	ELONGATION. 8in. %	REMARKS.
2·05	·26	·534	26·00	25·64	Unwelded plate not up to specification.
1·996	·264	·527	26·20	28·12	Unwelded heated plate—failure took place 3in. from heated strip.
2·09	·252	·527	25·60	24·0	Failed in plate 1½in. outside weld. Weld not machined.
1·99	·266	·53	26·38	22·5	Failed 1½in. - 2in. outside weld. Weld machined.
2·03	·264	·536	25·4	25·6	Failed 2in. outside weld. Weld machined.
1·96	·271	·531	26·4	25·0	Failed 2in. outside weld. Weld machined.
1·98	·536	1·06	28·6	28·5	Unwelded plate up to specification.
2·04	·515	1·05	26·5	15·6	Failure partly through plate and partly through weld. Weld not machined.
2·01	·45	·906	27·95	12·0	Failed through weld. Large crystals. No slags or bubbles. Weld machined.
2·03	·512	1·04	26·5	12·5	Ditto.
2·01	·456	·916	28·0	13·4	Ditto.

It will also be noted from the results that a specimen of plate was heated with the blowpipe and afterwards tested. The object of this particular test was to allay any suspicion that the local heating of the plate close to the weld had a detrimental effect on the structure of the parent metal. The results showed that the ultimate strength of this plate was slightly greater than that of the unheated plate, and the elongation value was also improved. This effect, which has been mentioned in connection with other tests, appears to be quite usual, and is probably due to the release of internal

Lap Welds.

Test pieces shall be made from plates not less than 6in. long, 2in. wide, and ·375in. thick, and are to be prepared from plates overlapped not less than 1¾in. They are to be welded at each end of the overlap and when tested, the strength of the joint is to be not less than that of the plate, or of 26 tons per square inch on the section of the test piece.

This is not an entirely satisfactory test because the stress in the material, that is, both in the weld and the parent metal, is difficult to estimate and

Fig. 6.

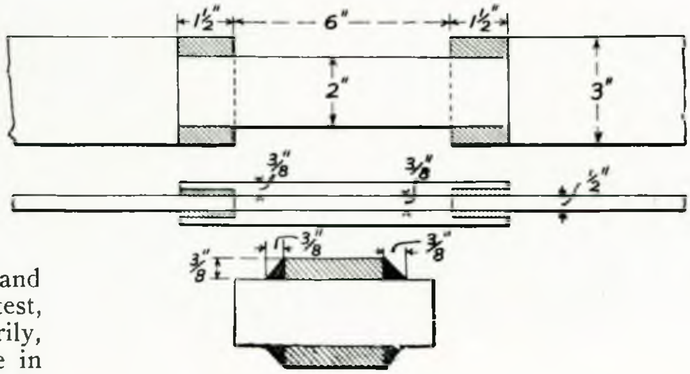


Fig. 7.

the specimen is much affected by the distortion and the inevitable bending which occurs. It is a test, however, which is not difficult to meet satisfactorily, and after certain modifications had been made in the procedure, the following results were obtained :—

LAP WELD TESTS.

Width. In.	Thickness. In.	Area. Sq. in.	Yield Point. Tons per sq. in.	Ultimate Strength. Tons per sq. in.	Remarks.
2·00	·394	·788	18·2	30·0	·25in. throat: Failed in plate 3in. outside weld.
2·02	·391	·790	17·9	29·5	·35in. throat: Failed in plate 5in. outside weld.
2·02	·390	·789	18·1	29·2	·3in./·35in. throat: Failed in plate adjacent to weld.
2·02	·391	·790	18·6	27·5	·3in. throat: Failed in plate adjacent to weld.

From the shipbuilders' point of view it is important that the shear value of a weld should be ascertained and that when stressed longitudinally a fillet weld should be capable of developing the strength of the plate. For this purpose test pieces were prepared in accordance with the following sketch. (See Fig. 7.)

It was a requirement that the shear strength of the weld should not be less than 4·12 tons per linear inch, and from the following results it will be seen that this requirement was more than met, except in one case :—

SHEAR TESTS.

Width.	Ultimate Strength.	Remarks.
	4·75/in.	Failure through weld. Good longitudinal fracture. No pulling away from plates.
	4·10/in.	*Failure through weld. No penetration into roof of fillet.
See Sketch.		
	5·02/in.	Failure through one weld.
	4·55/in.	Failure through 2 welds on one side.

All fillets machined to ⅜in.

* The failure of this test piece at a shear value slightly below that specified was due to the common failure of lack of penetration of the root of the fillet.

The joints between the plating on the side of a ship provide an example of a longitudinal weld stressed in the direction of its length, and it becomes of great importance to estimate the relation between a weld of this description and the parent metal on either side when the whole is subjected to a stress which may, it is assumed, approach the elastic limit of either or both the weld and parent metals. In order to ensure that a suitable relationship between them is maintained, the following test is required :—

Test pieces not more than 2in. wide and not less than 9in. long are to be cut from a plate ·375in. thick welded as for butt welds to include the length of the weld. The surplus weld metal is to be machined off, and the test piece shall be subjected to a stress of 14 tons per square inch on the area of the whole. The weld metal must not fracture or the test piece show disturbance of the junction of the weld metal and the parent metal.

Two test pieces were made from plating ⅜in. in thickness and the results from both were entirely satisfactory. This particular test is one of considerable interest and from which valuable information may be obtained, and it is perhaps worth while to illustrate a test piece, Fig. 8, which has been specially made with a weld of low ductility to show the result of the conjunction of high ductility parent metal with inferior weld metal.

As the stress is applied Luder's lines appear, and it is possible to see the discrepancy in the ductilities of the two metals. At a later stage the weld metal shows fine hair cracks commencing at the junction of the parent metal and the weld metal, and the specimen fails by one or more of these cracks spreading into the parent metal and causing complete fracture. Although it may appear at first sight that the ruling characteristic in a satisfactory weld of this description is the relative ductility of the metals, it is probable that a slight discrepancy in the modulus may have important results, and if the process of oxy-acetylene welding is to be satisfactorily applied to structural steel

Fig. 8.

work, it appears of some importance that careful measurements of the modulus should be made, and at the same time particulars of the limit of proportionality of the same specimens should be obtained.

Bend Tests.

It has always been a characteristic of tests on material used in ship construction that they have included requirements designed to show that the material was capable of being bent cold without sign of fracture. This is a form of test for ductility which is used to show the capacity for stretching of weld metal in a joint and is also an indication of the value of the bond between the weld and parent metal. The following requirements were included for tests of this description—"Test pieces made as for the butt weld test are to be machined flush and to have the plate edge rounded. They are then to be bent round a pin of a radius of twice the plate thickness with the weld central with the diameter of the pin through an angle of 120 deg. without fracture of the weld metal or disturbance at the junction of the weld metal and the parent metal". (See Fig. 9.) The results of these tests as made in the first series are given in the following table :—

BUTT WELDED PLATES—BEND TESTS.

Width. Inches.	Thickness. Inches.	Remarks.
2·00	·25	Weld machined. Edges rounded. Bent through 180° without fracture.
,,	,,	Ditto.
,,	,,	Bent through 120°. Bent round pin diar. 2t. No fracture.
,,	,,	Ditto.
,,	,,	Ditto.
,,	,,	Ditto.
,,	·50	Bent through 135°. Bent round pin diar. 2t. No fracture. Weld machined.
,,	,,	Ditto.
,,	,,	Bent 90° no failure. Machined.
,,	,,	Ditto.

Fig. 9.

In respect of the results being more satisfactory for the thinner plating, they follow the results of the butt tensile tests. The welds of the heavier plating in these tests fall below the requirements in some cases, and the tests were repeated, as will be shown later. The cause of the failure appears to have been partly due to insufficient knowledge of procedure of welding heavy plating, and partly due to the effect of the greater mass of weld metal and parent metal. The difficulties have been surmounted, and it is now possible to ensure welds of the highest quality on plating of practically any thickness.

Another form of bend test is illustrated in the following requirement and in Figs. 10 and 11.

A plate 9in. in length, 2in. in width, and ·375in. in thickness is to be welded at right angles to a similar plate of the same thickness. A gap of not less than $\frac{1}{8}$in. is to be left between the plates, as shown in the sketch. The vertical plate is then, when cold, to be bent parallel to the other without showing disturbance of the weld.

Tests of this character were carried out on a series of plates of different thicknesses, and in each case the specimens met all the requirements. This test is not a particularly satisfactory one, because

Fig. 10.

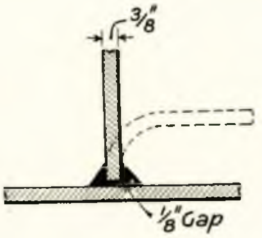


Fig. 11.

a great deal of the bending is inclined to take place in the vertical plate and so relieve the weld of stress, but the test does illustrate the possibility of making a satisfactory joint between two plates of this description where the vertical plate is separated from the horizontal plate by a gap which may be due to bad fitting or other practical reasons. There are many cases in shipbuilding where it might be useful to be able to make a joint of this description, and it is a condition which it is difficult to meet by electric arc welding.

The last test of the series is a particularly interesting one which is perhaps better known on the Continent than it is in this country, although here one of the Shipping Classification Societies and the Board of Trade have adopted it. The requirements are as follows :—

Test pieces approximately 2in. in width (see Figs. 12 and 13) are to be cut from a section formed by welding two pieces of plate 9in. in length by 6in. in width and ⅜in. in thickness so as to form a cruciform section, as shown in the sketch. The tensile strength through the welded joints is not to be less than 28 tons per square inch of the section of the attached plates.

Fig. 12.

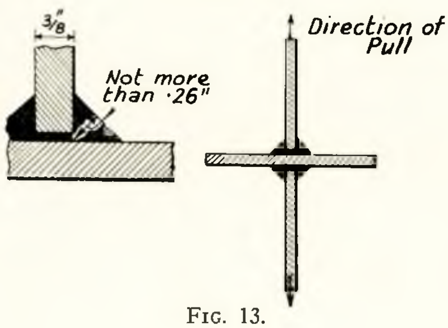


Fig. 13.

This type of test, which is known as a cruciform test, is one which is fairly difficult to satisfy. The essential conditions for success are that there should be good penetration both at the sides and the root of the fillet welds. The distortion of the test piece, which is liable to develop due to the heating of four adjacent fillets, also has a bearing on the result as the test piece will fail by tension in one fillet if the plates are not at right angles rather than by pulling both fillets off the horizontal plating. Failure to achieve thorough penetration at the roots of the fillets also results in the plates pulling apart and the weld forming a miniature archway, which again results in excessive stress on the weld metal.

In the oxy-acetylene process, since a fillet of the size specified for a plate ·375in. in thickness must be made in one run, there is a tendency for the outer part of the weld to suffer from lack of annealing, or in other words, from too rapid cooling, and consequently to have a structure which is more coarsely crystalline than is desirable and a reduction in ductility of the outer layer. The first attempts to satisfy this test were consistent but not entirely successful, but after the procedure had been modified slightly and the operators had some experience of making this form of test piece, which was new to them, results which could be considered satisfactory were obtained.

The foregoing tests conclude the first series and, although they did not meet the fairly stringent requirements laid down in all respects, yet they did show that the process could be successfully applied to structural steel of a limited thickness, and on these results the British Corporation intimated their willingness to accept oxy-acetylene welding of plating not exceeding ½in. in thickness in the structure of ships where it would be subject to primary structural stress, subject to the procedure being to their satisfaction. It was decided thereafter to proceed with further investigations on the welding of heavier plates, and after some research an improved rod was developed and used for repeat tests on heavier material, which are described hereafter.

It was desired to show that as good results could be obtained on what is regarded in ship construction as heavy plating as on the lighter plating, and these repeat tests were quite satisfactory from every point of view.

The results of the tensile test pieces are given in the table on next page, and they are consistently above the standards required.

Certain of the foregoing tests were repeated by making the specimens in a shipyard by a yard operator, as is required by the Rules of Lloyd's Register of Shipping, and as these were accomplished without difficulty, this body indicated their willingness to accept oxy-acetylene welding in shipbuilding without restriction of the thickness of plating employed.

REPEAT TENSILE TESTS ON BUTT WELDED PLATES.

¾in. and 1in.

Width. In.	Thickness. In.	Area. Sq. in.	Ult. Tensile Strength.	Remarks.
1·99	0·73	1·45	27·8	Silky fracture.
1·98	0·73	1·45	28·6	Ditto.
1·99	0·73	1·45	28·5	Silky fracture in plate.
1·99	1·0	1·99	28·2	Silky fracture in plate. This plate was used for shear test specimens.
1·99	0·99	1·97	27·4	Silky fracture in plate.
1·99	0·98	1·95	28·5	Fracture partly through weld and partly through plate.
1·99	0·98	1·95	29·1	Silky fracture in plate.

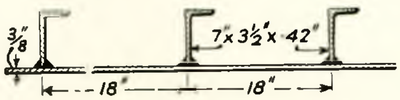


Fig. 14.

Test of a Welded Joint.

Those who believe that the use of welding in shipbuilding will ultimately displace the older methods of connecting the various parts of the structure quite rightly emphasise the importance of modifying the design and arrangements to suit the welded connection rather than to attempt to apply welding to replace the rivets in connections which have been designed to suit the riveted joint. It may appear obvious to the welding engineer that the first requirement of any form of connection between two parts to be welded together should be that it is suited to the method of making the joint, but the average shipbuilder has to make the best use he can of the material easily available. He has certainly used it to the best advantage, but he has to work with types of rolled section, for instance, which can never be adapted to a welded construction to make as efficient use of the material as could be done with sections rolled specially for the purpose.

One example will perhaps be sufficient to illustrate the point. A usual method of stiffening plating in a welded construction is to use an angle section inverted so that the toe of the bar is welded to the plate as shown in Fig. 14.

Stiffening of this type has the disadvantage that the section is not symmetrical in the plane of the applied load, and also usually means that the area in the standing flange of the stiffener is too great in relation to the depth to make the best use of the material. Prof. B. P. Haigh, of the Royal Naval College, Greenwich, drew attention to the desirability of using symmetrical stiffeners in the form of T sections, and later carried out further investigations to show how such T sections could be connected by welding most simply and with the assurance that the connection would develop the full strength of the stiffener. The form of connection he investigated was a right angle joint between two stiffeners attached to plating and such as might be the attachment of the frames of the ship to the deck beams.

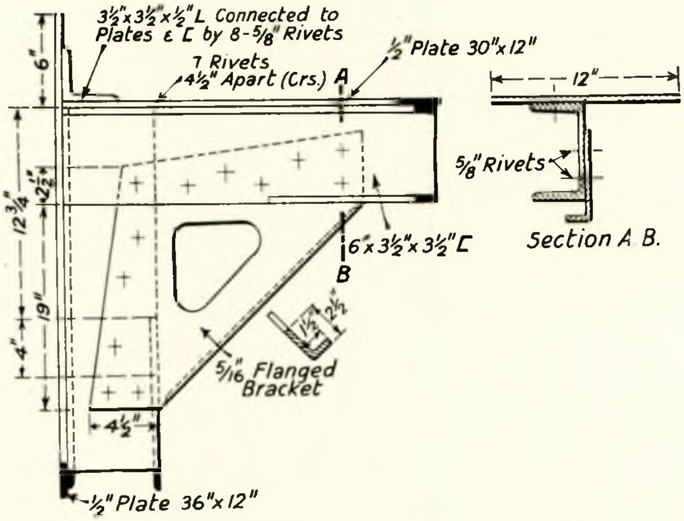


Fig. 15.

In the riveted ship this attachment is normally made by means of a beam knee, as shown in Fig. 15.

If T sections are adopted in a welded construction the connection can be made by running the beam out to the shell plating and butting the frame section to it, the attachment being made by fillet welds between the horizontal flange of the beam and the vertical flange of the frame and between the web of the frame and the flange of the beam. This is the simplest form of welded attachment of such a connection as could be made, but it has the weakness that the web and flange of the beam will fail under the load transmitted by the flange of frame at the point where this is attached. Stiffening plates were, therefore, introduced on either side of the beam so as to form the equivalent of additional webs at the beam end. These are indicated in the diagram of the joint in Fig. 16, and can be seen in the illustration of the test piece given in Fig. 19.

The method of testing is to load the joint so that the angle between the beam and the frame is increased or, in other words, so that the beam is pulled away from the frame. Investigations were also made on the strength of the joint when the load was applied in an opposite direction, that

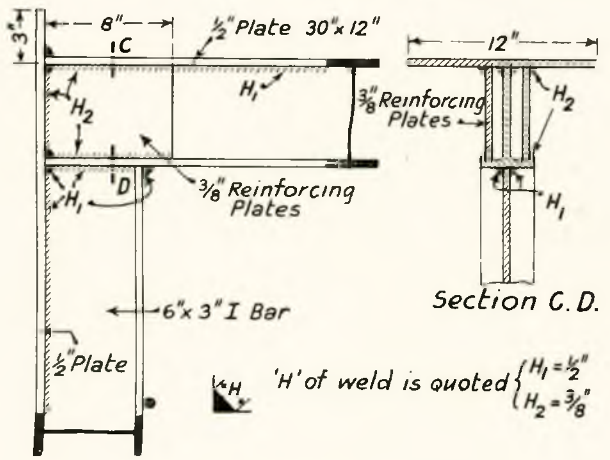


FIG. 16.

is, to close the angle, but in the particular experiment made on an oxy-acetylene welded joint, the beam and frame were pulled apart in the machine, illustrated in Fig. 17.

This shows one of the specimen joints under test and is of some interest on account of the means

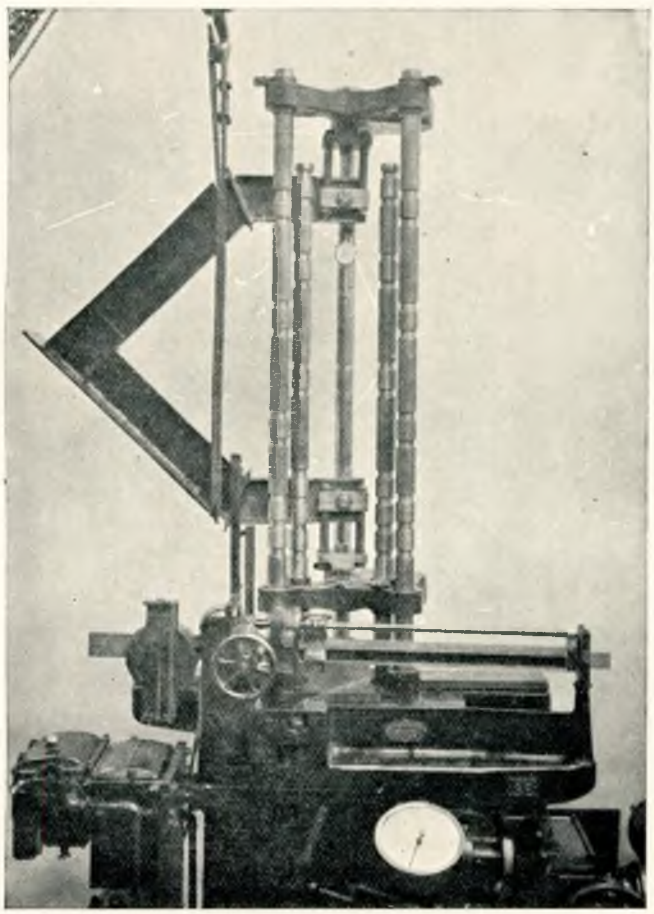


FIG. 17.

that had to be used to support the weight while the load was measured by the machine. The frame is being loaded by pulls that tend to open out the welded joint below the deck beam represented by the upper arm. These pulls are applied by links with ball and socket connections to the machine, and it is the pull on the upper arm that is actually measured. It will be observed that the links are very nearly vertical; and this direction of pull was maintained throughout the test, the weight of the frame being supported by means of a crane and sling, as illustrated. The sling is arranged so that it passes the upper arm of the frame without interfering with the measurement of the forces on the joint, passes also through the centre of gravity of the frame, and supports the lower arm of the frame with a force just equal to the weight. The correctness of the adjustment is shown by the vertical direction of the links. The illustration shows also the dial gauge and its connections arranged to measure the deflection of the frame under the measured forces.

In considering a test of this description it is only possible to draw comparisons between similar joints in which the attachments have been made by electric welding, or a joint of approximately the same estimated strength, employing a riveted bracket, and the accompanying diagram shows the deflection of five joints tested by Professor Haigh in exactly the same way and under the same conditions. (See Fig. 18.)

The accompanying table gives particulars of several yield points noted in the test:—

F—is the calculated load at which the stress in the flange of the stiffener may be expected to reach the "lower yield point", or the stress at which in an ordinary tensile test the plastic yield continues.

P—is an indication of the approximate limit of proportionality found by plotting the load deflection graphs.

Q—gives the load at which the slope of the load deflection curve has fallen to two-thirds of the slope of the initial elastic graph.

M—gives the maximum load carried by the joints.

In order that some idea of the stress distribution in the connection could be obtained, the whole surface was covered with resin applied in the form of powder, and then melted by a blowpipe until the surface of the parts was covered by a glossy varnish-like film. This film cracks very easily under strain, and makes it possible to see exactly which parts of the joints are stressed and approximately the lines of stress distribution. The test piece was loaded by increments of 200lb., and at every 1,000lb. the load was released and the test piece measured for permanent set. The elastic and permanent deflections were

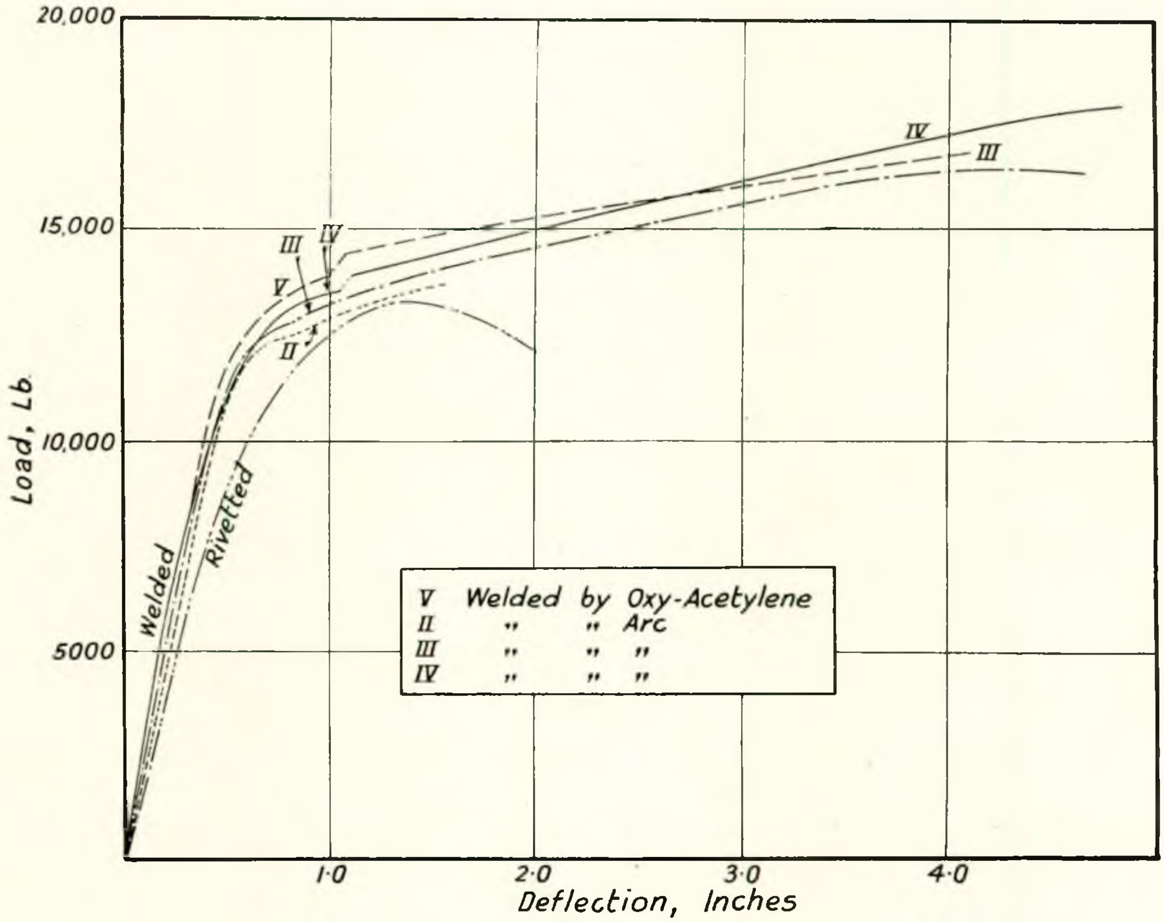


Fig. 18.

