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# Welded Steel Frames for Marine Engines.

READ

By C. H. STEVENS, C.B.E., M.I.Mech.E., M.Inst.N.A.

*On Tuesday, February 12th, 1935, at 6 p.m.*

Chairman: Mr. J. Hamilton Gibson, O.B.E., M.Eng. (Chairman of Council).

## Synopsis.

*THIS paper deals with the author's practice and experience in the design and production of welded steel frames for marine oil engines of the four-stroke type for main and auxiliary purposes. The method of construction in which primary loads are not transmitted through the welding is explained, and its application in the designs illustrated.*

*A description is given of three types of frames as actually constructed for main engines, together with line drawings and photographs of the frames in various stages of construction. Some auxiliary engines are also briefly described and illustrated in order to show the general adaptability of the methods of design to varying sizes and types of engines.*

*The advisability of separate cylinder water cooling jackets is mentioned, and means suggested for such arrangement. The question of removal of the crankshaft for repair or renewal is discussed, particularly in connection with welded steel frames.*

*A large-scale model will be put together during the meeting to demonstrate how the plates are cut and fitted.*

In placing before your Institute the following notes on welded construction for main and auxiliary marine engine frames, and descriptions of such frames actually constructed, the Author is referring only to his own practice and experience in the adaptation of his patents and ideas to oil engines of the four-stroke single-acting type. The methods are, however, equally adaptable to two-stroke or double-acting types.

The main feature of the designs to be described consists in the fact that the primary load due to compression and ignition is not transmitted through the welding, but is carried by the steel members themselves, and transmitted from one to the other through metal contact, and also by being contained within a single member which surrounds the forces. An exception to this rule is seen in some designs where a portion of the primary load may be transmitted from one member to another through welds in longitudinal shear.

The transmission of the primary load through welds in cross shear is avoided, because in the Author's experience welds so loaded may become unreliable in structures such as engine frames where the loading alternates between zero and maximum, and is frequently reciprocating and necessarily accompanied by a certain amount of flexing in varying degree. Thus, generally speaking, it will be noted that in these designs, for load transmission, the welding is of secondary importance, its function being to consolidate the assembled members. That does not mean that welding of a poor quality would be good enough for the job.

The welding in every part must be of the best. To that end the positions of the welds, the access to them, and a correct welding attitude are matters of the first importance.

All the welding should be downwards, i.e., gravity welding, and therefore the engine frame must be placed in the most favourable position for each weld. Thus during the progress of the welding we see the frame vertical, upside down, on its side, or at any angle, as best suited to the particular weld in progress. The welds are practically all fillet welds, and their dimensions are arranged in accordance with the various thicknesses of plates.

The first marine engines to be fitted with framework designed on these lines were those of a submarine, for which the columns and entablature with cylinder liner housings were made as two monoblocs joined by a bolted connection at the top of the central bay, each monobloc comprising three cylinder lines. They have been in commission for some time. *These columns have been described by the Author in a previous paper, and are illustrated here in Figs. 1, 2 and 3. Fig. 1, which is a view of the structure before the side plate is placed in position, shows clearly the method of transmission of the upward load from the cylinder head bolts to the girder across the tops of the columns and the side plates, and through the flanged column feet to the bedplate.

Fig. 2 is a view of a fully assembled and welded half, and Fig. 3 is a view of the