No.	Joint.	F.	P.	Q.	M.
I	Riveted	13,350	2,000	7,300	13,300
II	Welded	9,550	5,000	10,800	15,870
III	Welded	9,550	5,500	10,000	16,460
IV	Welded	9,550	4,000	9,500	17,820
V	O.A. Welded	9,550	9,000	11,000	16,760

measured by means of the dial micrometer gauge reading to 1-1000ths of an inch inserted between the extension arms of the test piece shown in Fig. 17. The specimen to which the information given refers is shown in Fig. 19.

The first sign of disturbance of the resin surface was shown at 7,500lb., when slight flaking was seen on the covered plate representing the shell plating of the ship. It seemed probable, however, that this area had some initial stress which may have been developed during the manufacture of the plate or may have been caused by the local heating effect of the fillet weld between the flange of the frame and the plate. With a load of 9,000lb. the first signs of yield were observed in the flange of the deck beam about 4in. from the face of the frame. The welds between the small side reinforcing plates and the beam flange then showed disturbance of the resin, and the flange of the side stiffening showed stress lines which soon continued into the web. The welds holding the reinforcing plates to the beam flange started to crack when a load of 15,000lb. was applied, and the flange of the deck beam suffered considerable deformation as a consequence. The joint failed completely at a load of 16,760 lb., and an examination showed that the corner weld had broken

Fig. 19.

through the throat. This total load probably represented a stress in the corner fillet of about 23 tons per square inch, which can be considered a very satisfactory result when compared with the other test pieces, and when it is remembered that this corner fillet was made in an overhead position. The surface of this particular weld was somewhat uneven, due to the difficulty of the operator, but the weld itself appeared to be good. The stress concentration, shown by the resin surface, indicated the desirability of obtaining a smooth surface on the weld whenever this is possible.

This particular experiment confirmed the conclusion already arrived at that it is possible to make satisfactory welds and welded joints under practical conditions, and in this case the size and nature of the test piece was such that it was reasonable to assume that any tendency to local heating being the cause of distortion and locked up stress in the joint had opportunity to show itself. There was no sign either in the making of the test piece or in its subsequent testing that any distortion was present, and careful observation during the test did not indicate the presence of locked up stress, except perhaps in the outer plate, as has already been mentioned. It was not possible to make full examination of the welds after the test piece had been broken, but there were signs that some of the welds were slightly crystalline in appearance, and in this connection it was noticeable that the test piece failed rather more suddenly than others, although it had resisted a greater load.

In the tests carried out for the Board of Trade and the Classification Societies, which have already been described, and certain preliminary tests of the same character which have been made, a tendency has occasionally been noticed for a weld to fail suddenly, although so far as could be ascertained, the ductility was satisfactory, and the tensile strength of the weld was all that could be desired. In such cases the break has been slightly crystalline, but it has not been possible to observe any difference in procedure which might account for this peculiarity and, while the matter is perhaps of no great importance, so long as the standard physical properties of the weld metal are quite satisfactory, it is suggested that further investigations might be made of the effect of procedure on the quality of the weld. It is possible that the rate of cooling of the weld metal may affect the subsequent structure, and that where the metal has been maintained at a relatively high temperature for some time a large grain structure is developed which would cause the weld to show these characteristics.

Professor Haigh has carried out a great deal of research on welded joints, information regarding which is given in papers read by him before the Institution of Naval Architects,* and acknowledgment is made to him for permission to publish the foregoing account of this particular test, and the illustrations which accompany it, and particularly to Mr. H. J. Tabb, late of the Royal Naval College, who carried out this test under the direction of Professor Haigh.

* (See particularly Transactions I.N.A. 1934).

Repair by Welding Propellers.

The repair of ships' propellers by welding is not a common practice, because it is a difficult type of repair to make, but the propeller is a component which is liable to damage by contact with floating objects, or with the ground when the vessel is navigating narrow waters. Larger or smaller portions of the blade tips are broken, and the effect on the efficiency and balance of the propeller often necessitates prompt repair or renewal of the broken blade. The propeller may be of cast iron or bronze cast in one piece, or may be built up of bronze blades bolted to a boss so that a blade may be easily renewed.

In the case of a cast iron propeller it is not usual to undertake repairs, as the difficulty and cost of replacing the broken piece would normally be out of proportion to the original cost of the propeller, and it is often found that, if the area of blade lost is not large, the efficiency of the propeller is not seriously affected, and the ship may at least proceed on her voyage or until the propeller can be replaced at a convenient opportunity.

The first example, however, is one of a repair carried out to two blades of the cast iron propeller shown in Fig. 20.

FIG. 20.

The circumstances in this case made it worth while to attempt a repair, and this was carried out by making a weld with bronze, or, in other words, by brazing a new tip on to the propeller blade. This repair was carried out on the spare propeller of a cargo ship without taking it ashore. The propeller was about 9ft. in diameter, and the maximum thickness of the blade in way of the break was about 1¾in. The break itself was cleaned and a new tip cast from a wooden pattern. The blade and the new portion were then set up in proper alignment, as can be seen in Fig. 21 which shows the brazing operation in progress.

Fig. 21.

No difficulty seems to have been found in making the actual joint, and the work was completed in something less than three hours after brazing had commenced. The length of the larger weld was about 33in., and approximately ¼in. was found to be the amount of transverse contraction which had to be allowed for in determining the original position of the new piece. It was found necessary to hammer the weld slightly, a process which did not appear to have any ill effect on the quality of the weld metal.

For a comparatively small repair of this kind it would seem at first sight that such a repair is cheap and simple and could be carried out in the limited time which is usually permissible in cases of this kind, but there are obviously one or two aspects of the matter which require consideration if one is to be assured of the permanency of the repair. The strength of a joint of this description is stated to be satisfactory as welds have been made on mild steel which showed a tensile strength of about 24 tons per square inch, but there does not appear to be very much information generally available on this aspect of the subject of bronze welding on ferrous metals. The more important matter perhaps from the ship repairer's point of view is the possibility that the presence of bronze in a joint between two cast iron or steel surfaces would result in intense corrosive action set up by the proximity of these two metals in salt water.

It is well known that electrolytic action takes place between a bronze propeller and the hull of the ship, and this would lead the marine engineer to look with grave suspicion on the combination of bronze and cast iron in the joint itself. It is only fair to point out, however, that the electrolytic conditions may be quite different in such a case, and indeed Professor Kiel has stated that his experiments on bronze welds in mild steel plate have so far, shown that the corrosion which might be feared does not in fact take place. If this can be substantiated the use of brazing or perhaps it might be termed "bronze welding" where there is a substantial quantity of deposited metal, on ferrous metals, may prove to be of great interest and value to the ship repairer, because this process can be carried out at temperatures and under conditions which obviate a great deal of the trouble which arises from distortion and contraction when welds are made on cast iron or a mild steel weld is made in steel plates.

The next example is of a repair of a more straightforward character in that it deals with the welding of a new portion to the existing blade of a bronze propeller. The propeller in this case is about 19½ft. in diameter and weighed no less than 7 tons, so that it was evidently of importance to make the repair, if this were at all possible. In this country attempts have been made to make welds of this description, but success has not always attended the efforts. The welds are inclined to be defective and the heat conditions are such as to cause disturbance and cracking of the material in way of the weld. In such cases it is more usual to arrange a mould round the blade and a new portion which has been cast and to join the two by continually pouring molten metal into the mould until the old and new portions of the blade are thoroughly fused, when the whole is allowed to cool and an almost perfect joint results. Sometimes when this type of repair is carried out small cracks develop towards the edges of the blade, and these are repaired by oxy-acetylene welding. In the case of the propeller illustrated in Fig. 22, however, a satisfactory oxy-acetylene welded joint was made, and it seems worth while to describe the procedure in some detail.

Fig. 22.

The length of the weld, which is shown in Fig. 23, was approximately 4ft. and the greatest thickness of the blade at the weld about 4½in.

A great deal of trouble in the actual operation appears to have been caused by the excessive heat given off by such a large volume of metal, and which made the conditions under which the welders worked, trying and not such as enabled

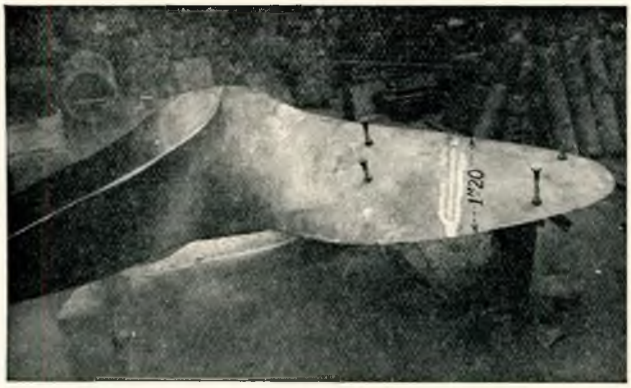


FIG. 23.

them to make a good weld. This difficulty was overcome by the use of long blowpipes and a suitable length of welding rod, which was manipulated by the man in charge of the work. Preparations were made by fastening the two portions of the blade together by angle bars fixed on the underside of the blade by the bolts shown in the photograph and in the small diagrams illustrating the repair, Fig. 24.

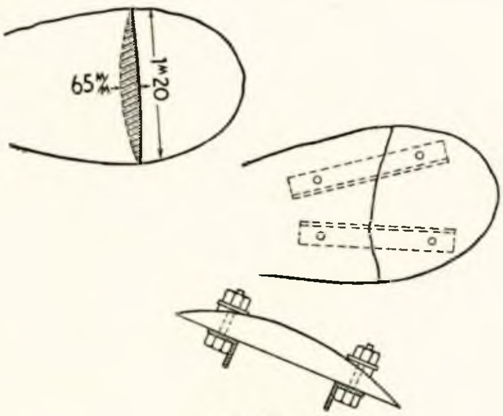


FIG. 24.

The joint was suitably "veed" out, the open part of the "vee" being on the upperside of the propeller, as shown in Fig. 25.

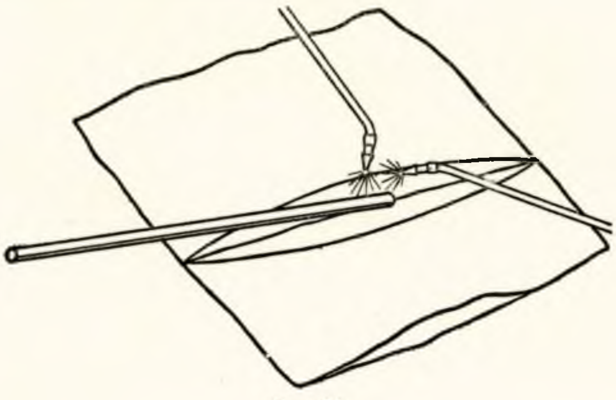


FIG. 25.

When the new portion of the blade had been fixed in position, a furnace was built round the joint and so arranged that the edges of the blade were left exposed, the main heat being directed to the thicker portion of the blade. The preheating process was carried out for about three hours, after which welding commenced. Three operators in all were employed, and in way of the thick portion of the blade one blowpipe was directed to one surface of the "vee", while another blowpipe was directed to the opposite surface and the welding rod manipulated by the third operator. The use of two blowpipes became unnecessary as the thickness of the blade decreased towards the edges, and the weld in this region was made in the usual way. The "vee" had not been cut down the full depth of the joint as it was intended to complete the weld from the other side of the blade, and the propeller was then turned over for this purpose. As this part of the blade had been in direct contact with the fire, it was necessary to cut away the metal in way of the joint to a depth of approximately 1in. in order to get down to sound metal and to remove small cracks resulting from the preheating. For the welding of the opposite side, the angle irons had to be removed and the propeller was suitably wedged up while the work was in progress.

Some difficulty was found in making a satisfactory weld at the edges of the blade where it was comparatively thin, due to the fact that the metal was hotter than desirable, but this was satisfactorily accomplished by backing the weld with a steel plate, as shown in the diagram in Fig. 26, and using a smaller flame. The weld was dressed with a pneumatic chisel after completion and the excess metal ground off in the usual way.

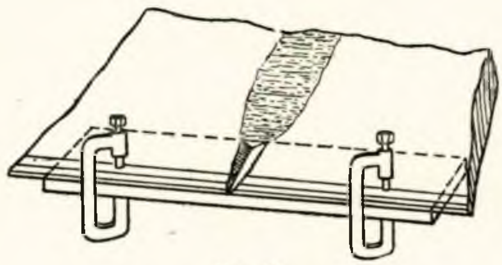


FIG. 26.

It is suggested that when work of this kind is being carried out the preliminary arrangements should be carefully made in order that there should be no break in the continuity of the welding. The stools for the operators should be of steel to resist the considerable heat, and all welding accessories should be at hand, while the men employed should, if possible, be accustomed to the conditions which are inevitable when large work which has been preheated is being handled.

In recent years the erosion of bronze propellers has presented a serious problem to the operators of high speed vessels, and many cases are on record of propellers having been rendered practically useless and dangerous after the ship has been running a very short time. This type of deterioration is not only very difficult to account for and to prevent, but makes it exceedingly difficult to repair the propeller because it may cover a considerable area of the blade. Repairs are sometimes effected by burning metal on in much the same way as has been described in the case of a repair of a broken blade, but the difficulties of dealing with a large propeller in this way are obvious, and the cost is very considerable.

Cases of serious erosion while not very numerous are very troublesome and expensive to the owners of the ship, and it appears that it is possible that the oxy-acetylene blowpipe may be called on to serve a most useful purpose if it can be successfully applied in such a case.

One case of this kind has already been dealt with and the eroded surface of the propeller built up by depositing metal on to it with the aid of the oxy-acetylene flame. So far it appears to have been a satisfactory repair, but it is not certain whether the deposit metal is more capable of resisting erosion than the original bronze of the propeller. It is established, however, that such reconditioning can be carried out without injury to the original propeller or to the material, and it is only a question of experiment to find the most suitable form of deposit. When fuller particulars of these experiments are available, it is hoped that it will be shown that a simple means of repair of damage of this kind will have been found.

The foregoing notes have been directed to the repair of large propellers, but there are many examples on record of repairs to small bronze propellers, and indeed these have been built up by means of the blowpipe. As in other applications the extent and success of this particular work depends to a large extent on the experience and skill of the operators. It is safe to say indeed that the first essential to the extension of activities of this kind is that industry should be provided with a good supply of skilled men of a type able to appreciate that each repair brings its own problem which often requires considerable ingenuity for its solution.

Fabrication by Welding and Cutting.

Although the possibilities of the application of oxy-acetylene welding to steel structural work in shipbuilding may yet remain to be developed, the usefulness of the welding and cutting blowpipe is so well established that they have been an indispensable asset to the shipbuilder for many years, and it is likely that, as methods improve, they will take an increasingly important place in modern shipyard economy.

The rapidity of the extension of their use will materially depend both on the "mentality" of each yard and the efforts of the industry to demonstrate the various ways in which the use of the oxy-acetylene flame can be applied most economically to the shipbuilders' problems. There are many cases in which the peculiar mobility of the flame as a cutting agent is of great value where the cutting has to be carried out on the ship after the structure has been assembled. The openings in shell plating to take doors, sidelights, etc., are a common example of cutting "in place", and there are many similar examples of the use of the welding flame. Ventilation trunks of light sheet steel are extensively used in all large passenger ships and the blowpipe is particularly suitable for both the construction of the trunks before erection, and the assembly on the ship. The accompanying illustration, Fig. 27, shows the ease with which shaped trunks can be constructed by this method.

This example could not have been riveted without serious increase in weight and cost, while other methods of welding do not offer the same advantages when dealing with thin material of this kind. An example of this class of work for the ventilation system of the "Normandie" is given in Fig. 28, and similar work has been carried out on the "Queen Mary" both of which examples indicate the extent to which the blowpipe is used in this field.

A great deal of oxy-acetylene welding is also used on the pipe work in these and similar ships to avoid the use of innumerable joints in the water service systems, while an excellent example of this kind is the welding of brine pipes carried out on a large refrigerated ship in London comparatively recently. The advantages of a weld in place of a "made" joint in such a case is obvious as any leakage from the joints may cause serious damage to insulation. Pipe joints

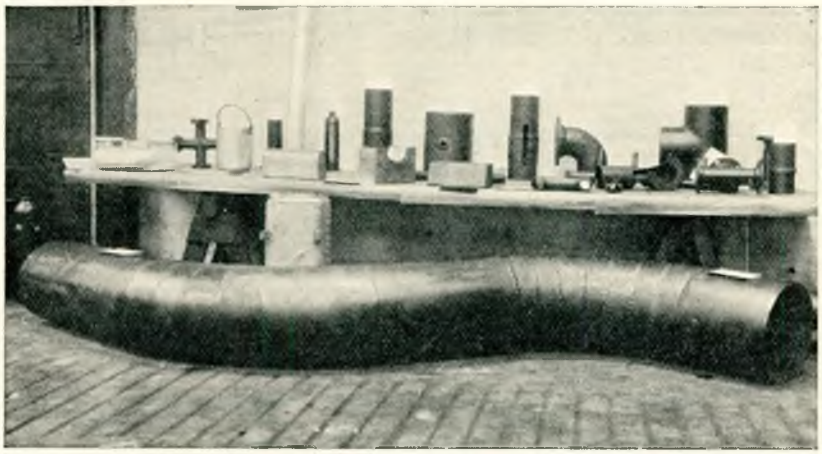


Fig. 27.

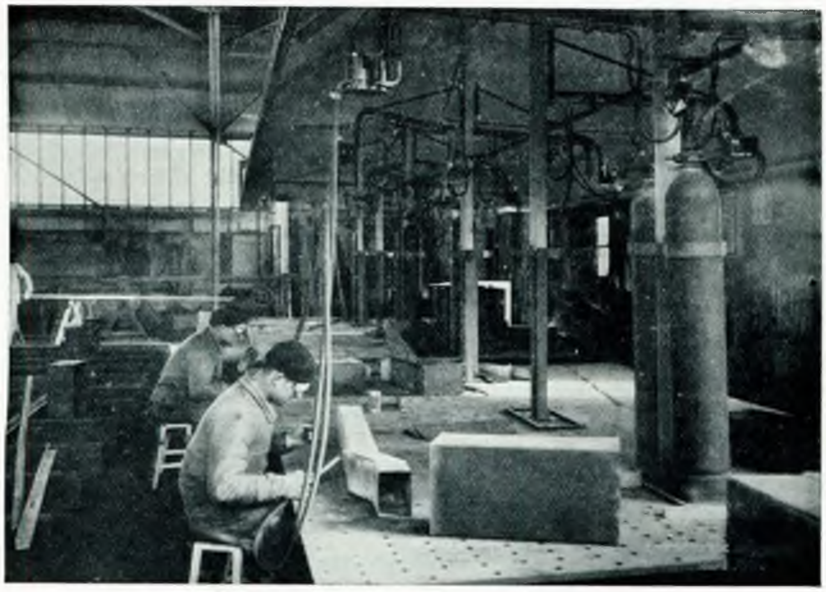


Fig. 28.

production of light semi-standardised items to become the work of firms specialising in such work. Ventilator cowls and standard lengths of trunks, light tanks, steel ends for wood hatch covers are all examples of this kind in which oxy-acetylene welding is used, while the steel lifeboat is a larger example.

As in many other industries, the cutting blowpipe is being used increasingly in the shipyard and marine engine shops to cut from the solid plate items which it is difficult or more expensive to produce by the usual method of forging. Slight variations in the dimensions of similar parts make it impossible to apply mass production methods to shipbuilding, even if these were otherwise satisfactory and in many cases the blowpipe is of great value. The illustration in Fig. 29 shows a mast ring and derrick heel which have been cut from the solid.

In both these cases most expensive forging has been avoided, and the result is a cleaner and more satisfactory job which, from the strength point of view, must compare very favourably with the forging. Fig. 30 is a good example of the substitution of castings by "cuttings".

of this kind can be made quickly and cheaply, and there is every prospect that the practice of employing welded joints will increase when the conditions do not impose large ranges of temperature and consequent expansion of the pipes. In practically every shipyard the handling and joining of light steel plating for a variety of purposes is facilitated or made possible by the blowpipe, but there is a tendency for the

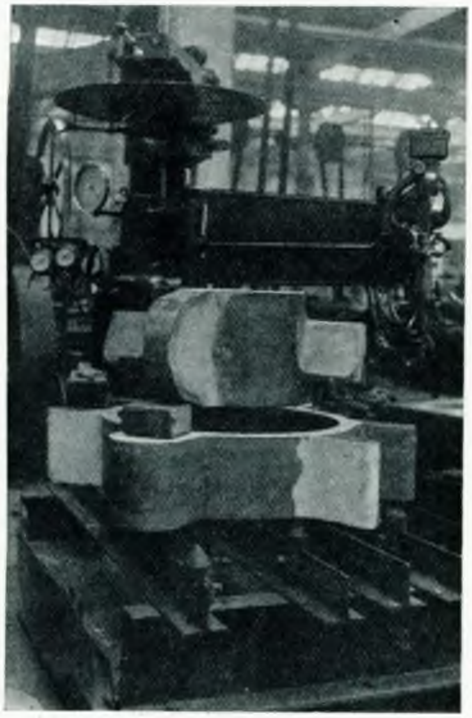


Fig. 29.

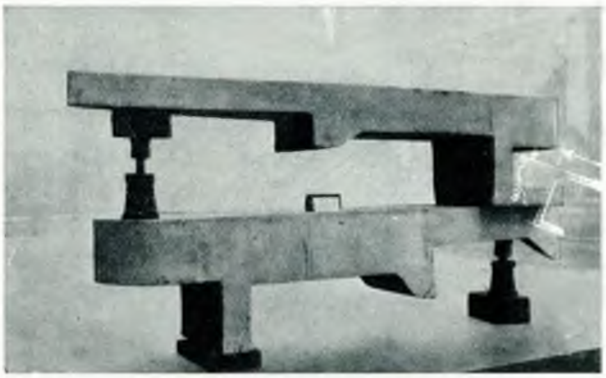


Fig. 30.

These are the upper and lower arms of a large streamline rudder of a type which has become so popular during the last few years, and in this case the material from which the arms were cut was 14in. in thickness and the cutting rate about 24ft. per hour. Economy in the time of production is an important factor, as is the certainty that delay will not result from imperfect casting.

The cutting of heavy plating and sections to the correct shape and dimensions, where these have not been delivered to the finished sizes from the mills, is a matter of routine in every shipyard, but is nevertheless a notable facility which shipbuilders owe to oxy-acetylene. Many examples of the use of the flame to meet particular circumstances could be quoted, and one is illustrated in Fig. 31.

FIG. 31.

In this case the blanks for drag links have been cut from sections of a discarded shaft, thereby increasing its "scrap" value considerably. The marine engine and boiler shops show innumerable examples of both cutting and welding, although the latter is confined to light steel work, such as fan casings, water servicing piping, etc. Fig. 32 is an example of multiple cutting in the boiler shop —crown stays for marine boilers being shaped with the minimum of labour.

FIG. 32.

Probably one of the most effective and commonest uses of the cutting blowpipe is in the shaping of engine crank webs, and the illustration in Fig. 33 shows the work in progress, and Fig. 34 the completed crankshaft.

The substitution of cutting for forgings is of great economical value in engine work, as these examples and the next show.

Figs. 35 and 36 show the operation of cutting a connecting rod from the solid material and illustrates the simplicity and accuracy with which such large and expensive components can be produced in comparison with the longer and more difficult process of forging.