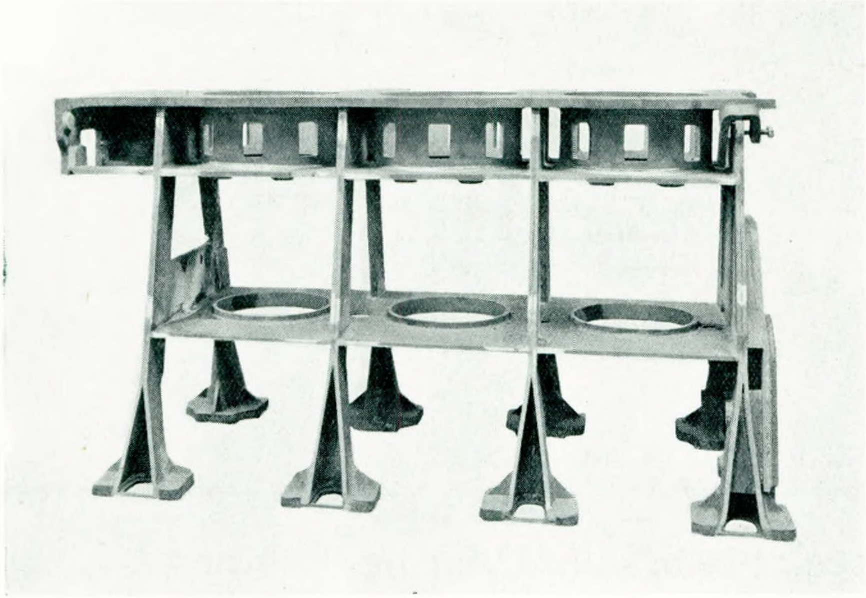

FIG. 1.—Columns.

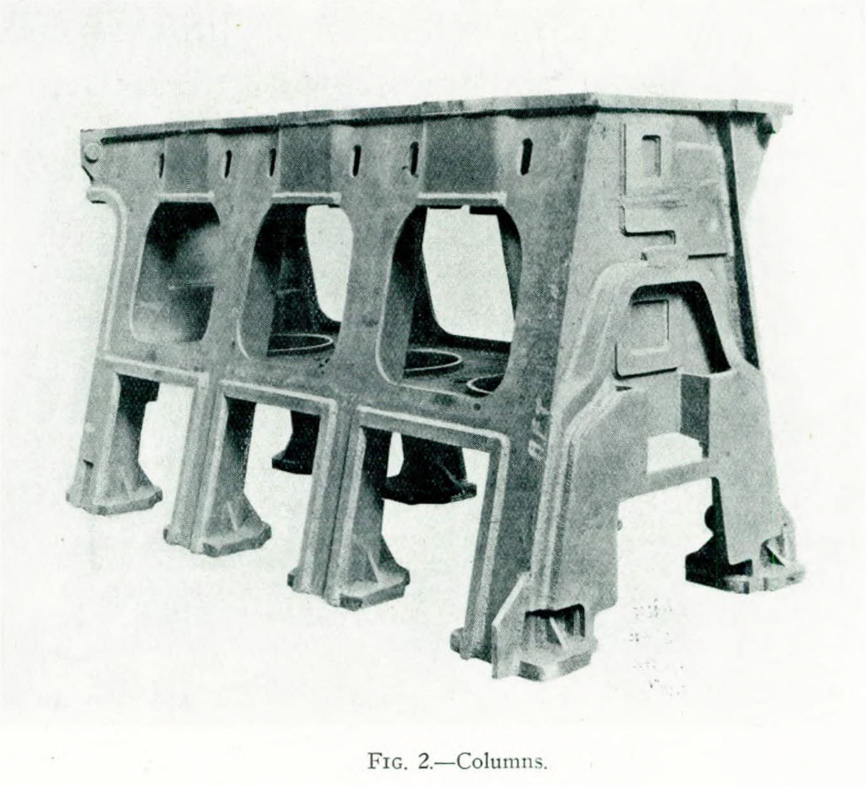

FIG. 2.—Columns.

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* "Steel Frames for Diesel Engines". Diesel Engine Users Association, 12th October, 1932.

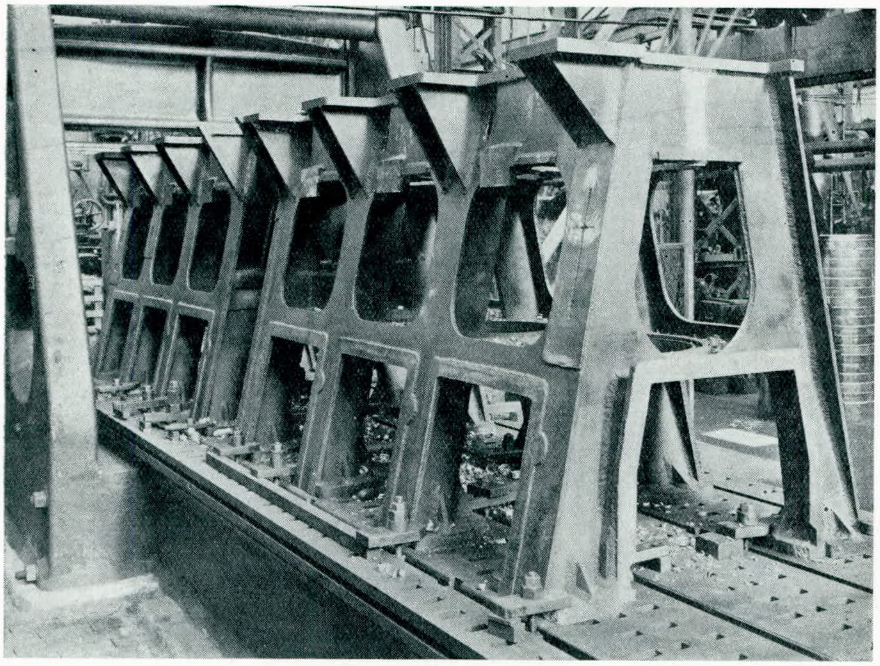

FIG. 3.—Columns.

complete job on a planing machine. This design has been entirely successful, and several later engines have been so fitted without variation.

A further step in the development of welded steel engine frames for Naval purposes has now been taken, and two twin screw sets of different powers have been constructed on the Author's complete sling frame design, which embodies entablature columns and bedplate in one piece, with the location or removal of the crank shaft from the end. The smaller twin set of these engines is of the same rating as those previously fitted with welded columns only, viz., 1,500 b.h.p., whilst the larger set is of more than double the power, having a combined b.h.p. of about 3,500. Both types are six cylinder four stroke engines.

The smaller engine frame is illustrated in Fig. 4 and consists of two monoblocs (each having three cylinder lines) connected near the centre of the camshaft drive bay. The bolted connection is formed by the flanging of the various plates as illustrated in Fig. 4. In this design the cylinder liners themselves carry the complete water jackets, and consequently there is no part of the steel frame in contact with the cooling water. The arrangement for transmitting the load from the cylinder head bolts to the sling frames and side plates is the same as used in the simple column design as illustrated in Figs. 1 2 and 3. In this case the removal of the crank-