The illustration in Fig. 37 is interesting, not because it shows unusual methods, but because the plate being cut is of special hardened steel, as is used for gun roller paths in battleships, which can only be machine cut with great difficulty and by the use of special tools.

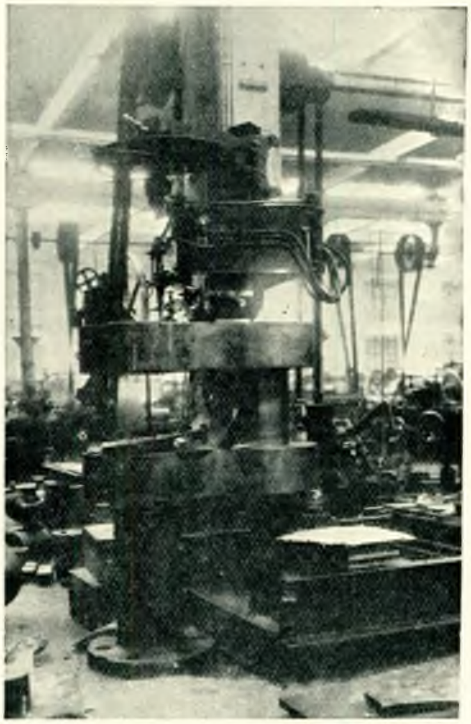


FIG. 33.

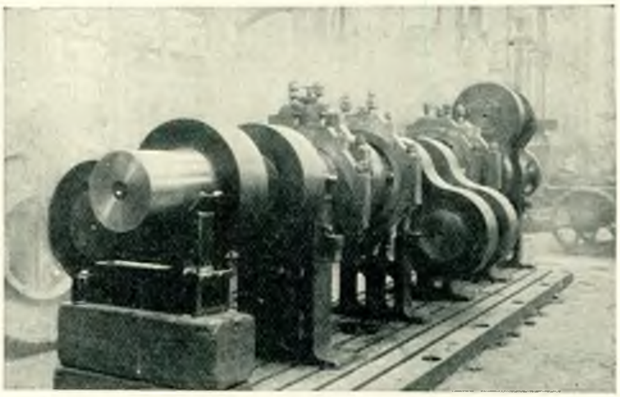


FIG. 34.

Oxy-acetylene has long taken an important part in the ship and marine engine repair shops, and provides many interesting illustrations of the skill and ingenuity shown in the repair or reconditioning of ships and machinery. The welding blowpipe is the more important tool in repair work,

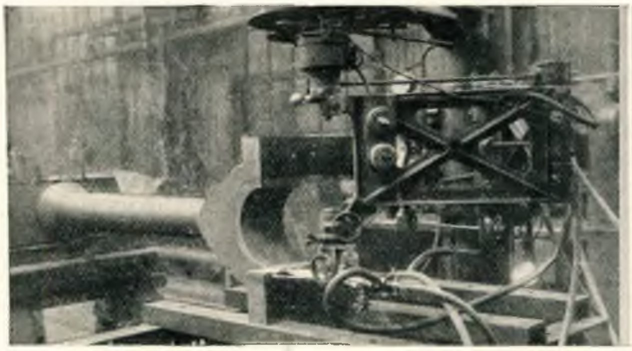


Fig. 35.

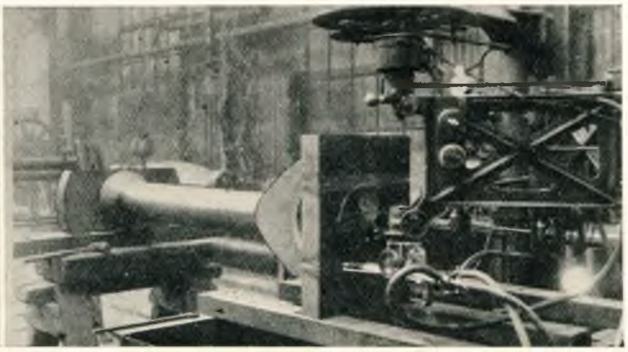


Fig. 36.

Fig. 37.

although the cutting flame is indispensable in many cases in the preparation of damaged parts before repair by welding or the cutting away of damaged plating and the burning out of the rivets attaching the damaged plate to adjacent sound plating. Fig. 38 illustrates the type of damage which has to be dealt with by cutting away all defective plating as a preliminary to making and fitting new shell plates.

Clearly some of this can simply be burnt away and scrapped, but the marking on the adjacent plating indicates that several plates are to be removed, and in some cases replaced. In dealing with these the rivet heads have to be burnt away with care so that the plating is undamaged, as shown in Fig. 39, where several plates are being removed.

The choice of blowpipe and the handling of it are both of great importance in this class of work, the success of which depends greatly on the individual skill and care exercised by the operator. The removal of damaged shell plating is a necessary preliminary in practically all shell repairs, and it is worth while to refer to the subject more particularly. It is of the greatest importance to employ only experienced operators in removing plating which is to be replaced, especially when much of the burning of rivets is to be carried out in the "overhead" position. The careless workmen often damages the sound plating or alternatively fails to remove the rivet head completely, and in either case causes unnecessary expense. These faults are common where the holes in the two plates have not originally been in line or the rivet head is difficult to locate, due to paint or corrosion. If the work is done with reasonable care, however, not more than from 2 per cent. to 5 per cent. of the holes should require subsequent attention. The regulation of gas pressure is important if the

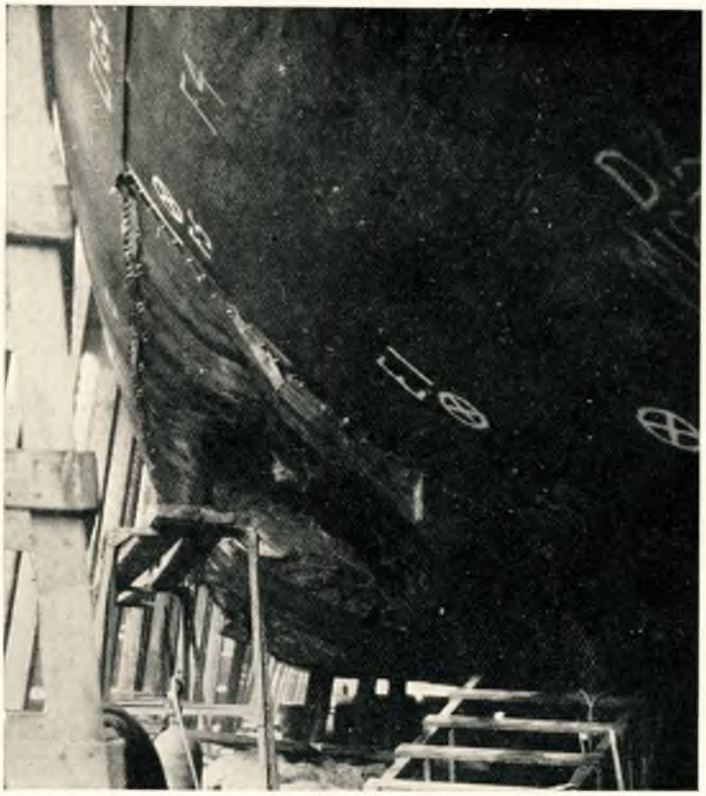


Fig. 38.

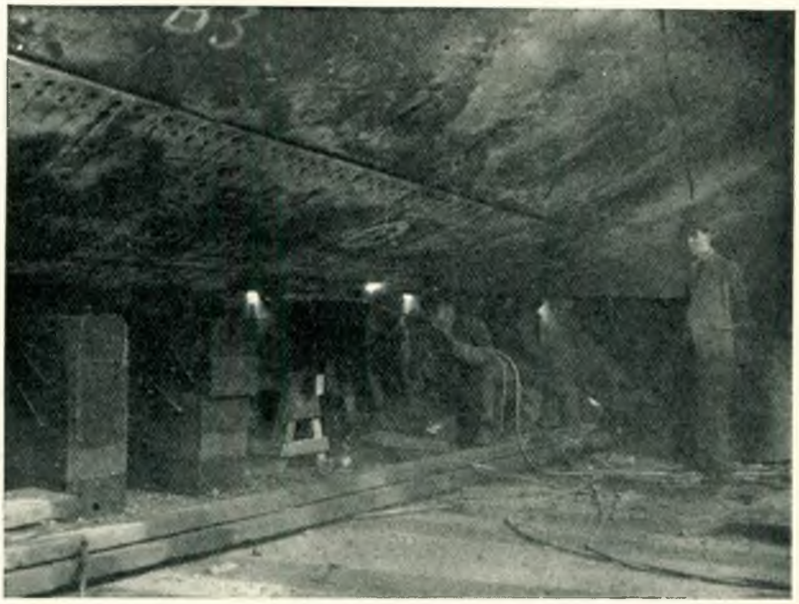


Fig. 39.

Examination at this time also makes the detection of careless workmen simple, and it is suggested that such are better employed where their lack of care is less expensive.

For the sake of economy it is usually better to use a smaller tip that will give the maximum speed of operation, although where the work is very dirty or badly oxidised, a larger tip than normally used is necessary.

greatest efficiency and economy is to be achieved, and this should not be left to the usual unskilled assistant, but some care should be taken that the regulation is carried out with intelligence. This is a simple matter if a man can be employed to look after a number of welders and their blowpipes. Failure in this service often results in the welder making unnecessary adjustments at the blowpipe which thereby loses in efficiency. Such adjustments may also put an undue strain on the tubing conveying the gases, and their fittings. Leakages at joints should be guarded against, and constant attention paid to the condition of all the apparatus. Operators should not be allowed to make adjustments, alterations, or to dismantle blowpipes for cleaning as this frequently results in damage to the nozzle and other parts. This difficulty can be overcome by arranging for proper examination and overhaul when the apparatus is returned to store at the completion of each job.

Demolition.

The removal of damaged or otherwise unserviceable plating from the ship being repaired probably constitutes the most important work for which the ship repairer uses the cutting flame, but the less usual uses to which he continually puts it are innumerable. By cutting up the turbine casing, shown in Fig. 40, it was possible to remove it for replacement without the costly removal of deck plating, casings, etc., while the plate rolls shown in Fig. 41 which were no longer serviceable were rapidly and simply dismantled by the process of Fig. 42.

The finest ships inevitably reach an age and condition when they have outlived their usefulness and must suffer disintegration, so that the various metals used in their building can be transformed and re-melted perhaps to help construct the ship which has rendered her predecessor obsolete. The illustrations of Figs. 43 and 44 show the process of demolition of the "Mauretania" made commercially possible by the use of the oxy-acetylene flame. The cutting blowpipe has made it possible to reclaim the scrap value of thousands of old ships, but it is not surprising that, where there is so much uncertainty as to the value of the material recovered, the efficiency of the cutting plant may mean the difference between profit and loss to the shipbreaker.

Fig. 40.

Fig. 41.

FIG. 42.

In the first photograph the tube plate has been removed and corroded parts of the furnace are being rebuilt, while in the second, the new tube plate has been fitted, and the attachment at the sides is being oxy-acetylene welded. Fig. 47 shows a tube plate partly renewed and ready for welding. These are examples of work done in France where the process has been used to a greater extent in boiler work than it has been in this country, although some years ago many successful repairs were carried out here. Great skill is necessary and is often shown by the operator in this class of work, in avoiding locked up stresses due to contraction by "stepping" the welding or dealing with certain portions in a particular sequence and also by hammering the weld metal as it is laid down.

The repair of ships' auxiliary machinery provides many examples of welding, particularly where damaged castings have to be dealt with, and the pump chamber illustrated in Fig. 48 is an average example. The pump crosshead shown in Fig. 49 is an illustration of a repair in which the weld has been reinforced by a cover plate welded over the joint. This practice is quite usual where the type of damage is such that the repairing weld is one which cannot be expected to take much stress. In this particular case the cover plate, which is

FIG. 43.

FIG. 44.

bronze welded to the casting, provides the necessary reinforcement.

Figs. 50 and 51 are good illustrations of the repair of a cylinder cover which might well have been regarded as a hopeless case, but for the blowpipe, and such examples might be quoted many hundreds or even thousands of times, each one presenting a different problem and requiring a similar degree of ingenuity.

The advent of the diesel engine has provided many opportunities for the use of the blowpipe for the repair of large castings, and the following

Machinery Repairs.

It is more encouraging to consider examples of the possibilities of prolonging the usefulness of various parts of the ship by means of the welding blowpipe. The illustrations in Figs. 45 and 46 show repairs being carried out to a marine boiler.

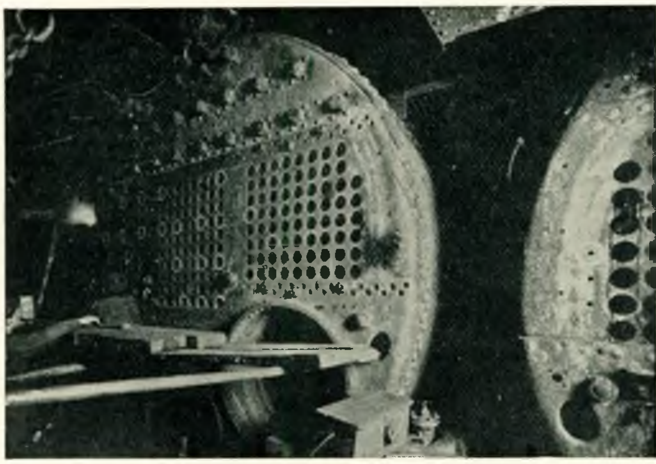


Fig. 46.

Fig. 45.

examples represent repairs to important components of these which have saved much time and money. Fig. 52 shows the damage sustained by the exhaust manifold of the engine of a large vessel, and Fig. 53 shows how satisfactorily it has been repaired by welding.

This manifold, and the example shown in Figs. 54 and 55, have been in service for some time since the repairs were made and have in no way proved inferior to the original.

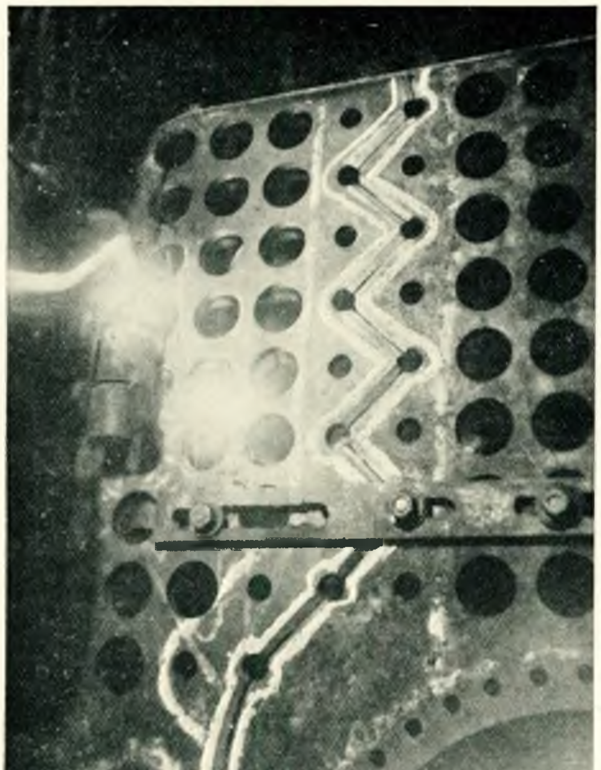


Fig. 47.

Fig. 56 shows a difficult and valuable type of repair which has been repeated many times and proved to be a satisfactory method in spite of the severe conditions to which it is subjected. The piston crowns of large diesel engines are liable to crack, due to the excessive heat conditions, and as these cracks usually occur in the centre of the crown, often taking the form of a star, the crown is still serviceable if they can be effectively repaired.

Fig. 56 shows how this has been done in the case of a piston 30in. in diameter, and it will be agreed that this is a very creditable achievement.

In this repair and also in that of the exhaust manifold, the preparation of the casting before the welding is commenced is of the greatest importance. In the case of the piston crown the crack is "veed" out with the blowpipe, as shown in the illustration in Fig. 57. A furnace or muffle of fire brick is built round the casting and heating is carried out by means of coal gas. The temperature is thus raised comparatively slowly until the whole is at a dull red heat when the welding is carried out by means of blowpipes having extension pieces fitted so that the welder can work at a distance from the heated casting. Care must be taken that a suitable welding rod is used which will deposit metal having approximately the same co-efficient of expansion as the parent metal in order that there is no possibility of the weld failing by difference in expansion of the two metals when the piston is working under high temperatures. The gradual cooling of the welded casting is, of course, as important as the preheating, and when this is complete the weld is "dressed" and the piston tested for distortion. These pistons gradually increase in diameter in service due to the continual heating and cooling to which they are liable, and it is usually possible to correct any slight distortion which the welding may have caused in the lathe.

The repair of bronze valve chambers, seats, and the building up of pump rods by depositing

Fig. 48.

bronze and afterwards machining are an every day occurrence in the engine repair shop, and here again there is practically no limit to the application of the blowpipe but the ingenuity and skill of the operators.

Although the engine room provides most of the work for the welders, deck gear and machinery often call for similar repairs. Broken hawse pipes can be welded, deck water service pipes renewed with welded joints, and winch cylinder blocks reconditioned, as illustrated in Figs. 58 and 59.

The teeth of cable lifting wheels of windlasses can be rebuilt, as is shown in Fig. 60, and practically any damaged or worn portions of cargo lifting gear repaired or reconditioned. Repairs of a major character have been made to fractured stern post and stem bars of several trawlers, and Fig. 61 shows one of these in progress, while Fig. 62 is an example of a repair to a damaged stern frame.

Hull Repairs.

The foregoing are typical examples of an infinite variety of repair for which the shipyard uses the blowpipe, and the possibilities are as large as these would indicate. Modern developments in materials have made it necessary that welding rods suitable for their repair should be developed, and special rods are now produced to meet most requirements, and the manufacturers of rods show a commendable readiness to assist the ship repairer in meeting special conditions. A possible development is in the application of oxy-acetylene welding to structural repairs. It has already been mentioned that repairs of this kind were carried out in the early days of the process with results that were not always satisfactory. Improvements in procedure, notably the introduction of the rightward method, seem to warrant further trial of it for the repair of cracks in shell plating, to quote one example. This kind of repair, however, is notoriously difficult to make satisfactorily by welding, but the excellent results in respect of the ductility of the welds made by the oxy-acetylene blowpipe should make them suitable for the purpose.

The possibility of building up corroded parts of the structure by means of deposited metal should also be considered for, although it appears at first sight that this would be too expensive to make it worth while, it is worth consideration.

This suggestion leads naturally to the consideration of the possibilities of a recent application of the blowpipe—metal spraying—which may be regarded as akin to welding an extremely thin layer of metal to the surface of the parent metal.

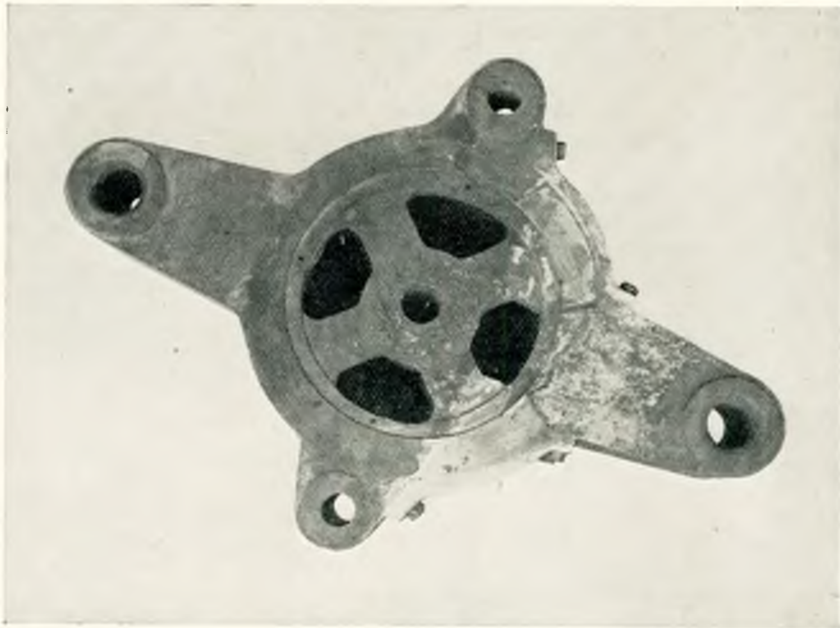


Fig. 49.

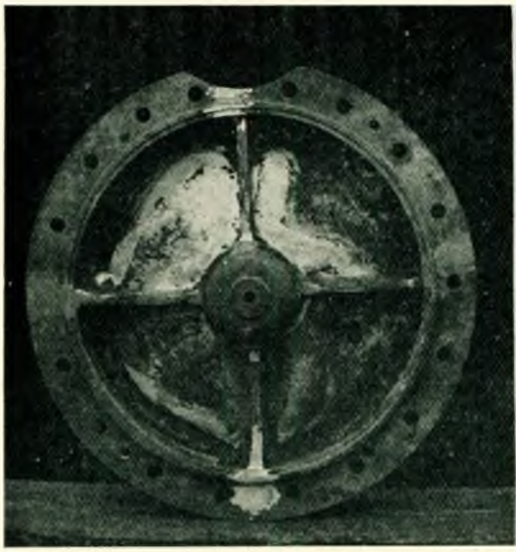


FIG. 51.

FIG. 50.

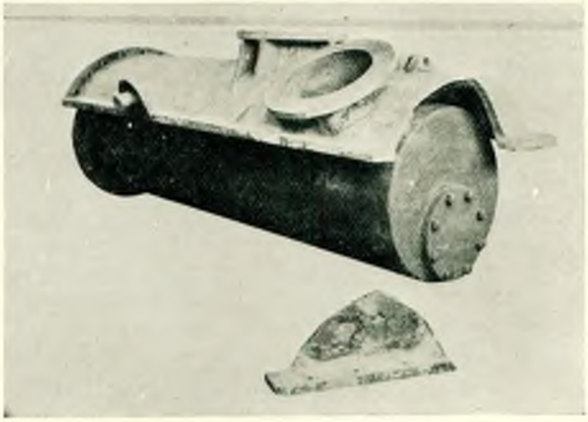


FIG. 52.

FIG. 54.

FIG. 53.

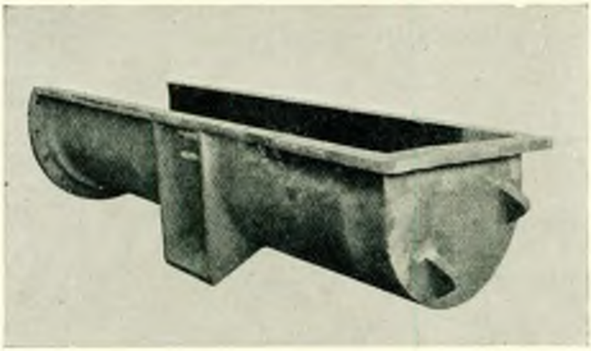


FIG. 55.

It has been used on board ship to coat spirit carrying tanks and prevent corrosion of the steel structure and, although the preparation of the steel work before spraying it with a metal coating—usually non-ferrous—is expensive, it has great possibilities for use in bulk oil carrying ships where the corrosion caused by oils is so rapid that the life of the steel work of the tanks really determines the useful life of the ship. Many applications suggest themselves, such as the building up of eroded propellers, shafting, and possibly the structure of the ship itself, in addition to protective coating when the parts are new, if the development of the process makes it practicable to apply it in this way.

The foregoing illustrations of the use and possibilities of the oxy-acetylene flame are largely drawn from shipbuilding and ship repairing in this country, but some of the examples given are from other countries where development has been along very similar lines.

Fig. 56.

The extent to which the blowpipe is used varies, as might be expected, but this variation is largely due to differences in organisation rather than to differences of technique. In France, for instance, the use of the blowpipe has been well organised and its progress there is probably greater than in any other country, particularly where shipbuilding and allied industries are concerned. This may be due to an absence of restrictive regulation which has been more noticeable in Great Britain.