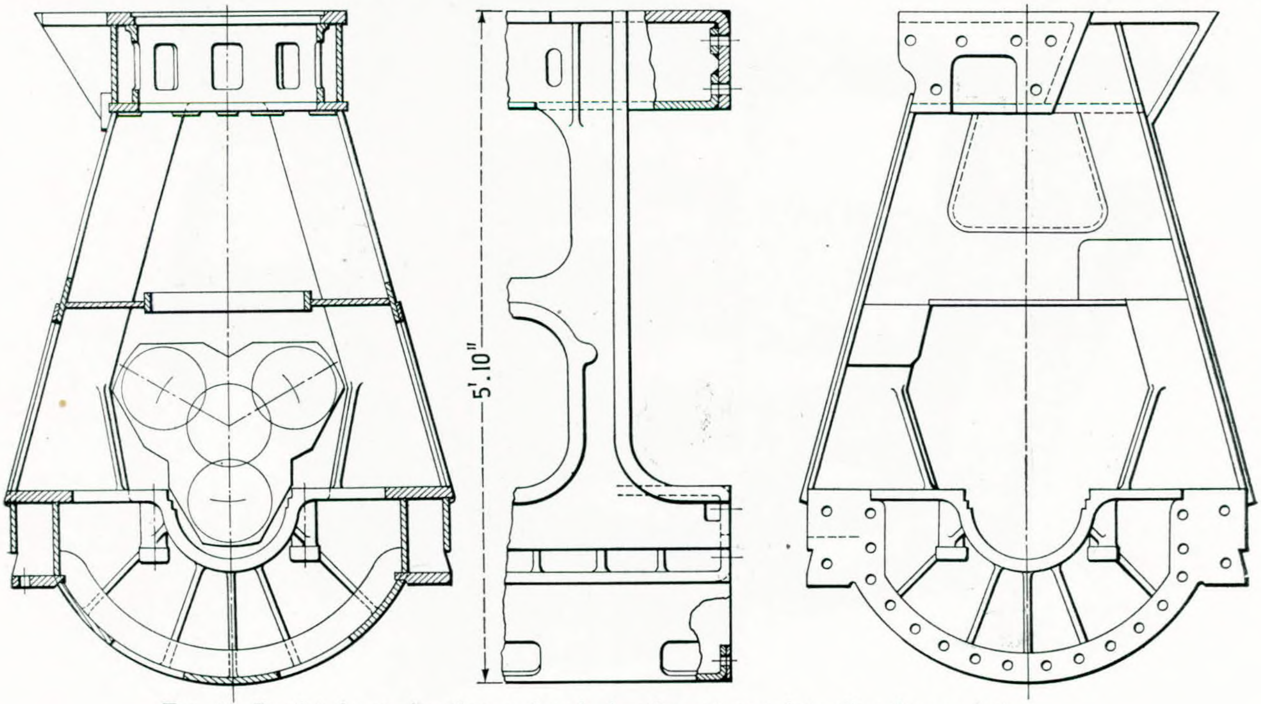

FIG. 4.—Partial front elevation and end elevation of complete sling frame design.