The following account of the procedure and arrangements for oxy-acetylene welding and cutting in the shipyard of Penhoet at St. Nazaire will be sufficient to give a general indication of the position.

Fig. 57.

This particular yard is well organised for the use of the oxy-acetylene blowpipe for both welding and cutting, and particularly in the past two or three years have had so much experience of its application to a very large ship, that the findings resulting from this experience are of considerable value.

Both the oxygen and acetylene used in the yard are produced in a small factory adjacent to the shipyard and from there are delivered in bottles in the usual way. The production price of dissolved acetylene is greater than when produced in medium or low pressure generators, but for work in the yard and on the ships it is essential that the gas should be stored in bottles in order that a

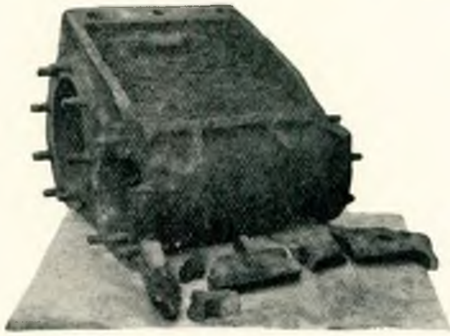


Fig. 58.

certain measure of mobility of the blowpipes can be attained. When used on the ship itself high pressure blowpipes are employed in the usual way, but when a considerable amount of work is done in one shop as, for instance, where the fabrication of ventilation trunks, metallic furniture and sheet-iron work is carried out, the gases are reduced in pressure and fed to the benches through pipe lines.

A certain amount of difficulty was found, due to the low temperatures inseparable from rapid pressure reduction, but this was overcome by reducing in two stages. The application of electrical heating to valves, etc., to prevent frosting was found to be too cumbersome to be a practical solution of the difficulty.

Fig. 59.

The usual precautions are taken regarding the testing of the gas bottles and great care is taken that a high standard of upkeep of blowpipes,

Fig. 60.

flexible tubing, etc., is maintained. Both in the workshops and on the ship, special means are taken to ventilate by fixed or portable ventilation pipes, particularly when the use of bronze welding rods is necessary or galvanised steel is to be cut. When bronze welding in quantity is to be carried out, the men are provided with absorbent masks.

The shipyard employs a total of about 5,000 men and about 150 welders and cutters, using the oxy-acetylene blowpipe. . Cutting for various purposes comprises about 60 per cent. of the work, and 70 per cent. of the total are employed on the hull and about 30 per cent. on boiler work and engine work.

Where the edges of plates are to be prepared for electric arc welding by oxy-acetylene cutting, machines, either automatic or semi-automatic, are commonly used. It is found that with these machines it is necessary that the purity of the oxygen should be in the order of 99 per cent. The cost of flame cutting is found to be slightly in excess of machine cutting, but this is more than offset by the convenience and the saving of cost in the handling of heavy plates, especially where the thickness of plates and the use of high tensile steel makes machine cutting very expensive.

Although in France the question of the effect of the cut surface on the strength of the welded joint has been raised, it does not appear that any objection is or has been taken to oxy-acetylene cutting. Experiments in this shipyard have shown that a "vee" joint flame cut by manual operation is about 10 per cent. less in value than when machine cut, but this is stated to be entirely due to the unevenness of the cut, and when the cutting can be carried out by mechanically operated flame cutting machines, the results are equal to the machine cut joint. Special machines have been developed in this yard for the cutting of shaped plates, and these are cut to great accuracy up to a length of 15 metres. In order to cut a plate with a double "vee" a special machine has been developed to carry out this operation without turning over the plate and, although this machine has not yet been put on the market, it appears that it has given complete satisfaction and has considerably reduced the cost of preparation of plate edges for this type of joint.

The class of work done is much the same as has been described as carried out in the yards of this country, but the procedure appears to be better standardised.

In a large ship recently built in this shipyard the total length of the ventilation trunks was no less than 43,000 metres, so that the fabrication of them deserves particular attention. In some cases

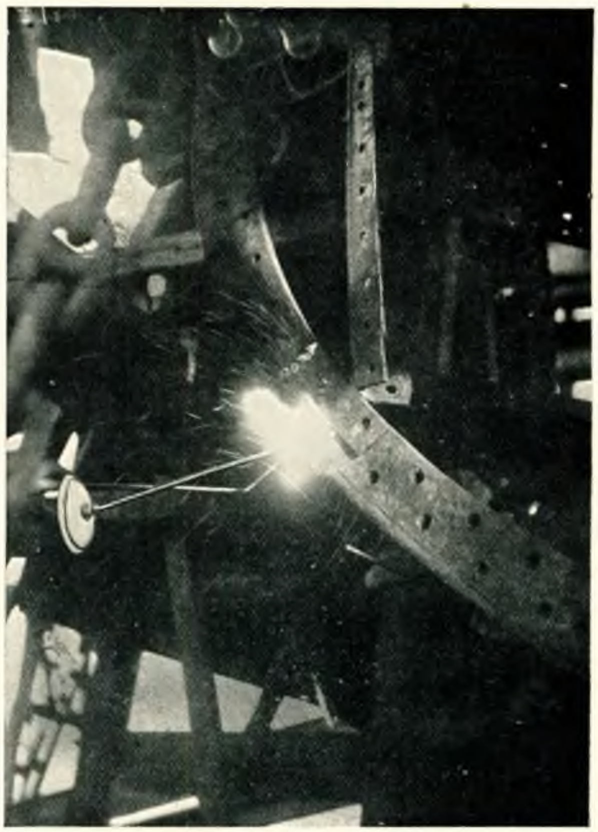


Fig. 61.

the trunks were made from thin plating, the overlapped joint of which was electrically spot welded, but where it was necessary to make continuous welds of the edge seams, the oxy-acetylene blowpipe was used. As the plating was galvanised before delivery, it was found that the most suitable method of making the weld was by means of a bronze rod, by the use of which the burning off of the galvanising in way of the joint was avoided and excessive deformation of the thin plating was not present to the extent noticeable when the direct welding of the plates was carried out. However, when the steel used was not galvanised, mild steel rods were used in the usual way, and it was found that the speed of welding was practically equal to that of brazing, while the cost was, of course, less.

A great deal of welding of oil and auxiliary steam pipes was also carried out in this yard economically and satisfactorily—the procedure being similar to that employed in this country. The use of alloys on aluminium for metallic furniture and for decorative purposes has meant that the blowpipe has been provided with yet another field of activity in shipbuilding. These alloys are not resistant to corrosion effects of salt water and sea air so that they are not used in the structure of the ship but for internal work. These remarks, of course, do not cover certain aluminium alloys which have been used for the structure of small craft. The joining of this class of alloy presents certain difficulties due to the heating effect on the metal itself. Duralumin is a particular example, and in this case it is necessary to anneal the material after jointing by welding. This annealing is sometimes carried out by an electrical resistance method which may, after more development, be suitable for small structural work.

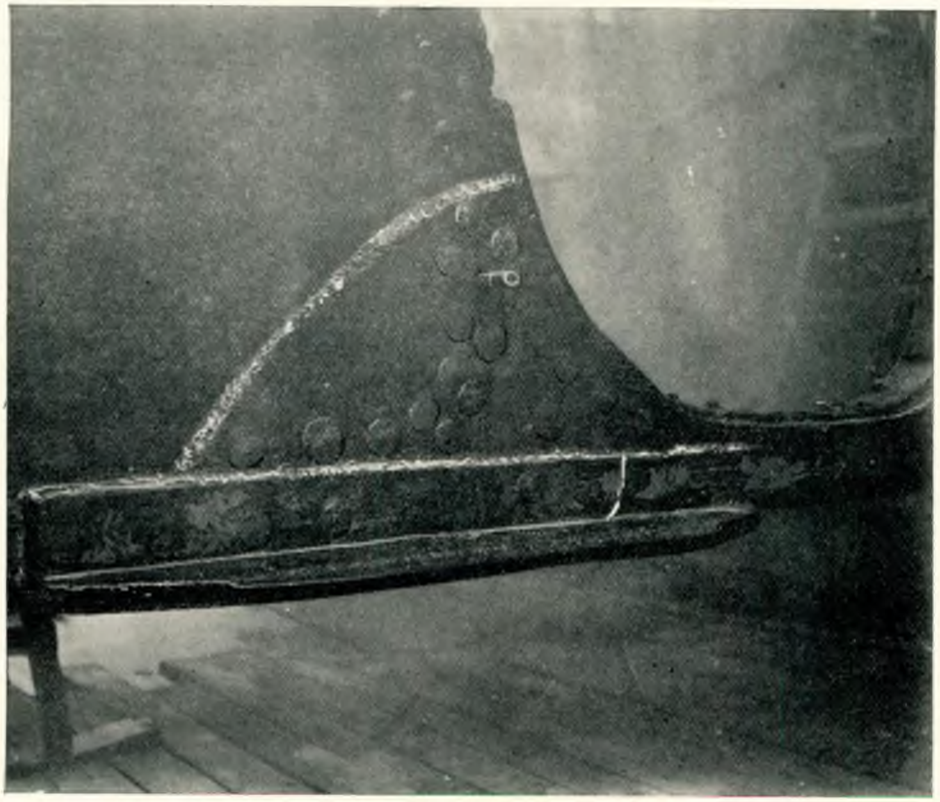


Fig. 62.

An endeavour has been made in the foregoing account of the use and possibilities of oxy-acetylene in shipbuilding and ship repairing to cover the subject as far as possible in a general way rather than to attempt to detail particular technique or procedure. These are matters of individual choice and circumstance, but further development cannot take place until the shipbuilder realises the possibilities of the processes which are at his disposal.

Grateful acknowledgments are made to the many institutions and firms in this country who have unreservedly placed their experience and knowledge at the disposal of the Committee, and to the correspondents in various countries who have sent information and illustrations which have been embodied in the Report.

INSTITUTE NOTES.

ELECTION OF MEMBERS.

List of those elected at Council Meeting held on Monday, September 7th, 1936.

Members.

Robert Balmer, Longwyn, Kingsway, Penwortham, Preston, Lancs.

Gerald Bishop, 12, Nash Road, Edmonton, N.9.

George Reader Chappel, Lloyd's Register of Shipping, Union Bank Chambers, 230, Chapel Street, Salford 3, Manchester.

William John Conolly, 5, Broome Street, St. Clair, Port-of-Spain, Trinidad, B.W.I.

Augustus George Crousaz, Eng. Rear-Admiral, 33, Burgh Heath Road, Epsom, Surrey.

William Alfred Loftus Dawkins, 68, Revidge Road, Blackburn, Lancs.

Michael Joseph Hanlon, 789, Boulevard East, Weehawken, New Jersey, U.S.A.

Bernard Hockey, Brundah, 344, Sydney Road, Balgowlah, Sydney, N.S.W.

George John Humphrey, Hazelmere, Pine Road, Kenilworth, C.P., S. Africa.

Fleming Miller, 114, Milton Road, Gravesend, Kent.

William Phillips Miller, Ivybank, Rose Street, St. Monance, Fife.

William Noble, Farringdon Street, Alderley, Brisbane, Queensland.

George Turnbull Reed, 42, Newlands Avenue, Alexandra Road, Sunderland.

William Sweet Smith, Assistant Government Marine Surveyor, Harbour Office, Hong Kong.

John Samuel Hodgart Stevenson, 5, Ashburton Road, Birkenhead.

Arthur Tilby, Ashfield, 41, Woodleigh Road, West Monkseaton.

William Morley Wright, The China Navigation Co., Messrs. Butterfield & Swire, Hong Kong, China.

John Frank Wynne, Morianfa, Southfield, Hessle, Yorks.

Associate Member.

Harold James Tabb. 13, Elwick Road, West Hartlepool.

Associates.

Leonard Charles George Alford, 54, George-a-Green Road, Wakefield, Yorks.

William Bennett Connolly, 15, Cecil Road, Seaforth, Liverpool, 21.

Phiroze Dinshaw Dadachanji, 30, Malcolm Baug, Jogeshwari, Bombay Sbn. District, India.

James Cyril Glen, Inchcape, Forefield Lane, Great Crosby, Lancs.

Douglas Robert Goldup, 58, Parkview Road, New Eltham, S.E.9.

George Harold Lake, Lime Leigh, 560, Derby Road, Nottingham.

Reginald Lumb, Ash Lea, Holton Le Clay, near Grimsby.

Henry Mason Maule, The Terrace, West Newport, Dundee.

Stanley Mavin, 16, Mantell Street, Moonee Ponds W.4, Melbourne.

David Maxwell, 2, Culloden Road, Arbroath, Angus.

David Alexander Stewart, 19, Argyle Street, Rothesay, Bute.

Cyril Oliver Tabbitt, Spaldwick, Huntingdon.

Leslie George Walley, E.R.A., R.N., H.M.S. "Titania", c/o G.P.O. London.

Students.

John Buckley, Dalehurst, Marble Hall Park, Cork.

Thomas Gibson Patton Burn, Ferndene, Windermere Crescent, Harton, S. Shields.

Robert Henry Clark, 16, Vine Street, Wallsend-on-Tyne.

James Conway, 2068, Dumbarton Road, Glasgow, W.4.

Frederick Alfred Everard, Accuba House, Greenhithe, Kent.

Louis Gill, Ashbrooke Ground, Sunderland.

Ernest Howey, 6, Lansdowne Road, Falmouth.

Sidney John Jarvis, 270, Cranbrook Road, Ilford, Essex.

Thomas Kameen, 6, Raby Gardens, Neston, Cheshire.

Waman Kachinath Katre, c/o Dr. V. L. Agashe, Bhwani Peth, Satara City, India.

Wesley Grundle Mears, 34, Merchants Quay, Newry, Co. Down.

Aleck Cross Newport, 55, Quebec Road, Ilford, Essex.

Donald Thomas Oxton, Blenheim, Blackheath, Colchester, Essex.

Edmund Francis John Plowden, 3, Duncan Avenue, Scotstoun, Glasgow, W.4.

Jack Holbrook Quintrell, 8, Broad Street, Penryn, Cornwall.

Robert William Wallace, 43, Fordham Road, Ford Estate, Sunderland.

Ernest Watson, 28, Firtree Avenue, Walkerville, Newcastle-on-Tyne, 6.

Probationer Students.

Arthur Bailey, 3, Downing Cottages, Falmouth, Cornwall.

Raymond Yandell Bennee, 16, Glenshiel Road, Eltham, S.E.9.

Adrian Richardson Billings, Cupola House, Dover Road, Folkestone.

Leslie George Bowley, 26, Church Road, Dover, Kent.

Ronald Victor Castle, 10, Salisbury Road, Dover, Kent.

David Davidson, "George & Dragon", Kelvedon, Essex.

John Dermott, 36, Snargate Street, Dover, Kent.

William Donald, Prospect House, St. Radigund's Dover.

Harold Roland Hill, 153, Jerningham Road, New Cross, S.E.14.

George Stevenson Horne, Corozal, Auchenlodment Road, Johnstone, Scotland.

Francis Kenneth Hutchings, 57, Church Street, Falmouth, Cornwall.

Ivor John Johns, 4, Trelawny Place, Penryn, Cornwall.

Kenneth Henry Marsh, 8, Rhyddings Park Road, Brynmill, Swansea.

Austin William Frederick White, 10, Berkeley Hill, Falmouth, Cornwall.

Thomas John Willis, 22, Union Place, Truro, Cornwall.

Transfer from Student to Associate.

Wilfrid Hunter, 31, Gladstone Terrace, Usworth Station Road, New Washington, Co. Durham.

Wilfred Thompson, 63, Percy Street, Tynemouth.

ADDITIONS TO THE LIBRARY.

Purchased.

"The Analysis of Commercial Lubricating Oils by Physical Methods". Lubrication Research Technical Paper No. 1 of the Dept. of Scientific and Industrial Research. H.M. Stationery Office, 1s. net.

"Air and Vapour Locks in Fuel Systems", by M. A. A. Allfrey, B.A. (Aeronautical Research Committee Reports and Memoranda No. 1693). H.M. Stationery Office, 1s. 3d. net.

King's Regulations and A.I. Amendments (K.R. 7/36). H.M. Stationery Office, 3d. net.

"Fan Engineering", edited by R. D. Madison under the direction of W. H. Carrier. The Buffalo Forge Co., Buffalo, N.Y., 622 pp., illus., $3.00 net.

Members who are interested in fan engineering will find that The Institute has available the very latest and most reliable information. There have just been added to the Library three recent and important publications on the subject, each well worthy of careful study. These are "Fan Engineering" edited by R. D. Madison under the direction of W. H. Carrier and published by the Buffalo Forge Co., "Fans" by T. Baumeister, Jun'r., and published by The McGraw-Hill Publishing Co., Ltd., and "Air Conditioning and Engineering" by the Engineering Staff of The American Blower Corporation. The second and third publications have been reviewed respectively in the December, 1935 (page 302) and July, 1936 (page 231) TRANSACTIONS. There remains to add here that the textbook on "Fan Engineering" published by The Buffalo Forge Co. is in keeping with the high value of kindred publications by the same authors—the name of Mr. Willis H. Carrier is a sufficient guarantee.

In due course there will be added to the Library the Specification for the Testing of Centrifugal and Propeller Fans for General Purposes to be issued shortly by the British Standards Institution, in the preparation of which The Institute has taken a very active interest.

Presented by H. L. Rees (Associate Member).

"Robert Boyle, Inventor and Philanthropist—A Biographical Sketch", by L. Saunders.

Presented by the Publishers.

Informal Discussion on the Horizontal versus the Vertical Oil Engine. Diesel Engine Users Association.

"Marine Lubrication—Steamships with Reciprocating Engines". The Vacuum Oil Co., Ltd.

"Marine Lubrication—Turbine Propelled Steamships". The Vacuum Oil Co., Ltd.

Transactions of the Liverpool Engineering Society, Vol. LVII, containing the following papers:—

"The New Compressed Air Tunnel at the National Physical Laboratory", by Relf.
"The Effect of High Temperature on the Properties of Steel", by Barr.
"Electric Boilers", by Grant.
"The Development of Large Turbines for Land Power Installations", by Robson.
"The Future of Steam Propulsion", by Johnson.
"Ships' Deck Machinery", by Morton.
"Automobile Transmission Systems", by Pilkington.
"Engineering Geology—The Proper Uses of Natural Sandstone", by Morton.
"The Evolution of the Iron Age and its Effect on Man", by Atkins.
"Statistics in the Service of Engineering", by Walton.

"The Alloys of Iron and Carbon, Vol. 1—Constitution", by S. Epstein. The McGraw-Hill Publishing Co., 476p., illus., 30s. net.

At first glance this book appears to be a theoretical discussion; then one notices that, as such, its style is unusual, being very readable and modest; finally, the reader is astonished to discover that the work contains much matter of value to those whose task it is to deal with the severely practical sides of steel and cast iron. Indeed, it is likely that this book stands alone in this respect. From its sixth chapter onwards, its pages are of enormous interest and use to the works metallurgist—and this represents three-fifths of the whole volume. Chapter VIII, dealing with structure, is both a delight and an education, and moreover is illustrated by over sixty perfect photographs and photomicrographs. There are invaluable "pointers", quite foreign to books of this kind, showing precisely how the data is applicable to the problems of engineering practice. For example, on page 250 the author says: "The Neumann bands arise during sudden deformations as under impact or in an explosion and are readily distinguished from slip lines which form under slow deformation". Could anything be put more clearly or be more useful to the man who did not know the practical application of the discovery of these effects? Here he gets a plain lead together with illustrations as "clear as crystal". Numberless remarks of similar worth occur throughout the book, and the chapters on "Inhomogeneities" and "Factors Affecting Quality" are particularly fertile.

Without any doubt we have here a work of the highest class which every worker associated with the control or use of ferrous metals should consider seriously before deciding he can do without it either as a guide or an education.

"Procedure Handbook of Arc Welding Design and Practice". The Lincoln Electric Co., Cleveland, Ohio, U.S.A., 3rd edn., 596pp. copiously illus., $1.50 net.

This is an American publication designed to present in a form convenient for ready reference the basic information on arc welding in its present state of development, i.e. up to August, 1935. It is divided into nine parts as follows: Part I, which gives a general description of plant, equipment and electrodes. Part II on the technique of welding. In this section, under the heading of "types of joints", prominence is given to closed butt joints which, however, are not considered good practice in this country. Butt joints should be open and in the single-vee type have a run deposited from the reverse side, as is referred to later on in detail. The closed butt joint is the main cause of the defect referred to in the succeeding article on "polarized light". The value of visual inspection of welding in operation is rightly stressed, particularly when the shielded arc is employed, as the cost of subsequent X-ray examination is prohibitive except for very special work. In Part III on "procedures, speeds and costs", the value of the joint illustrated in Fig. 84 is questionable, as there is not sufficient room for the movement of the electrode to give perfect fusion. For automatic arc welding in this country, machines are available with which covered electrodes, giving a better distributed shield to the arc than the autogenized method, are used. Part IV deals with the structure and properties of weld metal and Part V with the weldability of metals.

In the five parts referred to above, occupying 163 pages, the theoretical and practical aspects of the arc welding process are carefully dealt with. The remaining four parts cover some 408 pages and are devoted to the design of arc-welded structures, typical applications being copiously illustrated. The book, which merits a place in all libraries covering the subject of welding, concludes with a short section advertising Lincoln products.

"Mathematics for Technical Students—Part I", by F. G. W. Brown, M.Sc., Macmillan & Co., 215+ xviii pp., illus., 3s. net.

This book covers the first year course in practical mathematics laid down by the Union of Lancashire and Cheshire Institutes for the Preparatory Senior Technical Courses, and is adaptable for the courses of other examining bodies. The author has succeeded in uniting the fundamental principles of elementary applied arithmetic, algebra and deductive geometry. The first five chapters deal with arithmetic, while chapter 6 is devoted to algebra. An elementary study of graphs would have been advantageous at this part. Chapters 7, 8 and 9 deal with geometry and logically use the fundamental principles of arithmetic and algebra treated earlier in the book. Chapter 10 is devoted to the measurement of volume.

The book is clearly printed and contains numerous examples—a large number being founded upon actual technical data. It should be of great use both to teachers and students of the subject.

"Variability of Examination Results", by J. A. Seitz. Oxford University Press (Humphrey Milford), 55pp., illus., 3s. net.

When school examinations are held over so wide an area as Victoria, Australia, and the candidates presenting themselves for examination number many thousands it seems reasonable to expect that the percentage of passes should remain fairly constant from year to year. The publication under review gives statistics showing that during a period of ten years there has been considerable variation in this percentage and the author pleads for modification in dealing with the examination results which shall stabilize the percentage of passes at approximately 60 per cent. It will be difficult for the examining authorities to deny the justice of this plea. The purpose of an examination is to ascertain if a candidate's knowledge has reached some required standard, and the standard for these public school examinations is that to which the secondary school pupil attains at the particular age for which the examination is framed. As there is more likelihood of variation in the standard of the test than in the mean quality of several thousands of secondary school pupils, any serious departure from the agreed percentage of passes suggests that the test is at fault rather than the candidates. The author's recommendation that the percentage of Honours granted in the subjects should also be standardised is perhaps more debatable.

It must be remembered, however, that "stabilisation of percentage of passes" can only be applied to examinations for which the number of candidates is large and the required standard is that of the ability of the candidates. Examinations devised to test fitness for some definite privilege or special qualification cannot be treated thus, although even in these examinations large entries render a certain amount of stabilisation possible.

"Indicator Diagrams, Steam and Oil, for Marine Engineers", by W. C. McGibbon. James Munro & Co., Ltd., 5th edition, 247pp., illus., net.

The continued demand for this book among marine engineers, particularly those who are studying for Board of Trade Certificates, and to whom the author, the late W. C. McGibbon, is very familiar, is reflected in the fact that this book has reached a fifth and enlarged edition.

The present edition is very fully illustrated by some 263 plates, including many examples of indicator cards printed in the very pleasing style of white lines on a black background. The author has the Board of Trade Examinations for First and Second Class Certificates always in mind throughout the book and has written the text in a very simple style, sedulously avoiding all advanced theory. His chapter on the laws relating to pressure and volume with numerical examples is very elementary. He has been assisted in the production of this enlarged edition by Archibald Martin and Hugh Barr, who have included a chapter on Diesel engine cards, scavenge pump and air compressor diagrams, Doxford combined valve timing, valve lift, and power diagrams. Common faults in the running of Diesel engines are illustrated in a series of cards, and a reference is made to expanded diagrams. An interesting chapter follows on indicator gears as fitted to some of the leading Diesel engine designs, including some very clear sketches. Finally the book reverts to the steam reciprocating engine fitted with an exhaust turbine, and indicator cards are shown with and without the turbine in action and a brief note is given upon the effect of superheated steam.

Although primarily written for the student, the book contains much information on valve diagrams, indicator cards, and miscellaneous defects of valves as shown on the diagrams that should prove of great interest and value to seniors who already possess their certificates.

"Elementary Engineering Thermodynamics", by Vincent W. Young and Gilbert A. Young. McGraw-Hill Publishing Co., Ltd., 220pp., illus., 15s. net.

The authors, who are professors of mechanical engineering at the Universities of Oklahoma and Purdue respectively, have collaborated in producing a book which gives the mechanical engineering student an introductory course on the fundamentals of thermodynamics before he receives a more specialized instruction in the application of thermodynamics to internal combustion engines, power plant design, refrigeration, etc.

The reviewer, from his experience in examining students in the subject of heat engines, has found that the majority of students usually make quite a good job of answering a question of a practical nature, but fail badly when confronted with a question involving an application of the properties of gases and vapours. In the technical colleges of this country the time available in an engineering course for the study of the subject of heat engines is generally insufficient, and in consequence teachers are more or less compelled to devote too much time to the more practical side of the subject and neglect the theory. In the U.S.A., according to the authors, it is usual to have either a parallel or an introductory course in thermodynamics; it would be a decided advantage if such a scheme were adopted in this country. Pages xi and xii give a full list of symbols and abbreviations and it is a pleasure to find that the authors have been consistent in the use of these throughout the book. It also gives one additional pleasure to see that the "slug" has been adopted as the engineer's unit of mass.

The first four chapters deal, in the usual orthodox manner, with the laws of gases and non-flow processes. It is noticed that the authors have preferred to label the sum of the internal and external energies as *enthalpy* and not *total-heat* as is customary in textbooks published here.

Chapter 5 deals with the Carnot cycle, introduces the student to the meaning of entropy, and concludes with a useful summary of the non-flow processes for gas systems. This summary might have been improved upon by adding two columns, one showing the P V diagrams and the other the T ϕ diagrams for the five processes.

In chapter 6 the Otto and Diesel cycles are discussed and mention is also made of cycles of historic interest.

The theory of air compressors and the theoretical advantages of small clearance volume and multi-stage compression are dealt with in chapter 7. In using the term *free air* it is very necessary to specify the temperature as well as the pressure; the authors refer to the free air as the air handled at atmospheric pressure without any reference to the temperature.

Chapters 8 and 9 deal with the properties of vapours and the non-flow processes for vapours considered on the temperature-entropy and enthalpy-entropy diagrams. The theory of the flow through nozzles forms the subject matter of chapter 10 and on page 130 values of the critical ratio for steam under various initial conditions of superheat are tabulated. These figures are a little bewildering to those of us who are used to putting $n=1{\cdot}3$ in the adiabatic equation for dry (superheated and supersaturated) steam with a corresponding critical ratio of 0·5456.

Chapter 11 deals with the Carnot and Rankine cycles using a vapour as the working substance. Fig. 11 : 4 on page 142 is incorrect for the pressure line in the wet region on an enthalpy-entropy diagram is inclined and not horizontal. (The slope dh/ds is a measure of absolute temperature). In section 5 of this chapter a more detailed explanation of the method of transferring an indicator diagram to a temperature-entropy diagram would be preferred. In the same chapter the reheat cycle, and the regenerative cycle (feed heaters in cascade) for a steam turbine are discussed, and the chapter concludes with notes on the uses of mercury, diphenol oxide, and sulphur dioxide as working substances for a heat engine.

The chapter on refrigeration deals with the theory of the reversed Carnot cycle, the cold air machine, the vapour compression machine, and the ammonia absorption plant.

A special feature of the book is the concluding chapter, which deals with mixtures of air and vapour and with the construction and use of the psychrometric chart. The inclusion of this chapter is most opportune as students will be able to study thermodynamics applied to the very important process of air-conditioning. Students will find this chapter of greatest assistance to them when read in conjunction with the section on air conditioning given in Mr. J. D. Farmer's paper on "Recent Developments in Marine Refrigeration", Vol. XLVIII, Part 4, May, 1936, TRANSACTIONS.

The appendix includes steam tables, up to the critical pressure, tables of the properties of ammonia, sulphur-dioxide and carbon dioxide, a temperature-entropy diagram, a Mollier diagram, and a psychrometric chart. The Mollier diagram is drawn to too small a scale for practical use and the authors would be well advised to include a larger diagram, in a pocket, in the next edition.

Each chapter contains a number of carefully selected worked examples, and a large number of examples are given at the conclusion of each chapter. It would be more satisfactory to a student if answers were given to these questions.

The authors are to be congratulated upon the logical way in which they have presented the subject matter, and when one has become familiar with their symbols one will find that the book is easy reading. The student preparing for an engineering degree or for the Associate Membership Examination of The Institute will find the book a useful acquisition to his library.

ABSTRACTS.

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

American Tanker Activity.

"The Marine Engineer", September, 1936.

Orders have been placed for eight large single-screw tankers by the Standard Oil Company of New Jersey. This is said to be the largest ship order ever placed by an American private corporation, the value of the contracts exceeding $13,000,000. The main particulars of the vessels, together with the names of the builders, are as follows:—

No. of Ships.	Builder.	Dimension.	D.W. and draught.	Remarks.
Four ...	Federal S.B. & D.D. Co., Kearny, N.J.	435′×66′ 6″×34′ 6″	12,800 on 28′ 1¾″	Isherwood longitudinal framing and Arcform design.
Two ...	Bethlehem S.B. Corporation, Sparrows Point, Md.	442′×64′×34′	13,000 on 28′ 2″	The new Frear-Bethlehem hull, with fluted plating bulkheads.
Two ...	Sun S.B. & D.D. Co., Chester, Pa.	442′×65′×35′	12,900 on 28′ 4″	Isherwood longitudinal framing and Arcform design.

All eight ships will have a capacity of 105,000 barrels of petrol and in each case the service speed will be 12 knots. Following recent American practice in the tanker field, steam turbine propulsion will be adopted for all eight vessels. Tanker owners in the States have demonstrated that the modern steam-turbine propelled bulk oil carrier is a highly efficient and most attractive proposition, such vessels as the "G. Harrison Smith", "R. F. Resor", "T. C. McCobb", and others. These new vessels, following those earlier arrangements, will have double-reduction geared turbines, taking high-pressure, high-temperature steam from water-tube boilers; the boilers will be of the Babcock and Wilcox type in some ships, while others are to have Foster-Wheeler boilers.

The new ships are intended to replace some comparatively old 10-knot tonnage, and will be used in coastal service. As they are to have a higher speed than the tonnage to be replaced the aggregate deadweight capacity of the new ships is to be less than that which is to be withdrawn, while the operating economy likely to result from the change will be substantial.

These contracts are of interest to European readers for several reasons. In the first place, the cost of these vessels is extraordinarily high by British and Continental standards. The aggregate deadweight of the eight ships is 103,000 tons, and the approximate cost over $13,000,000; this gives a cost per deadweight ton of over $126, or £25 5s. Such a figure is fully twice the rate per ton at which similar vessels could be built in British yards, while eighteen months or two years ago motor tankers could also be built in this country for the figure of £12 10s. or so—to-day the price has hardened to about £15 a deadweight ton. Conditions as to wages, overhead expenses, and other factors differ widely as between this country and America, and so any such comparison cannot have more than an academic interest.

Another feature of these American contracts which is interesting to European tanker experts is the popularity of the geared turbine water-tube boiler combination; on this side of the Atlantic the Diesel engine is at present almost universal for tanker propulsion, and experience shows that the confidence reposed in it has not been misplaced.

From the data in our possession the "Gulfbelle", the latest American turbine-driven tanker, is remarkably interesting. In certain recent installations the boilers have been placed above the turbines, but in the "Gulfbelle" these occupy the normal position. An interesting feature is the provision of steam-turbine-driven rotary-type cargo oil pumps. These American vessels are certainly both bold and interesting in conception, and their reliability and high economy in service indicates that their design is fundamentally sound. Let us hope that one of the British tanker owners will try out the modern high-pressure geared turbine plant for tankers. It is far removed from the double-geared installations of the immediate post-war period, with which some far from happy experiences were obtained. We believe that the experiment, if such it need be called, would prove very instructive.

In connection with these American steam-driven tankers, it is interesting to record that no less an authority than Mr. Robert L. Hague, of the Standard Oil Company, of New Jersey, recently stated when he was in this country that their modern high-pressure water-tube boilered geared turbine tanker vessels had been found most satisfactory; they have been operating them over seven years. Mr. Hague's company have built ships to ply between American ports, and these include 40 Diesel-driven vessels. Now, Mr. Hague stated, they are getting more and more interested in these turbine-driven steamships. On voyages between the Gulf of Mexico and New York they have considerably reduced costs by using the latest type of steam machinery.

Shortage of Engineers.

"The Marine Engineer", September, 1936.

Considerable publicity has been given of late to the present shortage of sea-going engineers. Such a shortage was inevitable after a lengthy depression for a high percentage of those sea-going engineers who were rendered unemployed when their ships were laid up have become absorbed in other branches of engineering or, in too many cases, have now been permanently lost to engineering. A grave aspect of this shortage—brought about by the same depressed state of the engineering industry—is that the number of young men now training to become marine engineers is woefully small. These young fellows were only the most enthusiastic of the potential supply of engineering apprentices of a few years ago—others who would have embraced an an engineering career in better times turned their attention to other, and seemingly safer, lines of business for careers.

There seems little prospect of an improvement in regard to the present shortage of sea-going engineers, particularly insofar as the more experienced certificated men are concerned. An official of the Chamber of Shipping recently stated that the shortage may seriously affect the mercantile marine, and this view is undoubtedly correct.

Two possible avenues of tackling this urgent problem offer themselves. One which has been put to us is beyond consideration: a reduction in the standard required to obtain a "pass" for a Board of Trade certificate of competency. No long-sighted sea-going engineer or shipowner could agree to such a course at a time when the calls on sea-going engineers' abilities are becoming more and more exacting and the modern ship is becoming a greater "box of machinery". Such a policy would, in due course, harm all concerned. The second course is to raise wages. They are, without mincing words, unattractively inadequate. The seagoing engineer of to-day is a highly-trained and intelligent man, far removed from the "sea-going fitter" rule-of-thumb man of days gone by. If the calling is to continue to recruit the right type of man he must be offered sufficient remuneration to attract him to the sea and keep him there—too many men are nowadays leaving the sea after obtaining their certificates and obtaining posts in power and pumping stations and elsewhere. Freights are improving and shipping profits are rising slightly, thanks, in no small degree, to the efforts of marine engineers in producing and operating highly economical machinery installations.

A great deal of tongue-in-cheek theorizing could be indulged in to show why there is still a shortage of sea-going engineers and why it is likely to continue. The problem is primarily a mundane one. Its solution can be summed up in two words: pay more.

Funnels for Merchant Ships.

By John Gray.

"The Marine Engineer", September, 1936.

The funnel for a large boiler installation is usually attached to the top of the uptake with a

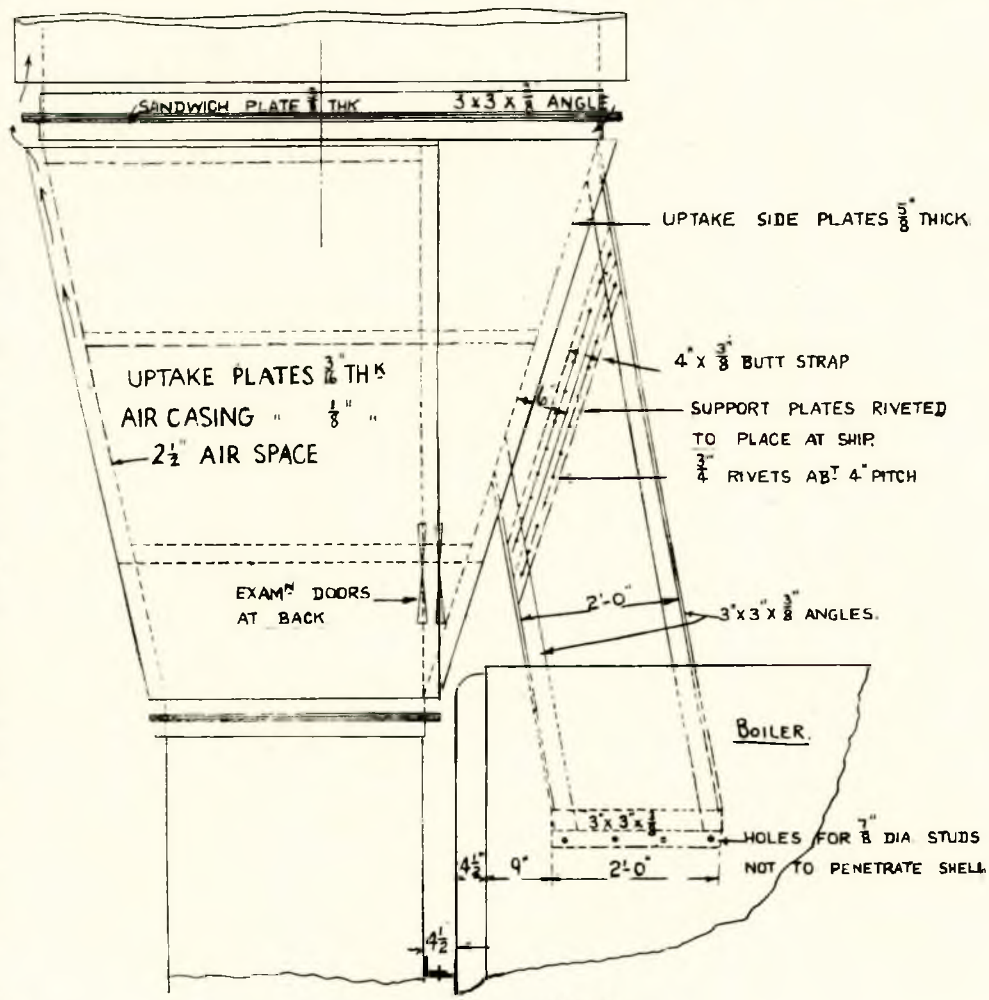


Fig. 1.

sandwich plate intervening, a hole being cut in this sandwich plate the same diameter as the funnel to permit the round section of the funnel to accommodate itself to the square section of the uptake. This method leaves four objectionable blank corners at the front, back, and sides of the uptake, but its alternative, as adopted by Admiralty practice, of working the corners from the square to the round, and dispensing with the sandwich plate is so costly and difficult an operation that except in very high class merchant work the aforesaid simpler method is always adopted.

To overcome these blank corners, however, as between the cheaper and the expensive methods, and with a view to prevent the eddying of the gases at these parts separate shaped plates worked from the square to the round at each corner are sometimes fitted which direct the gases from the blank corners into the main portion of the funnel. The weight of the funnel is supported by one of two methods. The first is by means of plates attached to the sides of the uptake at the base of the funnel and carried down to the boiler tops, forming a good stiff support for this purpose. This arrangement, as shown in Fig. 1, leaves the whole of the funnel free to move with the rise and fall of the boilers. It will be noted that the side plates of the uptake are specially thickened to take these funnel supports, whilst the edges of the support plates are stiffened with suitable angle bars. In large funnels, say from about 10ft. diameter upwards, instead of the angle bar another plate at right angles to the side plates could be fitted, thus forming a right-angled strut on to the boiler top. These support plates are attached to the boiler shell by means of angle bars and studs, and care must be taken that these studs do not penetrate the boiler shell plate.

The second method referred to is used in the case of very large and heavy funnels when the weight is often taken up by the ship structure, as shown in Fig. 2. It will be observed that in this case, channel supports "A" supplied and fitted by the shipbuilders, are arranged at the base of the funnel. Riveted to these channels is a base plate "B", which forms the seat for the main portion of the funnel, and takes its entire weight. The funnel is completed by the small length of round portion "C", which is attached to the top of the uptake by means of the sandwich plate described above, the other end being telescoped into the funnel proper, thus forming an expansion joint which accommodates any expansion of the boilers.

The inner funnel is almost always made round on account of the simplicity of manufacture. It is usually made of $\frac{3}{16}$in. to $\frac{1}{4}$in. thick plating having longitudinal and circumferential lapjointed seams, usually riveted with $\frac{5}{8}$in. diameter rivets, about 6in. pitch. In better class work, it is often sub-divided into various compartments right up to the top, according to the number of boilers. Each boiler discharges its waste gases into the separate compartments provided for it, thereby ensuring that they are working independently from the other. The diameter of the funnel is made large enough to take all the waste gases from the boilers, and its corresponding area is usually fixed about 25 per cent. of the grate area in coal-burning installations. For oil burning this figure may be reduced to 20 per cent. as combustion is generally more complete and there is less chance of sooting taking place.

In smaller classes of vessel the funnel may only be a single tube which is carried through the shipbuilders' casing, a hole about 1ft. larger in diameter than the funnel being provided for it, as in Fig. 3. Around this hole is fitted a gravat "A", and around the gravat, and attached to the funnel, is a cape "B". This gravat and cape serve the purpose of an outlet for the hot air from the stokehold as well as preventing any water from getting below the casing. From below the shipbuilders' casing

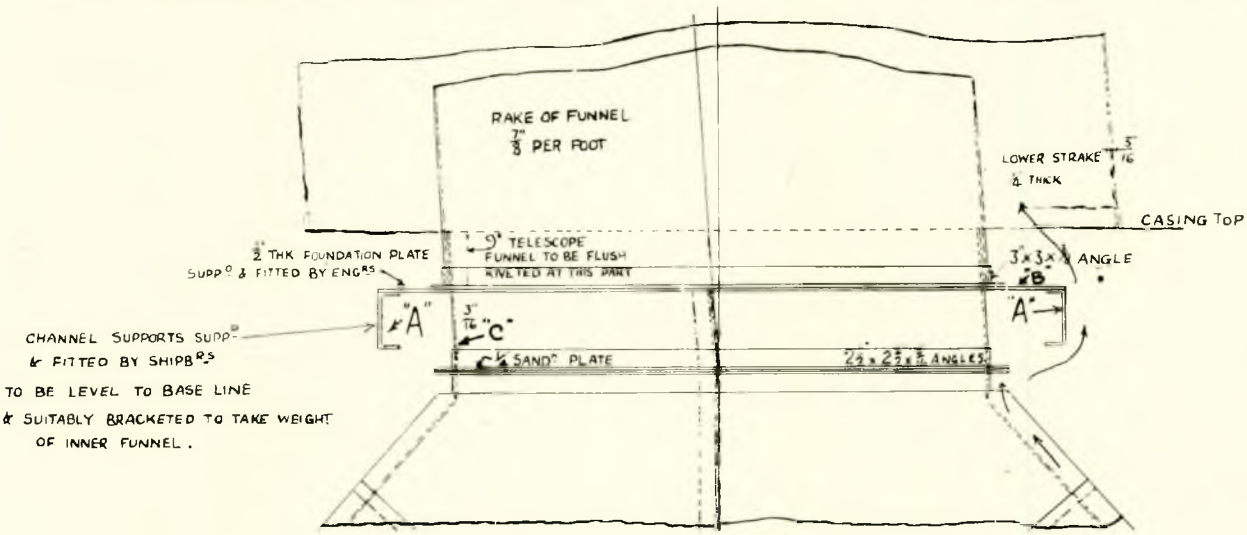


Fig. 2.

to the bottom of the funnel attached to the uptake base, an air space is formed, "C", consisting of a plate $\frac{1}{8}$in. thick, attached to the funnel by means of thimbles and bolts. This air space ranges from 3in. to $4\frac{1}{2}$in. wide, according to the size of the funnel. The air space has its beginning in the uptake, is carried down in the stokehold, and conveys the hot air from the stokehold to the exit at the gravat in the case of a single funnel, or between the inner and outer funnels in the case of a double funnel, as well as preventing the heat from radiating into the stokehold.

In the case of natural draught installations only, where the only means of checking the draught is at the ashpit dampers, a damper is always fitted at some position in the funnel, having a weight attached, to ensure it always being in an open position. By means of this damper, which has operating gear led to a suitable position in the stokehold, the draught can be regulated, and if the boiler is not in use for the time being, the draught can be temporarily checked. Forced draught boilers, however, need have no damper in the funnel, because the draught can be regulated by the speed of the fan, and the air valves in the fan trunk can be arranged in medium positions to suit the required steaming of the boiler at any particular time. In oil fuel installations working under forced draught, flap valves are usually fitted in the air supply trunks, and they must be fitted with gear connected to the fuel cock supplying oil to the burners. These flap valves are arranged in such a manner that there is always air passing to the furnaces previous to the oil supply. This meets the Board of Trade requirements to ensure that there is no possibility of backfiring as would easily happen with oil, with consequent injury to the stokehold personnel, the Board of Trade definitely stating in their rules "no boiler whether main or auxiliary in which oil fuel is used shall have a damper or other possible means of obstruction to the draught in the uptake or funnel".

The foregoing apply to all funnels, whether they are single tubes or not, but in better class merchant ships the inner funnel is usually surrounded by an outer casing. The outer casing of the funnel may be round, and its diameter fixed with regard to its appearance in the ship. Sometimes for this purpose it is made elliptical so that it presents a larger appearance in the ship in a fore and aft direction, and its athwartship direction being narrow it offers less restriction to the wind pressure. In this case the outer funnel is attached to the shipbuilders' casing, and takes the place of the gravat as in the single tube. The hot air from the stokehold instead of having its exit at the gravat has its exit between the inner and outer funnels, and escapes at the top of the funnel. Distance plates (*see* Fig. 4) are arranged between the inner and outer funnels to keep them the requisite distance apart, and as the outer funnel base in this instance is fixed to the ship work, whilst the inner funnel base is attached direct to the uptake, which in turn is attached to the boilers, care must be taken that these distance plates are left free to slide between the funnels to accommodate the rise and fall of the inner funnel due to the expansion of the boilers. These distance brackets or plates are about $\frac{3}{8}$in. to $\frac{1}{2}$in. thick, and are attached by means of double angle bars and rivets to the inner funnel only; they are allowed to slide freely at the outer funnel. Various angle bar stiffeners are arranged on the seams, especially if the outer funnel departs much from the circular shape, in order to stiffen the flatter portion of the sides.

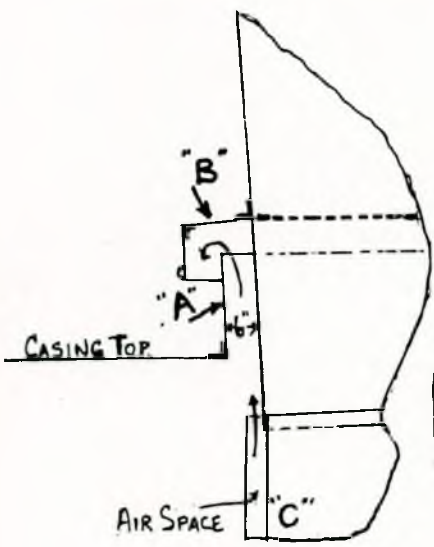


Fig. 3.

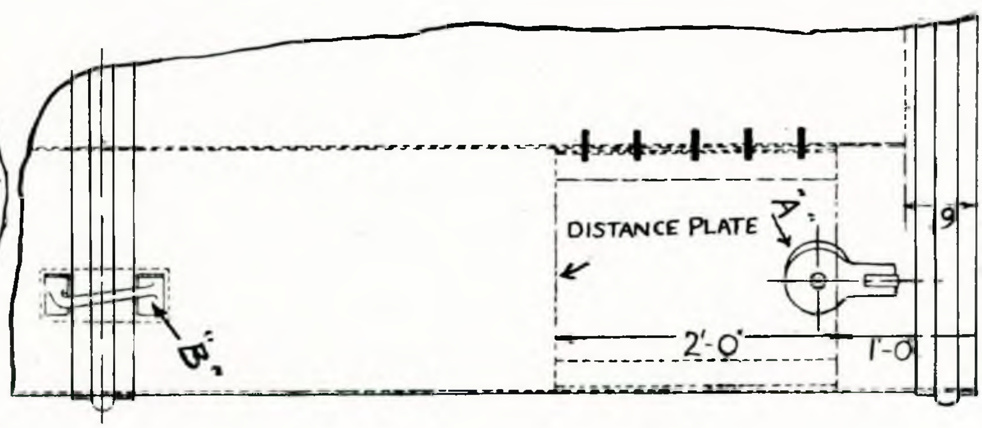


Fig. 4.

Some companies, for the sake of appearance, prefer their outer funnels without any obstruction in the shape of plate laps or the snap head of the rivets, and should this be the case the plates will butt together at the seams, a back strap being fitted behind and the rivet heads made flush with the plate outside. At the top of the funnel a bowling ring $5\frac{1}{4}$in. by $\frac{1}{2}$in. section is fitted around the diameter (*see* Fig. 4). This band gives the necessary stiffening in way of the six or eight gantling blocks "A" fitted around the circumference at this part. These gantling blocks serve the purpose for hauling the painting boards up and down the funnel when painting. About one diameter from the top of the funnel a second bowling ring is fitted and jig handles "B" are straddled across this band, which gives the necessary stiffening for the guy ropes. Usually six or eight steel wire ropes, according to the size of the funnel, 2in. circumference, are fitted, being led to the deck for the purpose of steadying the funnel. The spacing of these bands is sometimes very important, because many shipping companies have their own particular distances apart to suit their private shipping marks, and careful note should be taken of this. If the space between the inner and outer funnel is very great, and if the ship is meant for service abroad in a rainy climate, a hood is fitted at the top of the funnel, which prevents the rain from getting in between the funnels. Nowadays, especially if the boilers are of the water-tube type, rain catchments are fitted in the inner funnel. These catchments are of a trough section and the water is led off by a pipe to the bilge or other convenient place.

In the case of funnels for Diesel work, which usually consist of a large single tube, and serve the purpose, as a rule, of accommodating the main and auxiliary engine silencer and small pipes from the auxiliary boiler, etc. These funnels or casings are closed at the top with a flat plate to prevent rain from getting down, and the pipes passing through this plate have expansion allowed for. A drain 2in. in diameter is led from this flat to the bottom of the funnel to drain any matter which may lodge there, also one or two vents according to the size of the funnel to take off the hot air from the stokehold. The height and rake of a funnel is usually arranged to suit the ships' appearance.

Stern-tube Bearings.

"Shipbuilding and Shipping Record", 3rd September, 1936.

The problem of finding a suitable material for the stern-tube bearings of a ship presents certain difficulties, since while great strength with a low coefficient of friction is demanded, the usual bearing metals cannot be employed owing to the electrolytic corrosion which occurs when, in conjunction with the steel of the shaft, they are acted upon by sea water. At present, lignum vitæ appears to meet the rather exacting requirements sufficiently well, but an alternative is now available in the form of bakelised cloth. This material has proved very satisfactory for the bearings of rolling mills and it possesses the advantage from the marine engineer's point of view that no oil is required for lubrication, the bearing being fed continuously with a stream of water which serves the double purpose of acting as a lubricant and keeping the bearing cool. The material, which has been developed by a well-known British firm, has a compressive strength of 30,000 to 50,000lb. per sq. in. and a Brinell hardness number 25 to 40, so that in this respect it lies between white metal and bronze, but it is stated that at very high bearing pressures the life of the bakelised bearing is many times that of the latter metal. It can be used for loads up to 1,500lb. per sq. in. under normal conditions with water lubrication and for loads up to 4,000lb. per sq. in. if a special grease lubrication is employed. In view of the success which has attended the use of these bearings under the admittedly difficult conditions met with in rolling-mill practice, it would be of interest to determine their suitability in stern tubes.

Pipe Clips.

"Shipbuilding and Shipping Record", 3rd September, 1936.

One of the most important jobs to be carried out in the engine room after the machinery has been installed is to see that all pipes are adequately "clipped" or supported in such a manner that they will not move under the influence of vibration or the rolling and pitching of the ship. With the use of high superheat temperatures the problem of supporting the pipes assumes a new difficulty since the supports should permit of a certain measure of expansion and contraction without inducing dangerous stresses in the material. To meet the difficulty, particularly in so far as it applies to the main and auxiliary steam pipe lines between boiler room and engine room, spring-loaded pipe supports are often used and an improved type is now available which, it is claimed, gives a constant supporting force over the entire range of movement. The weight of the pipe is carried by a powerful spring secured to one end of a bell-crank lever, the pipe being carried by a vertical rod from the other end, the bell-crank lever being so proportioned that the increase in the tension of the spring as it extends is compensated by a corresponding increase of leverage of the load. The end of the lever carrying the spring is slotted so that adjustment corresponding to about 20 per cent. of the load can be made by altering the effective length of the arm. These supports are available in different sizes for loads ranging from 500lb. up to 7,500lb., with a vertical movement of the pipe up to 2in.

The Atlantic Record.

"Shipbuilding and Shipping Record", 3rd September, 1936.

For over one hundred years the performances of the vessels which established and carried on the trans-Atlantic passenger service have afforded unflagging interest to the general public on both sides of the Atlantic.

Notwithstanding the statements of the Cunard

White Star directors that the construction of the "Queen Mary" was governed by the intention to maintain a regular and express service in conjunction with a sister ship irrespective of any attempts on existing records, the general public looked for the early accomplishment of a "fastest passage".

When the "Queen Mary" was first contemplated the largest and fastest ships on the Atlantic service were the "Europa" and "Bremen", vessels of 50,000 tons gross with a speed eclipsing that of the famous Cunarder "Mauretania", then a ship having 25 years' service. In 1929 the "Bremen" accomplished the crossing of 3,164 knots in 4 days 17 hours 42 minutes, giving an average speed of 27·83 knots. This was afterwards exceeded by the "Europa" in 1930, an average speed of 27·91 knots being then obtained.

The maintenance of a regular weekly service by the two contemplated Cunarders called for an average sea speed considerably in excess of that required to break the records held by the two German ships. Incidentally, the records had to be exceeded in order to maintain the scheduled times; inherently, therefore, the original designs of the "Queen Mary" incorporated the factors of form and power which would enable the schedule to be fulfilled.

After the construction of "No. 534" was begun the French challenge was considered. The "Normandie's" dimensions were evidently based on those required for the new British ship and the speed decided on was much the same as that required by the Cunard stipulations. Owing to vexatious delays in the construction of "No. 534" due to the world financial crisis, the French liner was completed last year and immediately established records which have stood till now.

The "Queen Mary's" task of beating existing records was accordingly much more difficult. The unexpected entrance of the "Normandie" on the scene, while not upsetting the fundamental ideas of the Cunard Company regarding the desirable schedule to maintain, did make the winning of the Blue Riband a doubtful achievement.

On her maiden voyage the "Queen Mary" almost achieved a record crossing but was baulked by fog. The long-established rule of the Cunard Company, viz., "safety first", caused her speed to be reduced when within sight of the record. The general public has been impatiently waiting and hoping that this would be soon accomplished and lost sight of the fact that due time ought to be given for the running in of her engines and that the builders may have been under guarantee for the behaviour of her machinery installation. According to the Press, certain restrictions which were imposed in this connection were waived during the recent crossings, with the result that new records on the eastward and westward journeys have been established.

The interesting point now arises regarding the ability of the "Normandie" to beat the "Queen Mary's" new figures. Some people, even in this country, believe that the French liner has not yet shown her full capabilities. Apparently her distinctive appearance appeals to them without regard to the limitations of the power available or the restrictions imposed by the modifications made in order to minimise vibration.

On the other hand, the "Queen Mary's" record does not necessarily indicate her ultimate achievement. It is well known that the "Mauretania's" performances improved with the passing years.

Should the owners of the "Normandie" decide to challenge her rival an interesting series of runs are sure to be made. It is doubtful whether any useful purpose is to be served by constant rivalry. The best service which can be given by both of these great ships is the safe transport of their passengers within the most desirable times of departure and arrival at their destinations.

The Deterioration of Turbine Blading.

"Shipbuilding and Shipping Record", 26th August, 1936.

One of the most serious problems which faces the owner of turbine-driven steamships is the deterioration of the blading, and a considerable amount of attention has been given in recent years to the question of determining the causes of this deterioration and, if possible, finding ways and means whereby it may be prevented. It is now generally recognised that the wear which occurs is due to two distinct causes, viz., erosion and corrosion, the former, generally speaking, being the more prominent at the high-pressure stages of the turbine, and the latter at the low-pressure stages. Briefly, when steam is generated in the boilers, particularly at the high rates of generation employed in modern steamship practice, the particles of solid matter contained in the feed water are carried over with the steam, or perhaps in the moisture contained in the steam, to the superheater elements, and while they may be deposited here, many of them will pass through to the main turbine stop valve, ultimately impinging with high velocity on the edges of the blades. These particles, as an examination of boiler scale will show, are of almost diamond hardness, and so small when separated from the particles of water in which they left the boiler as to be of needle sharpness, so that it is of little wonder that even when the high-pressure blading is made of the highest-grade material, it suffers more or less rapid erosion under the influence of the steady bombardment by these particles. It will be at once apparent that the elimination, or at least the minimisation, of this portion of the deterioration of turbine blades can be effected by the use of the purest feed water, combined with the efficient straining of the steam, not only before it leaves the boiler drum, but at as many points as possible along its path from the boiler through the superheater to the turbine blades. In addition, the material chosen for the high-pressure blading must possess great surface hardness, so as to minimise the effect of such erosive influences as succeed in acting upon it.

The deterioration of the low-pressure blading comes under a different category. It can be easily shown that as a consequence of the expansion of the steam in the turbine, moisture is formed, the amount of moisture at any given stage depending upon the initial pressure and superheat of the steam. The modern tendency to employ a high initial superheat temperature serves to retard the appearance of moisture as the expansion proceeds, but no initial superheat within the realm of practical use can be given which will render the steam dry right down to condenser pressure. This, of course, is one of the reasons why reheating of the steam at one or more stages of its expansion is being tentatively adopted on certain installations. Unfortunately, with an increase in the initial pressure, assuming a constant superheat temperature, the point at which moisture appears is earlier in the expansion, or, in other words, the percentage of moisture at the end of expansion is greater. Thus, apart from the adoption of inter-stage reheating of the steam, the elimination of this moisture is impossible. The moisture appears in the steam in the form of fine particles of water which, owing to their greater density in comparison with the surrounding steam, move at a gradually decreasing velocity. Hence, instead of gliding over the working surface of the blades as does the steam, the particles of water bombard the leading edges towards the back of the blades. Moreover, the moisture, if it does not cling to the surfaces of the blades, is thrown outwards by centrifugal force, causing it to pile up under the shrouding. The continual wetting of the surface of the blades leads to corrosion, as is evidenced by the fact that in the low-pressure stages it is always towards the outer blade tip that the greatest amount of deterioration occurs. Further, once the surface of the blade begins to deteriorate as a result of corrosion, its molecular structure becomes weakened and it falls a far easier prey to the erosive influence of the bombardment by the water particles. Thus, at the low-pressure blading the deterioration may be said to be due to a combination of corrosion and erosion. It is apparent that if the moisture in the low-pressure steam is not eliminated by re-heating, then there only remains the minimisation of its effects by the use of specially-designed blading, in conjunction with the efficient drawing of the turbine casing, so that the water thrown off by the blades is removed at every stage. Certain makers have already produced designs of low-pressure casings in which this is done.

High-speed Diesel Engines for Sea-going and Inland Waterways Vessels.

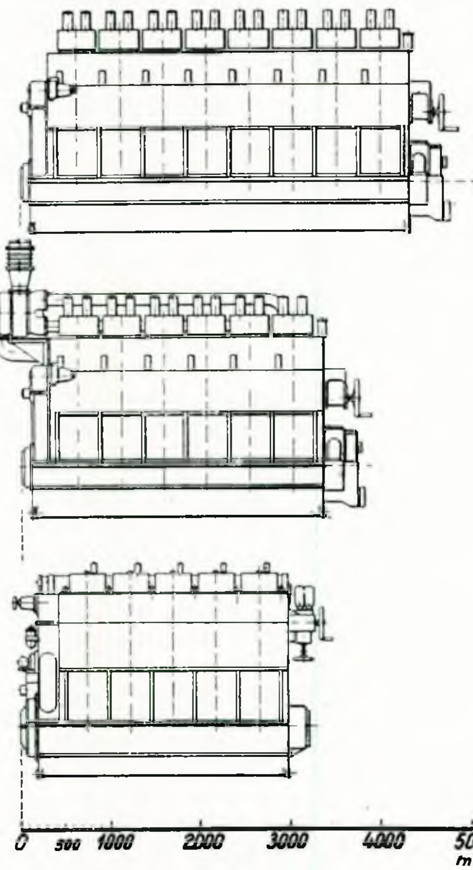
"The Marine Engineer", September, 1936.

This lecture treats of how far the high-speed Diesel engine has been developed for various types of water transport (with the exception of naval work) and of what particular designs the M.A.N. Co. have found most suited for their individual requirements.

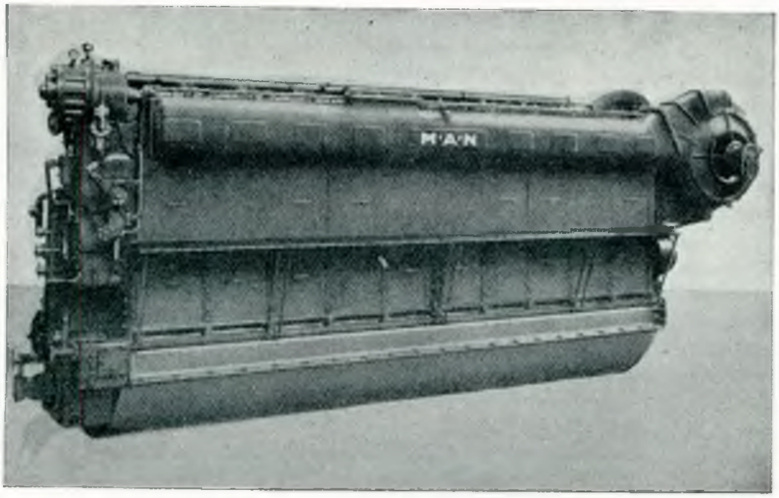
For ocean-going vessels two engine types have come to the fore during the last few years, the first a double-acting two-stroke, with speeds up to 230 r.p.m.—mean piston speed 1,140ft. per min.—with a cylinder output of about 650 b.h.p., and a weight of about 95lb. per b.h.p., and the second a trunk-piston two-stroke for speeds up to 250 r.p.m. —mean piston speed 1,180ft. per min.—with a cylinder output of 375 b.h.p., and a weight of about 88lb. per b.h.p. In both types the accessories such as coolers, air receivers, silencers and pumps add a further 9lb. per b.h.p. to the weight.

The first type has been fitted to new ships of the Bremer Hausa Linie, two engines driving the propeller shaft through Vulcan gearing. A Norwegian-America Line passenger vessel now building by Deschimag in Bremen is to be fitted with four such engines totalling 18,000 b.h.p.

The trunk-piston two-stroke type is usually coupled to Vulcan gearing, but sometimes directly to a reduction gear; rarely is it used for direct propeller drive, as in this case the advantage of the



Top: Trunk-piston four-stroke engine; weight 80lbs. per b.p.h., including pumps.
Middle: Trunk-piston four-stroke engine with super-charging; weight 65lbs. per b.h.p., including pumps.
Bottom: Trunk-piston two-stroke engine; weight 60lbs. per b.h.p., including pumps.



Ten-cylinder four-stroke marine Diesel engine of 1,600 b.h.p. at 700 r.p.m., with turbo-charging on the Büchi system.

high speed is lost. The largest electric transmission installations at present building are for cargo and passenger vessels of the Hamburg-America Line and have a maximum output of 24,000 b.h.p. in six units.

For medium-powered coastal motorships the four-stroke trunk-piston engine is most common. When the limit of piston speed increases is reached, further output can be obtained by supercharging either by a direct or an exhaust-gas-driven blower; the latter has an advantage in that the engine fitted with it has a rather better fuel consumption than one fitted with the direct blower drive.

An interesting comparison is available between some new vessels for the Neptun-Reederei of Bremen. For two of these ships trunk-piston two-stroke engines are being used, each with five cylinders and totalling 1,020 b.h.p. on twin screws; the weight of the two engines with attached pumps is 27·2 tons, i.e., only 60lb. per b.h.p. The accessories (air receivers, silencers, flywheels, and spares), add 4·3 tons, making the total installation weight about 31·4 tons. The engine speed of 350 r.p.m. is reduced to 150 r.p.m. on the propeller shaft; each gear unit with flexible coupling, weighs 2·9 tons. Two other ships are fitted each with four-stroke engines, with Büchi supercharging, giving 1,020 b.h.p. at 364 r.p.m. The weight of the engines with attached pumps amounts to 29·5 tons which, with 4·8 tons for the accessories, totals 34·3 tons, i.e., about 10 per cent. heavier than the two-stroke installation. If the four-stroke installation is planned for the same output without supercharging and with practically the same speed, the total weight would be 35·5 plus 5·2 tons, i.e., 40·7 tons, which is 30 per cent. heavier than the two-stroke ship. The sketch shows the comparative size of the engines for the three installations just considered.

For naval and certain other special requirements such as coastguards, customs cruisers, aero-plane salvage boats, etc., a very interesting engine has been developed, as shown in the second sketch. This has a cylinder size of 11·8in. by 15in., and a speed, according to requirements, up to 700 r.p.m. Special attention is paid to lightness of construction (without departing from cast iron), and exhaust supercharging is fitted. Available with from six to twelve cylinders, these engines give 1,000 to 2,000 b.h.p. each. The weight of the bare engine amounts to 17·6lb. per b.h.p., including accessories; the mean piston speed is 1,770ft. per min.

In most cases these engines have been directly coupled to the propeller; the largest in service up to the present is a triple-screw installation of 4,800 b.h.p. total power, but a ship is now building which will have four of these engines totalling 8,000 b.h.p.

The lecture dealt later with machinery installations in river and lake boats of a type not common in England. They usually are of medium power with engine speeds of up to 400 r.p.m. The two-stroke trunk-piston engine offers considerable advantages over the four-stroke type for most installations of this type.

For engines running at 800 to 1,200 r.p.m., the tendency is more and more towards the extended use of reduction gears, usually in conjunction with reverse gears. A typical M.A.N. unit of this kind is of 240 b.h.p. at 900 r.p.m. The piston speed is 1,300ft. per minute and the weight of the engine with accessories amounts to about 31lb. per b.h.p., and 40lb. per b.h.p., including the reverse and reduction gears.—*H. Becker (Director M.A.N. Co.), Lecture before 15th general meeting of Hamburg Tank Society.*

Deposits in Steam Turbines.

"Engineering", 21st August, 1936.

While the accumulation of deposits on turbine blades has been familiar since the turbine found its place as a prime mover, it has been looked upon generally as a source of annoyance or inconvenience, and only in exceptional cases has the accumulation become sufficiently heavy to cause real concern for the actual safety of the machine. That efficiency and load-carrying capacity was progressively and adversely affected by deposits as they accumulated on the blading was realised, but in the main, and with machines designed for what are now considered relatively low steam pressures, these effects were tolerable over periods of reasonable length, say between annual overhauls. With the advent of steam pressures of 1,000lb. per sq. in. and over, however, the formation of deposits on the blades in the high-pressure cylinder has become a matter of primary importance, and has had the effect of focussing general attention on the causes and prevention of blade fouling.

The rapidity with which deposits are formed and the probability of carrying them over to the turbine undoubtedly increases with steam pressure, though cases of appreciable loss in output have been reported in this country at pressures as low as 350lb. per sq. in. In the high-pressure stages of turbines operating at pressures of, and in excess of 1,000lb. per sq. in., the dimensions of the steam passages are such that the presence of even small amounts of deposit is sufficient seriously to impair the capacity of the machine, and, moreover, of even greater potential consequence, the deposit may result in the imposition of unbalanced loads considerably beyond those anticipated by the designers.

Of the solid matters normally present in boiler waters, caustic soda will remain sticky and plastic at superheat temperatures and Straub places the entire responsibility for the formation of turbine blade deposits on the presence of this substance in the steam. The field data examined by him, the course followed in his experimental work and the results accruing from it appear to justify his conclusion. For example, the analyses of deposits from stations experiencing trouble showed caustic soda contents of from approximately 8 per cent. to 70 per cent. In his experimental work, he certainly was able to produce deposits with steam contaminated with sodium silicate and also with sodium phosphate, but again attributes their formation to the fact that both these salts may give rise to caustic soda.

Prof. Straub's conclusions are interesting and appear reasonable, but it is possible that they do not complete the story. That caustic soda will remain sticky and retain adhesive properties at the steam temperatures concerned will be admitted and that its presence will provide a binder for other solid matter also present is readily appreciated. There is undoubted evidence, however, at least in this country, that deposits may be formed even in the absence of caustic soda or at least where it is present in so small an amount that it is hardly conceivable that it could serve effectively as a binder or cement. Experience shows that, here, these deposits do not normally contain caustic soda (or sodium carbonate to which caustic soda is quickly converted on exposure to the atmosphere) in quantities at all comparable with those recorded in the analysis of American deposits*. Exceptional cases have, of course, been known where, in mixed-pressure sets, the presence of oil in the steam exhausted from reciprocating plant has served as a binder and enabled deposits to build up on the blades of the turbine.

In the matter of prevention, Prof. Straub puts forward several suggestions, most of which aim at converting the caustic soda in the steam to some other sodium compound which is non-sticky, or so reducing the relative proportions of caustic soda to that of the dry salts also present that it is insufficient in quantity to serve as a binder. One suggestion is to introduce carbon-dioxide gas into the steam so as to convert the caustic soda to sodium carbonate. In the laboratory experiments this was found to be effective. It was also found possible to nullify the effect of caustic soda by introducing into the steam various organic materials such as chestnut extract, pyrogallol, sodium benzoate and sodium gallate, the mechanism in these cases being the hydrolysis or saponification of the organic matter by the caustic soda and the consequent exhaustion of the latter.

A third procedure suggested as a result of laboratory work was the introduction into the boiler water of sodium sulphate in definite proportion to the caustic soda. When sodium sulphate was present in amount equal to not less than 4·4 times that of the caustic soda, it was found experimentally that the formation of deposits was almost inhibited, the suggested explanation being that the small particles of sticky caustic soda were so coated with dry sodium sulphate that adhesiveness was destroyed.

With regard to these proposals, the introduction of carbon dioxide into the steam or of organic matter into the boiler would hardly seem likely to appeal favourably to those responsible for the operation of boiler plant. The use of sodium sulphate, if reliably efficacious, would perhaps be regarded as feasible in view of the fact that in many cases it is already introduced into the boiler to inhibit embrittlement.

As we have already suggested, however, it appears to be possible for deposits to form even in the absence of caustic soda, or at least when it is present in amounts relative to those of the non-sticky salts, much smaller than those indicated by Straub's work and it would seem that other measures for dealing with the problem should be carefully considered.

In the early days of the turbine, deposits were removed by opening up the machine and laboriously hand scraping the rotor, blade by blade—a most formidable task. More recently, some measure of success has been achieved by washing the turbine with wet steam. Where the composition of the deposit is such that a reasonable proportion of it is water-soluble, this method certainly suffices to remove the deposit and the removal can be effected without having to remove the covers from the machine. The N.E.L.A. reports, above referred to, contain several instances in which this procedure has been adopted. Washing is, however, by no

* A typical analysis of caustic soda-free scale taken from a machine in this country is as follows in percentages:—Silica, 6·66; iron oxide, 16·0; calculated as Fe_2O_3; aluminium oxide, 4; sodium chloride, 41·5; sodium sulphate, 9·3; calcium phosphate, 23·6; magnesium phosphate, 3·38; sodium carbonate, trace (as phenolpthalein alkalinity); caustic soda, trace. In another case analysis gave the following:—Calcium carbonate, 63·36; magnesium carbonate, 17·95; magnesium hydroxide, 1·80; sodium chloride, 2·39; iron oxide, 6·40 (calculated as Fe_2O_3); and silica, 7·92.

means without its disadvantages. In the first place, it is not always efficacious; in the second, it necessitates the machine being taken off load or at least being put on a much reduced load; and thirdly, it is not good practice in view of the temperature changes it involves.

Experience in this country has shown that it is possible to avoid deposits or to reduce them to a tolerable degree by lowering the concentration of solids in the boiler water, and where pressures below 1,000lb. per sq. in. are concerned, this measure offers fair hope of substantial alleviation. American experience appears to be in line with this. This will not suffice, however, in high-pressure plant where no deposit however slight is tolerable with equanimity, and in such plant the only really satisfactory and reliable procedure is to ensure the maximum degree of purity of the steam.

The Dartford-Purfleet Tunnel.

"The Engineer", 21st August, 1936.

On Thursday, 13th August, it was officially announced that Mr. Hore-Belisha, Minister of Transport, had, in conjunction with the Joint Committee representing the County Councils of Essex and Kent, made arrangements for work to begin in the course of the next few weeks on the construction of the Dartford-Purfleet tunnel. As a first step, it is proposed to construct a pilot tunnel, and also the shield chambers and certain other ancillary works in connection with the main tunnel. For this purpose the Minister recently invited tenders, and he has now accepted the tender submitted by Charles Brand & Sons, Ltd., which was the lowest of ten tenders received. The pilot tunnel will be constructed to an internal diameter of 12ft., and will be approximately 900 yards in length. Two ventilation shafts, with an internal diameter of 18ft., will be driven on the Kent and Essex banks of the river, and at the foot of each shaft a shield chamber, 35ft. in internal diameter, will be provided, as starting-off points for the main tunnel when it is constructed at a later date. The shafts will be approximately 100ft. in depth and the depth of the pilot tunnel below the existing bed of the river will be about 20ft. to 25ft. Temporary access roads on either side of the river, including two temporary bridges over railways, will be constructed. The pilot tunnel and the ancillary work will cost approximately £300,000, while the cost of the whole scheme is estimated at about £3,200,000. It has been agreed on behalf of the County Councils of Essex and Kent that the Ministry of Transport should be directly responsible for carrying out the work.

The Re-conditioned Liner "Ceramic".

"The Engineer", 21st August, 1936.

On Saturday evening last, 15th August, a large party of guests of the Shaw Savill Line joined the re-conditioned liner "Ceramic" at Gourock, and after a short cruise in the Western Isles came round to Liverpool, which was reached on Monday afternoon. A good opportunity was given to inspect the alterations which have been made to the ship during her short stay of about three months at the Govan yard of her builders, Harland & Wolff, Ltd. The "Ceramic" was built at Belfast in 1912 for White Star Line service, and has always been a popular ship. She is now one of the largest liners in her owners' Australian trade. The cabins and public rooms throughout have been completely rearranged and renewed, and the cabins will now accommodate 336 passengers. Considerable alterations have been made to her combined triple-screw reciprocating and turbine machinery, with a view to increasing the power and speed of the ship. The condensing plant has been completely modernised in accordance with the latest present-day practice, which involved the converting of the existing condensers to the two-flow regenerative type, also rearranging the main air pumps to improve accessibility and give increased efficiency. The boiler feed heating system has also been dealt with to ensure higher efficiency and economy, while the latest design of bronze streamlined propellers have been fitted in order to give a better performance. We are given to understand that during the measured mile trials a speed of nearly 16 knots was attained. Whilst the ship was in the hands of the contractors, the opportunity was taken of putting her through Lloyd's survey, and the highest class certificate was obtained.

Power from Rubbish.

"The Engineer", 21st August, 1936.

An incinerator at Providence, in the United States, has been designed to combine power generation with refuse disposal. According to the "Engineering News-Record", the hot gases from the burning refuse are conducted to either one of two waste heat boilers. These boilers, working at 200lb. pressure, are connected with two 1,250-kW. turbo-generators. The units have been installed in duplicate to ensure continuous operation, and provision has been made to fire the boilers by means of oil burners when the incinerator furnaces are being re-lined.

A New Lagging Material.

"The Engineer", 21st August, 1936.

Particulars of a new type of heat-insulating material described at a recent meeting of the Verein deutscher Chemiker are given in the "Chemical Trade Journal and Chemical Engineer". The material is made by the addition of a foaming agent to solutions of synthetic resins, and is distinguished by its low weight per unit volume and exceptional heat resistance. It can be made in grades weighing from 10 kilos. to 100 kilos. per cubic metre. The material does not absorb water, even when immersed for months at a time, and even in an atmosphere saturated with steam, water absorption for long periods is exceptionally slight. The flocky form of the material has no tendency to disappear even after prolonged shaking, and imparts good, sound-deadening properties. It is not inflammable, but carbonises at very high temperatures, removal of the flame being followed by no after-glow. It can be easily worked by cutting, sawing, etc., and can be painted with water glass with or without the addition of mineral colours, steatite, or the like. Owing to its properties, the material is claimed to be suitable for the refrigerating industry, for warm water pipe lines, roof insulation, airships and aeroplanes, linoleum, etc.

An International Meeting of Naval Architects.

"The Engineer", 28th August, 1936.

The first international meeting of Naval Architects and Marine Engineers to be held in the United States will take place in New York from 14th to 19th September, when the following papers are to be read :—"Safety at Sea", by Dr. James Montgomerie; "Fire in Passenger Spaces", by Mr. E. Leslie Champness; "Safety of Life at Sea", by Monsieur Abel De Berlhe; "Observations on Actual Application of Safety and Loadline Conventions", by Mr. Shozo Ikushima; "Safety of Life at Sea", by Rear-Admiral J. G. Tawresey; "The 'Normandie'," by Monsieur Paul Romano and Monsieur Fernand Coqueret; "Modern Atlantic Liners", by Mr. Ernest H. Rigg; "The Rolling of the s.s. 'Conte Di Savoia' in Tank Experiments and Sea Courses", by Dr. Ing. R. de Santis and Dr. Ing. M. Russo; "A Study of Ship Performance in Smooth and Rough Water", by Dr. Gunther Kempf; and "Power, Speed, Economy, and Seaworthiness of Medium-sized Fast Liners under the Influence of the Most Recent Developments", by Dr. E. Foerster. The British delegation, under the leadership of the Rt. Hon. Lord Stonehaven, President of the Institution of Naval Architects, and Dr. J. T. Batey, President of the North-East Coast Institution of Engineers and Shipbuilders, will number about 100, including ladies, and will sail from Southampton on Saturday, 5th September. It will be representative of the Institution of Naval Architects, the Institute of Marine Engineers, the Institution of Engineers and Shipbuilders in Scotland, and the North-East Coast Institution of Engineers and Shipbuilders. All the arrangements for the British delegation are in the hands of Mr. G. V. Boys, M.A., the secretary of the Institution of Naval Architects. The Society of Naval Architects and Marine Engineers of New York has arranged an attractive series of visits and social meetings, and the meeting, which will be attended by delegations from Canada, France, Germany, Great Britain, Italy, Japan, Spain and Sweden, promises to be most successful in every way.

[*Editorial Note.—The Secretary of The Institute is attending this Meeting, and his report thereon will be published in an early issue of the Transactions*].

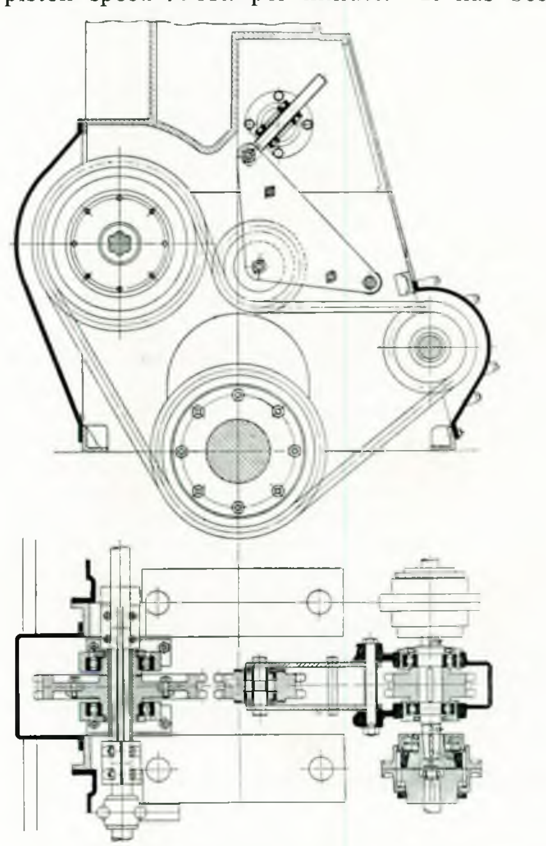
Six-cylinder Sirron Unit.

"The Motor Ship", September, 1936.

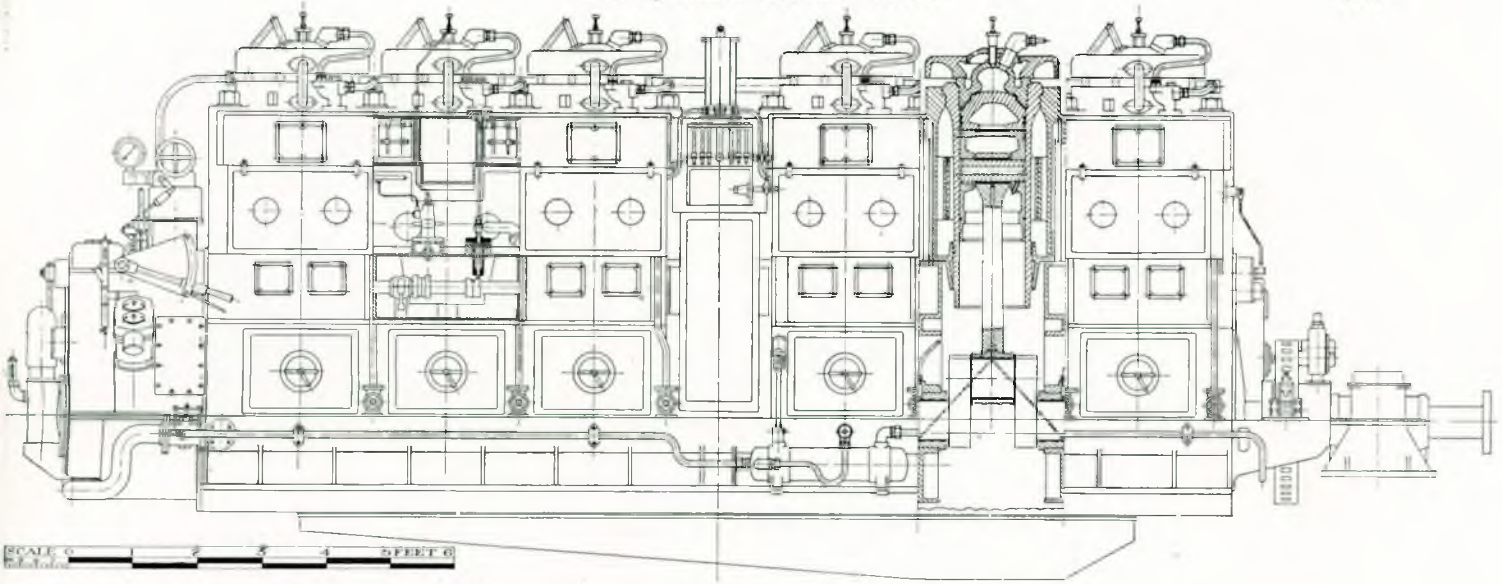
This is the first occasion that drawings have been reproduced of a six-cylinder Sirron engine, and as these enable a clear idea to be formed as to the general construction, apart from certain of the important working parts, we need not give an extended account of all the details.

Formerly, the Sirron engine incorporated rotary valves for controlling the exhaust port opening. It has been found possible to eliminate these valves, owing to general improvements which have been made to the scavenging system, and, at the same time, to keep a relatively high mean effective pressure. The combustion chamber design has been modified and the cylinder covers are altered. They are of cast iron in place of steel, and the same applies to the piston crowns. With the new engine there is a centrally arranged chain drive to the camshaft and to the layshaft for operating a set of six rotary scavenging air blowers, which again are of a new type.

The engine develops its maximum rated output at 300 r.p.m.; it has a cylinder diameter of 320mm., or about 12⅝in., the piston stroke being 400mm., which is equivalent to 15¾in., so that the brake mean effective pressure at full load is 72lb. per sq. in., and the piston speed 790ft. per minute. It has been



Arrangement of chain drive to the camshaft and layshaft for operating the scavenging air blowers.

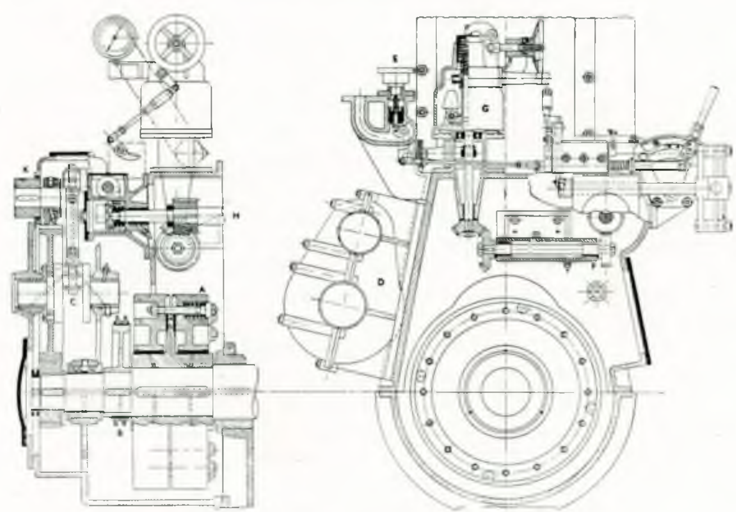


Longitudinal elevation of the six-cylinder 650 b.h.p. Sirron engine.

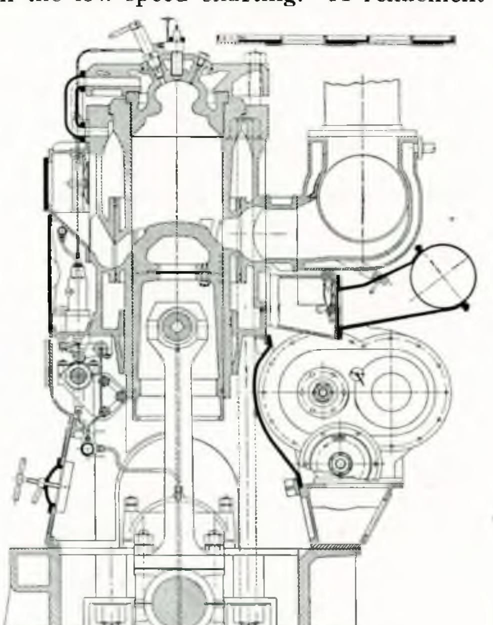
ascertained that the lubricating oil consumption over a long period works out at the low figure of 0·0015lb. per b.h.p. per hour, whilst the fuel expenditure is 0·38lb. per b.h.p. per hour. The engine works on a compression pressure of 450lb. per sq. in., and the maximum combustion pressure is between 700lb. and 750lb. per sq. in. Bryce fuel injection pumps are employed.

Alongside each fuel pump is the push-rod for the air starting valve, the rollers being lifted clear of the cams except when compressed air is admitted to the starting system. The air containers are charged up to 400lb. per sq. in. and at the forward end of the engine there is a small two-stage compressor. There are two 20-ton bilge pumps and a water cooling pump, all arranged vertically and driven by rocking levers actuated by a crank, gear-driven at half the speed of the main shaft.

The layshaft which drives the blowers runs at 600 r.p.m.; the driving chain passes over a jockey pulley and round the camshaft sprocket wheel. At the end of the layshaft is the forced lubricating oil pump, which is of the gearwheel type and is dismountable without breaking any pipe joints. There is a gearbox at each end of the engine for the purpose of increasing the blower speed to 1,200 r.p.m. The air pressure represents about 4in. of mercury at the normal full load. It should be noted that the blowers are in two self-contained sets of three apiece, each with its own gearbox, whilst there is a slipping device on each drive, together with Bibby detuners on the low-speed shafting. A refinement



Governor gear and controls. A.—Damper. B.—Eccentric for driving air compressor. C.—Crank for driving pumps. D.—Blower drive gearbox. E.—Master air control valve. F.—Governor drive shaft. G.—Governor. H.—Forward end of camshaft. K.—Pump lever.



Sectional elevation through one cylinder.

in the new engines is the provision of forced lubrication to the blowers, and this applies to all the important bearings in the engine, including the gudgeon pins; the connecting rods are bored for the passage of the oil, and retaining valves are fitted at the foot of each rod. The scavenging air suction to all the blowers is taken from a common trunk and in the ship Burgess silencers will be fitted. All the trunking is lagged to reduce noise.

Control Mechanism.

The controls, however, remain substantially as before, and comprise two hand levers in addition to the governor regulating wheel. Each cylinder has ahead and astern cams for fuel and starting air, and one of the levers moves the shaft in a fore-and-aft direction. This lever is interlocked with the main starting and control lever, which places the whole engine on air, then on air and fuel, and, finally, on fuel alone to all six cylinders. The control arrangements are such that the engine is stopped when the lever is at the extreme limit of travel in either direction, i.e., pushed fully in or pulled out.

The governor is of the centrifugal type, arranged to cut off the fuel supply at a certain speed, but the amount of fuel "on" at any time cannot exceed that determined by the position of the main control lever. A long horizontal rod passes through each rack forming part of the Bryce injection pump, and this rod is spring-connected to the racks so that if one pump seizes the rod is still enabled to move by compressing the spring of the defective pump and opening the remainder in the normal manner. The machinery will be required to run at a minimum speed of 50 r.p.m.

This particular engine is for installation in the motor coaster "Suavity", built by Messrs. G. Brown & Co., Greenock, for Messrs. F. T. Everard & Sons, Ltd. She is 175ft. in length between perpendiculars, 27ft. 9in. in breadth, and the depth is 12ft. The service speed with the vessel fully loaded is 10 knots.

Problems of Higher Pressure Steam.

By a Marine Engineer.

"The Journal of Commerce", 10th September, 1936.

In this country engineers are slow to accept innovations, and that is perhaps the reason why we are still building more reciprocating steam engines than any other nation. On the other hand, competition is so great, and the need for speed and economy so strong, that it is difficult to understand the reluctance of owners to adopt plant which could help them.

Lloyd's Register returns show that there is still a preference for steam propulsion in Britain. There is, however, but little inclination to take advantage of developments in pressure and temperature beyond a certain point. We are certainly a very long way from adopting really high steam pressures, and a lack of confidence in the turbine still seems to exist, for the two must go together.

Land power stations are the nurseries which rear ideas for marine adoption, and they have given a lead for a long time, particularly on the Continent and in America. In Britain, 450lb. per sq. in. is about the maximum pressure in use even for land work, but boiler plants working at 1,200 to 3,200lb. per sq. in. have been in use for years abroad, yielding high efficiency and giving satisfaction.

When the metallurgists can produce a metal at a reasonable price to deal with higher temperatures, it will, no doubt, be made full use of, but at the moment 850 to 900° Fahr. is the maximum to use with safety.

It is not suggested that ships in any and every trade should have high-pressure plant, but where there is a regular service it could often be adopted with great advantage. Boiler-room space would be saved while still obtaining ample power, as in the "Tannenberg", the boilers and machinery of which have been described in "The Shipbuilding and Engineering Edition". This ship, with engines of 12,000 s.h.p., has only two boilers, working at 1,000lb. per sq. in., and a service speed of 16½ knots while developing 6,500 s.h.p. At full power, the speed is 20 knots, the reserve being used to maintain the service when the need arises.

As a matter of comparison, take an up-to-date high-class cargo ship of 16 knots full speed, equipped with four water-tube boilers working at 240lb. per sq. in. The shaft-horse-power will be about 8,500, and the rate of evaporation per boiler about 15,600lb. per hour, compared to 28,000lb. in the "Tannenberg".

At the present day there are a great many designs of water-tube boilers, and when certain metallurgical difficulties are overcome, as they certainly will be, there can be few arguments against the adoption of higher steam pressures.

It is not a great many years ago since it was fully realised that the ratio of the heat in water to the total heat in steam increases rapidly with increasing pressures. This fact is now taken advantage of in land stations by the use of economisers, but high-pressure boilers enjoy this benefit in their design in that the feed water is heated rapidly in its path through the tubes. One objection to any departure from old types that has often been voiced by shipowners is the need for specially qualified engineers. To anyone who has experienced the transition from 180 to 400lb. per sq. in., this objection is without the slightest foundation. A competent man can deal as well with a steam joint to hold 750lb. pressure as with one to hold 20lb. so long as the joint is properly designed.

That is also the stated opinion of those with years of experience in the running of high-pressure stations. To disregard their experience will be to retard progress most unjustifiably.

The problem of pure feed water has been met satisfactorily; in fact, it repays the cost of its installation for any plant, normal or high pressure. Water-tube boilers receiving colloidal treatment, in conjunction with light condensers, can reduce boiler cleaning expenses by 75 per cent., and in this connection it may be said that to put any but the best material in condensers is not an argument against high pressures or temperatures.

As things are, there is as much need for a boiler with a high evaporative efficiency to burn either coal or oil as there is for new designs of airplanes. One would be as important as the other in the event of hostilities, for stores of liquid fuel could never reach the dimensions necessary to ensure a plentiful supply, whereas we have coal in abundance.

Deflection of Welded and Riveted Ships.

Notes on the Comparative Movement of the Structure.

By a Ship Surveyor.

"The Journal of Commerce", 10th September, 1936.

It has been suggested more than once that the all-welded ship compares unfavourably with the riveted ship because she is not able to adjust herself to the strain which a ship meets at sea. There is, perhaps, an unjustifiable sense of comfort and safety in listening to a ship working in bad weather. There is the impression that she is meeting and resisting strain which would not be experienced in a completely rigid all-welded ship. This sensation has caused many an experienced seafarer to doubt whether the all-welded ship gives that satistory service which years of experience have led him to expect from the riveted ship.

This movement of the ship's structure is common enough under sea-going conditions, but unfortunately the opportunity of causing it under conditions which are known, and in which it can be measured, does not arise very often, and there are only two or three commonly-known examples in which it was possible to say that, when subjected to certain loads, a ship is deflected or bent to a known extent. Before examining the possible effects of welding on the amount of the deflection likely to take place under given conditions of loading, it is necessary to examine the effect of the riveted joints in a ship on the deflection.

The classic example of an experiment of the kind is contained in a paper presented to the Institution of Naval Architects in 1905 by the late Sir John Biles, in which he described experiments made on H.M.S. "Wolf" by a committee set up by the Admiralty to investigate the strength of torpedo-boat destroyers. The ship was supported in dry dock in a way which approximated to the condition which would be met with among waves, and careful measurements of strain and deflection were taken. The results were very carefully analysed at the time, and have since been the subject of investigations on more than one occasion. In papers read at the Institution of Naval Architects by Mr. G. H. Hoffman in 1925 and 1928, he examined them afresh in the light of more recent knowledge.

Theoretical and Practical Results.

The main point to be noted is that whereas the stresses calculated on the basis of the beam theory as ordinarily accepted agree fairly closely with observed stresses, yet the deflection of the ship girder did not generally agree with the results as obtained from the same theory. This discrepancy is also evident in the results of experiments described by Mr. Foster King in Japan in 1929, and which were made on two vessels built for Messrs. Alfred Holt & Co. Here, again, stresses were more or less of the kind one might expect from theory, but the value of E was not so satisfactory. Deflections measured are greater than might be expected, and the value of E corresponding to them is always much less than that of the steel of which the ship is built.

So many factors affect the relation between the calculated and the measured deflection of a ship subject to longitudinal bending that it is difficult to ascertain the reason for the discrepancy in the results with any degree of certainty. The calculated deflection of a given beam under a given load involves the use of the moment of inertia of the section, and in the structure of a ship this is a figure arrived at after making several assumptions. The standard calculation assumes that all continuously longitudinal material is effective in contributing to the value of the beam.

A little reflection will show that, although this may be a sound enough assumption for comparative purposes, it leaves out one important factor. If the vessel is in the trough of the wave and the upper deck is in compression, the longitudinal material will only be effective in resisting compressive stress if it is of sufficient stiffness to prevent failure by local distortion. The simplest case is that of thin deck plating. The material itself is well able to stand a compressive stress of, say, 7 tons per sq. in., but if a thin plate, supported by beams 30in. apart, is subjected to such a stress, it will not, in fact, resist, but will fail by buckling just as would a long thin pillar under similar circumstances.

Use of Thin Material.

It is evident then that the calculation for inertia of the section must be modified in respect of the ability of the longitudinal material of resisting local distortion of this character which would prevent it standing up to the primary stress. If, however, this thin material can be held to its original form, it can be made to take its part in the structure; for instance, if a thin deck plate is sheathed with wood it will be prevented from buckling and the area of the steel plate will be effective. In this example, in addition to the area of the plate we have the sectional area of the wood deck, which is evidently effective to some extent under compression, so that the calculation for moment of inertia requires modification also in this respect.

The effectiveness of thin material under various loads has been fully investigated, but it has usually been assumed that apart from the question of local failure the structure itself was effective in compression. When a deck is in tension an allowance is sometimes made for the reduction in material due to the punching of rivet holes, but in compression the total sectional area is assumed to be effective. This, however, is probably not correct, and in any riveted structure the joints are liable to a certain amount of slip, the extent of which cannot be ascertained and almost certainly varies with the stress on the connection.

In comparing the welded ship with the riveted ship from the point of view of deflection of structure, it is, therefore, necessary to assume that although the actual deflection will be greater than is shown by calculation, the deflection of the riveted ship will be greater than that of the welded ship by the amount of slip or movement in the riveted joints of the former. It is known that up to certain stresses a well riveted joint will shown no signs of slip because the contraction of the rivets forces the surfaces of the plating together and provides sufficient friction between them to resist the stress.

This question of movement in the connections of any structure is of considerable importance, because such movement, taking place as it does in the part of the structure which first becomes liable to high stress, permits that part to relieve itself, and thus pass on the concentration of stress, so that ultimately each part of the structure is taking its fair share of the load.

When a welded ship or structure is compared with a riveted one it is often referred to as a rigid structure, but this description is only comparative. It is known that in welded structures high concentrations of stress spread themselves out to a considerable extent. The closing weld, that is, the last weld laid down between two parts of an otherwise completely closed ring, may be subject to such high stresses, due to the contraction of the weld, that the weld cracks even as it is being laid down.

If a run of welding of sufficient size and ductility can be laid the weld can be completed, and subsequent examination of the joint shows that this part of the structure is not under any higher stress than the remainder. The stress in the weld metal and the adjacent parent metal may take time to adjust itself, but in a space of, say 24 hours, the stress appears to spread itself sufficiently for all practical purposes.

Residual Stress.

In the completed structure it may be expected then that there is little or no residual stress in the welded ship, but there is still the possibility that a structure of this kind will not be able to adapt itself to impose stress as well as a riveted structure. Its ability to do so clearly depends on the amount of ductility in the welded joints and on the relation between the yield point of the parent metal and that of the weld metal in the joint.

This aspect of the matter is not quite so simple as it first appears, and is most easily considered by taking a butt weld in a plate subject to tension. If, for instance, this weld is in a plate of 26 tons per sq. in. material, having a yield point of 15 tons per sq. in., and the weld metal itself has an ultimate tensile strength of 22 tons per sq. in. and a yield point of 18 tons per sq. in., it is rather disconcerting to find that a specimen joint will usually break in the parent plate, although the ultimate strength of the weld metal is inferior.

The reason is that elongation and contraction of the area of the plate takes place before that of the weld, and the plate gradually thins out and breaks. This is an example of a joint which, in effect, is so much stronger than the parent metal in which it is made that it passes on any concentration of stress, but, although a test piece may show these results, it is evidently not a satisfactory condition of affairs from the point of view of a structure in which the conditions of the test piece may not be reproduced.

It is clear that if the joints in a structure are properly designed, the ideal state of affairs would be that the material of the joint should be identical with that of the parent metal. That is, that the ductility should be as great and the yield point approximately the same. If under this condition a particular part of the structure is stressed beyond the yield point it should be capable of yielding sufficiently to pass on the stress concentration.

There is a tendency in some quarters to differentiate between the parts of the ship which are subject to primary stress, where first-class electrodes must be used, and other parts where the quality of the electrode can be disregarded. In a ship, where any part of the structure may be liable to movement when the vessel is in a seaway, it will always pay the shipbuilder to use electrodes of approved strength and ductility.

Eighteen New British Tankers.

Doxford and Harland-B. & W. main engines are employed in equal numbers in these large vessels.

"The Marine Engineer", September, 1936.

Some time ago, it may be recalled, a series of 18 single-screw tankers were ordered in this country by the British Tanker Co., Ltd., London. These ships were ordered as follows:—

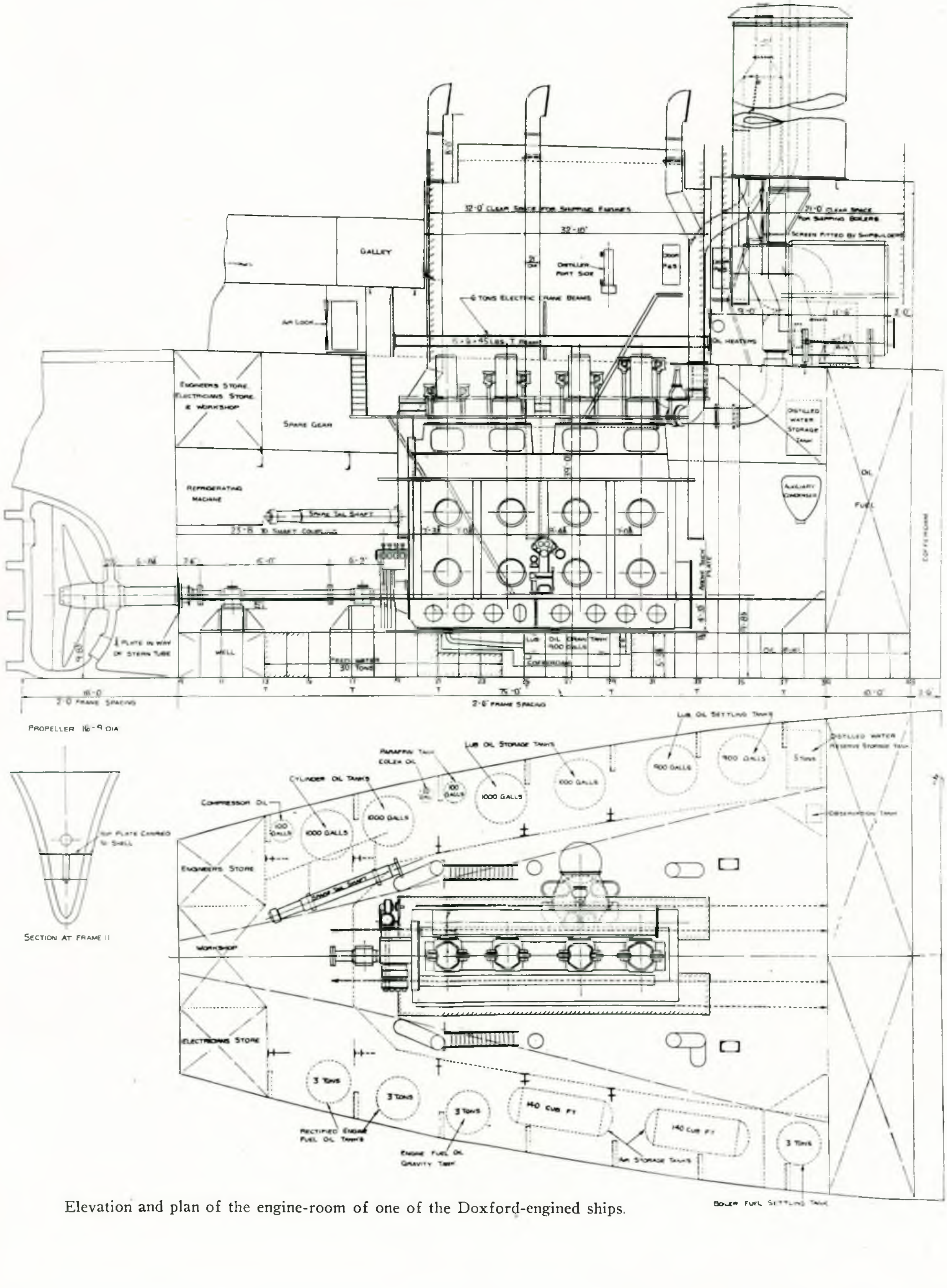
Six with Swan, Hunter & Wigham Richardson, Ltd.

Six with Harland & Wolff, Ltd.

Three with Cammell Laird & Co., Ltd.

Three with Lithgow's, Ltd.

The vessels ordered from the English yards are all to have Doxford two-stroke cycle opposed-piston main engines, while those placed with Lithgow's, Ltd., are to have Harland-B. & W. four-stroke



Elevation and plan of the engine-room of one of the Doxford-engined ships.

cycle engines supplied by John G. Kincaid & Co., Ltd. The six ships ordered from Harland & Wolff, Ltd., naturally have machinery of their own manufacture, these engines being of the four-stroke cycle single-acting Harland-B. & W. type, with under-piston supercharge.

The first of the series to be completed is the "British Fame", one of the ships ordered from Swan, Hunter & Wigham Richardson, Ltd. The accompanying general arrangement plan of a machinery space for one of these vessels is that of a typical Doxford-engined ship of the series, the general layout of the vessels fitted with the Harland-B. & W. machinery being broadly similar so far as the auxiliaries and their disposition are concerned. The illustration which accompanies the article, incidentally, is that of the "British Fame", and in the main this article will be more fully concerned with the Doxford-engined ships of the series of which the "British Fame" is the first.

All the vessels have been built under special survey to Lloyd's Register's highest class for ships carrying petroleum in bulk. Their principal particulars are as follows:—

Length overall	481ft. 0in.
Length between perpendiculars ...	464ft. $2\frac{1}{3}$in.
Breadth moulded	61ft. 9in.
Depth moulded	34ft. 0in.
Deadweight capacity	12,250 tons.
Maximum draught	27ft. 6in.

The hull is provided with two longitudinal oil-tight bulkheads and is of the single-deck type with poop, bridge and topgallant forecastle. The vessel has a straight stem and well-proportioned cruiser stern; the stern post is carefully streamlined and an Oertz streamline rudder is provided. The main framing is arranged on the combination system, that is, longitudinal framing is provided in the bottom and at the deck with normal transverse main frames. There are 16 transverse oil-tight bulkheads, those with the two longitudinal bulkheads dividing the cargo spaces into 27 tanks with a deep tank forward below the small general cargo hold. As the capacity of the centre tanks is approximately double that of the wing tanks, no summer tanks have been provided. There are two cargo pump-rooms, the forward one being located between tanks Nos. 2 and 3, and the after one between tanks Nos. 6 and 7; the equipment of the pump-rooms will be discussed later.

For dealing with general cargo there are two 7in. by 12in. steam-driven winches, while steam drive is also used for the Emerson Walker windlass and the two capstans. The capstans and winches for the majority of the vessels were supplied by John Lynn & Co., Ltd., Sunderland, while those for the Lithgow-built ships have been manufactured by the Clyde Crane & Engineering Co., Ltd. The steering gear is of the two-ram steam-hydraulic type, the Hele-Shaw pump being driven by a two-cylinder steam engine; the steering gear in each vessel has been supplied by John Hastie & Co., Ltd., Greenock. There is a Siemens rudder indicator and revolution indicator.

In order to obtain the highest possible propulsive performance model tests were carried out in the National Tank at Teddington before the lines of the vessels were finally settled. The propeller design adopted is also the result of careful investigation and is according to the latest researches. In several of the ships the propeller has been supplied by the Manganese Bronze & Brass Co., Ltd., while the Clyde-built vessels have screws which were manufactured by Bull's Metal & Melloid Co., Ltd., Glasgow. The Harland & Wolff-built ships, on the other hand, have propellers cast in Stone's manganese bronze in the shipbuilder's own foundry.

An interesting feature worth recording is the provision of loud speakers fore and aft, with microphones on the bridge, in order to facilitate docking of the ship; this equipment has been supplied by the Telephone Manufacturing Co., Ltd. The usual loud-speaking Navy-type telephones provide communication between the engine-room starting platform and the bridge, and the chief engineer's room.

Modern tankers invariably operate to a very exacting schedule involving very little time in port. For this reason owners wisely study the comfort and well-being of their officers and crew to a greater extent than does the average cargo ship owner. The standard of accommodation, for instance, is generally high and in this respect the new British Tanker ships are no exception. The captain's accommodation is arranged on the upper bridge deck and comprises a spacious day room, bedroom and bathroom. The deck officers are accommodated amidships, where there is also a limited number of spare cabins. In the bridge structure there is also a spacious dining room and smoke room for the deck officers. The engineer officers have their accommodation in the poop deck house, where the chief, second, third, and fourth engineers are berthed. Here, also, is a comfortably furnished engineers' mess room and pantry, while around the engine casing are to be found the European and native galleys. Rooms for the fifth, sixth, and seventh engineers are located on the port side in the upper deck aft, while on the starboard side there is a large room for five assistant stewards and another one for the cook. A hospital and separate bathroom are arranged in the upper deck aft. The petty officers, sailors, firemen, greasers, carpenter, etc., are berthed in the forecastle, the accommodation complying with the latest requirements of the Board of Trade.

As indicative of the excellent standard of furnishings and decoration provided it is interesting to note that the amidships saloon and smoke room have, in each case, been furnished by Maple & Co., Ltd., the well-known London furnishing contractors. It is also interesting to note that because of the tropical conditions under which the vessels will often operate the whole of the accommodation is provided with mechanical ventilation on the Thermotank system, while provision is also made for heating the air during cold weather. The ships' provision stores are provided with refrigerating machinery by Seagers, Ltd., of Dartford.

Each ship has four large steel lifeboats and two wooden lifeboats located aft, all being carried under Welin-Maclachlan davits. The navigational equipment is exceptionally complete, for in addition to the usual wireless apparatus each ship has a Marconi sounding device, a Kelvite sounding machine, and a Walker's patent log.

Pump Room Equipment.

The pumping equipment for the two cargo oil pump-rooms is steam-driven, each pump-room housing two duplex horizontal direct-acting steam-driven cargo pumps, each of 230 tons per hour capacity. The cargo oil pumps have been supplied by three different specialists as follow: the Swan, Hunter and Lithgow-built ships have cargo pumps by J. P. Hall, Ltd., those built by Harland & Wolff, Ltd., have pumps by G. & J. Weir, Ltd., while the Cammell Laird-built ships have cargo oil pumps by Hayward Tyler & Co., Ltd. In addition, the forward pump-room also accommodates a horizontal 8in. by 8in. by 10in. steam-driven duplex ballast pump, as well as a steam-driven oil fuel transfer pump which raises fuel oil for the main engine from the tank below the forward hold to the cross bunker in the after part of the vessel, and, if required, to the double bottom fuel tank below the cross bunker.

Machinery.

Each of these vessels is propelled by a set of airless-injection Diesel machinery capable of producing in service a power of 2,850 b.h.p. In the Doxford-engined ships this output is obtained at 98 r.p.m. of the shaft, while in the Harland-B. & W. ships the crankshaft speed is 105 r.p.m. The specification called for a trial power 15 per cent. in excess of the above figure, that is, about 3,300 b.h.p. The mean indicated pressure in the Doxford-engined ships is 85lb. per sq. in., while in the four-stroke cycle-engined vessels the corresponding figure is about 115lb. per sq. in. The specific fuel oil consumption at full load is in the region of 0·36 to 0·38lb. per b.h.p. per hour. The power mentioned above is sufficient to give the vessels a loaded service speed of 11½ knots, while the ballast speed is 12½ knots.

The Doxford engines are of the latest all-welded type, each with four cylinders 600mm. in diameter by 2,320mm. combined stroke; the engines are of the balanced differential stroke type in which the stroke of the lower piston is appreciably greater than that of the upper piston. The scavenge pump is located at the back of the engine and is driven from one of the crossheads by means of rocking levers, the same system of levers driving various pumps, to which reference will be made at a later stage. The Harland-B. & W. engines as fitted in the Harland & Wolff ships and those with Kincaid-built machinery which have been ordered from Lithgow's, Ltd., are of the latest airless-injection four-stroke cycle type with under-piston supercharging such as has been used in a number of recent tankers. Each engine has six cylinders 740mm. in diameter by 1,500mm. stroke, and, unlike the Doxford engines, the main construction of columns, bedplates, etc., is in cast iron.

Distilled water has been employed for cooling wherever possible, not only for the main engines but also for the auxiliary Diesels. Thus, jackets and pistons are cooled by this medium in the Doxford engines, as are the jackets in the B. & W. type engines. As the standard arrangement for piston cooling in these latter engines makes use of lubricating oil as the coolant, this has been adhered to in the vessels under discussion.

In both the four-stroke cycle and two-stroke cycle engines the lubricating oil and cooling water pumps are driven off the main engine. In the case of the Doxford engine the rocking levers, which, incidentally, have forced lubricated bearings of massive proportions, there is a double-acting forced lubrication pump of 30 tons per hour, a double-acting sea-water circulating pump of 180 tons per hour, and a double-acting distilled jacket water pump of 125 tons per hour, arranged in a group together with the double-acting scavenging air pump. A somewhat different arrangement is used in the B. & W. engines, for the pumps are arranged in a group at the back of the engines, being driven from the crankshaft by means of chain gearing in the manner which has already been employed in other four-stroke cycle-engined tanker installations. In this case the forced lubrication pumps are of the reversible Houttuin type made under licence by Stothert & Pitt, Ltd. The sea-water circulating and fresh-water cooling pumps are arranged in the same group as is the forced lubrication pump.

There are independent standby pumps for all these essential main engine services. For instance, the vertical duplex steam-driven ballast pump of Dawson & Downie make can be used in all ships of the series as a standby sea-water cooling pump, while there are steam-driven standby jacket and piston cooling water pumps and forced lubrication pumps. Two independent steam-driven pumps, one standby, are provided in the Doxford-engined ships for the separate cooling circuit for the fuel injection valves, and there are two 100-tons per hour duplex double-acting steam-driven bilge and sanitary pumps. The fuel oil transfer pump is of the horizontal duplex double-acting pattern, and the two starting air compressors are steam driven units, each of a free air capacity of 125 cub. ft. per minute. The starting air pressure in the Doxford-engined ships is 600lb. per sq. in. There are two 140 cub. ft. air reservoirs for storing the starting air. In the Harland-B. & W.-engined ships the starting air pressure is somewhat lower, the steam-driven compressors having a discharge pressure of 350lb. per sq. in. Here, again, two starting and manœuvring air reservoirs are fitted.

As a great deal of steam is required on the average tanker for driving cargo pumps, for heating coils, and for tank steaming-out connections, as well as for deck machinery, steering gear, and engine-room auxiliaries, fairly large steam generating plant is usually required and this is the case in the vessels under discussion. Each ship is provided with two single-ended return-tube Scotch boilers, these being located in a separate compartment on the upper deck at the forward end of the engine-room. One boiler is 13ft. 6in. in diameter by 11ft. 6in. long, and is arranged with oil-firing for the wing furnaces and exhaust gas "firing" to the centre furnace only. The two firing systems are kept quite separate and normally at sea the heat obtained from the exhaust gases is sufficient to raise all the steam required for the steering gear and engine-room auxiliaries. The heating surface in the wing furnaces amounts to 1,375 sq. ft., whilst that of the centre furnace is 1,220 sq. ft. in the Doxford-engined ships, the figures for the four-stroke-engined vessels being approximately the same. It is interesting to note in this connection that the heating surface for exhaust gases is actually slightly more in the four-stroke cycle-engined vessels than is the case in the Doxford ships—a distinct compliment to the highly efficient scavenging of the Doxford engine. The second boiler has two furnaces, both oil-fired, and is 11ft. 6in. in diameter by 11ft. 6in. long.

The boilers are fitted with Brunditt circulators and the oil-burning equipment is of the Wallsend-Howden type; the two oil-fuel pumps are of Weir manufacture and the usual complement of heaters and duplex strainers is provided. The boilers are arranged to work under Howden's system of forced draught, there being one motor-driven forced draught fan and one driven by a Howden Thermall-type steam engine. A spark arrester is fitted in the funnel in the interests of safety and a steam fire-extinguishing system is arranged under these auxiliary boilers. The boiler feed pump is a direct-acting Weir unit of standard type and there is a surface type feed heater in each ship. Make-up feed water is supplied by a 25-tons per day evaporator which has an automatic feed regulator; a combined feed filter, and float tank is provided in the boiler feeding system and the auxiliary condenser into which the various steam-driven auxiliaries exhaust is, in the case of the Doxford-engined ships, provided with 80/20 cupro-nickel tubes.

Great care has been exercised in arranging for the purification of the fuel and lubricating oil. Each ship is provided with two 300-gallons per hour totally enclosed fuel oil centrifuges which have their own steam heaters. These machines can either be used in series, when the second purifier is operated as a clarifier, or else they can be run in parallel, which arrangement allows of one machine being used as a standby unit. For purifying the lubricating oil each vessel has one 300-gallons per hour totally enclosed centrifuge which has a steam heater capable of raising the temperature of the oil from 40 to 200° F. This purifier has a wash water connection led from the lubricating oil heater drain to the separator. The various centrifugal purifiers in the different ships are of Vickcen and Titan make, the actual distribution of the orders not being known to us at the time of writing. In addition, there is a Streamline filter for the lubricating oil, this operating in conjunction with the centrifuge on the bypass system.

Electricity for lighting and ventilation, as well as for driving the centrifugal purifier motors, refrigeration machinery, and other equipment in the vessel, is supplied from two 30-kW. generating sets. One of these is driven by a Diesel engine and, as has already been mentioned, the engine is provided with its own self-contained separate distilled cooling water service as well as with a steam connection for warming up the engine prior to starting in cold weather. The generator in each ship is of Sunderland Forge make and in the Lithgow and Cammell Laird ships the driving engine is a five-cylinder Paxman-Ricardo unit, while in the Swan, Hunter and Harland & Wolff ships a four-cylinder National engine is employed; in both instances the normal revolution speed is 600 r.p.m. The steam-driven generator set has a normal rotational speed of 550 r.p.m. and the driving engine is of the totally enclosed Thermall type designed to operate with steam at a pressure of 120lb. per sq. in. In addition, there is a small 8 kW. at 750 r.p.m. steam-engine-driven generating set for port lighting and for supplying current for the Suez Canal searchlight.

The trials of the "British Fame" were carried out on 20th August off the mouth of the Tyne, the contract requirements being readily fulfilled; a speed of 12·8 knots was reached. It may be mentioned that all trials for the series of ships are to be conducted on Anglo-Iranian fuel oil; the same make of lubricating oil is to be used for the main and auxiliary engines, although a special grade of Shell oil is used in the compressors. We are indebted to the British Tanker Co., Ltd., for permission to publish this article and for assistance in its compilation, and in particular we should like to place on record our indebtedness to Mr. H. S. Humphreys, Assistant Superintendent Engineer of the British Tanker Company.