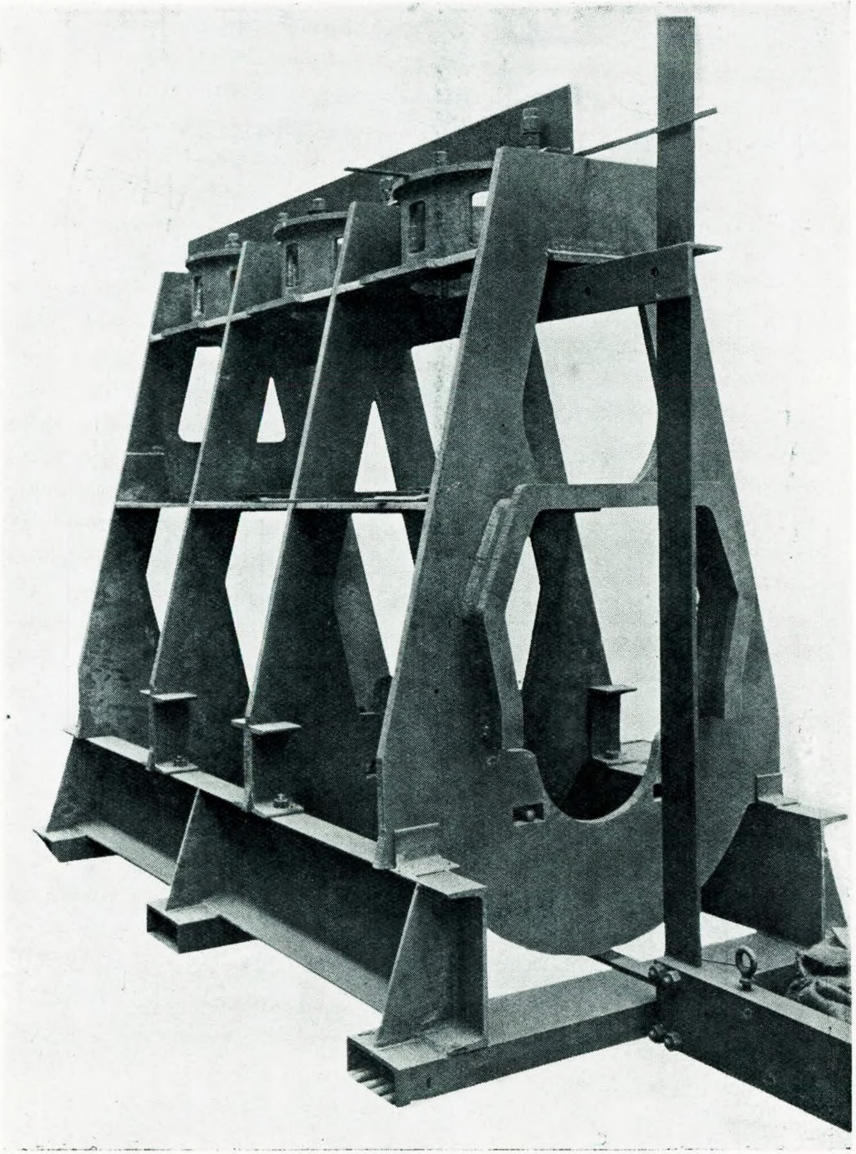

FIG. 5.—Complete sling frames in course of erection.

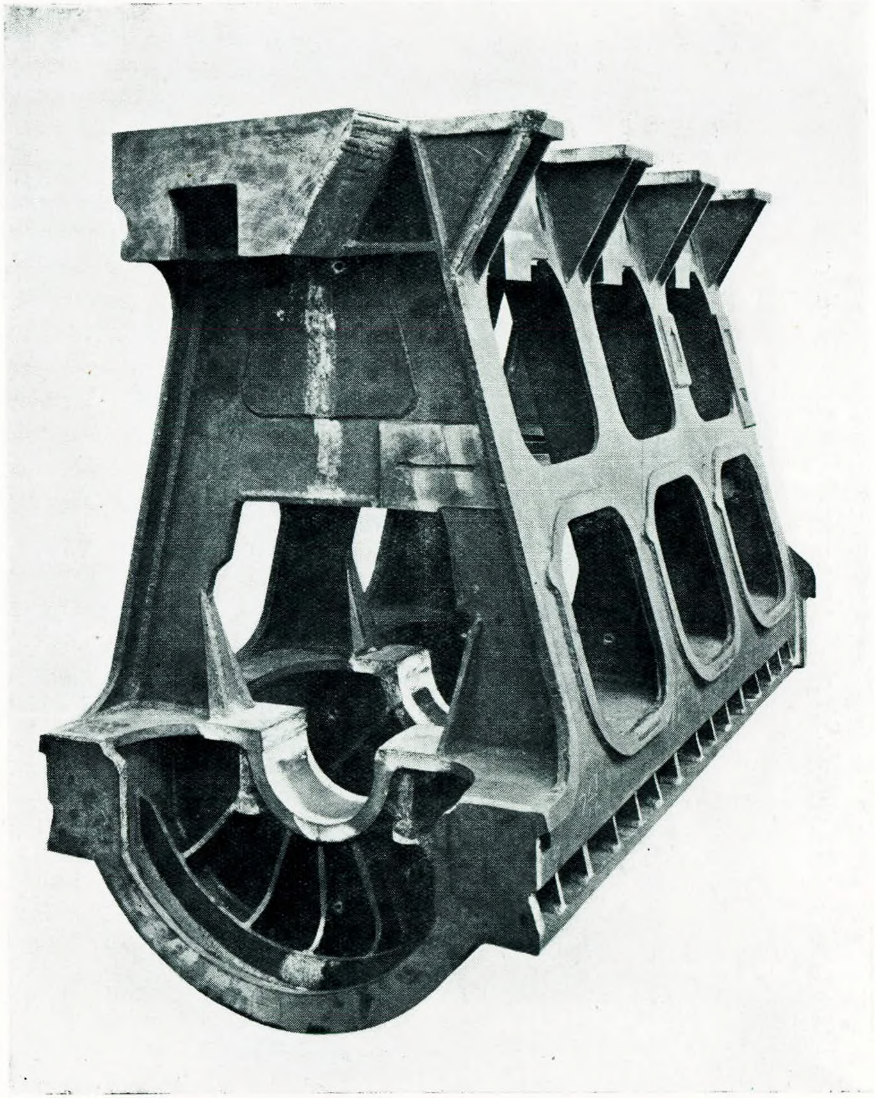

FIG. 6.—Finished half frame showing joint in central bay.

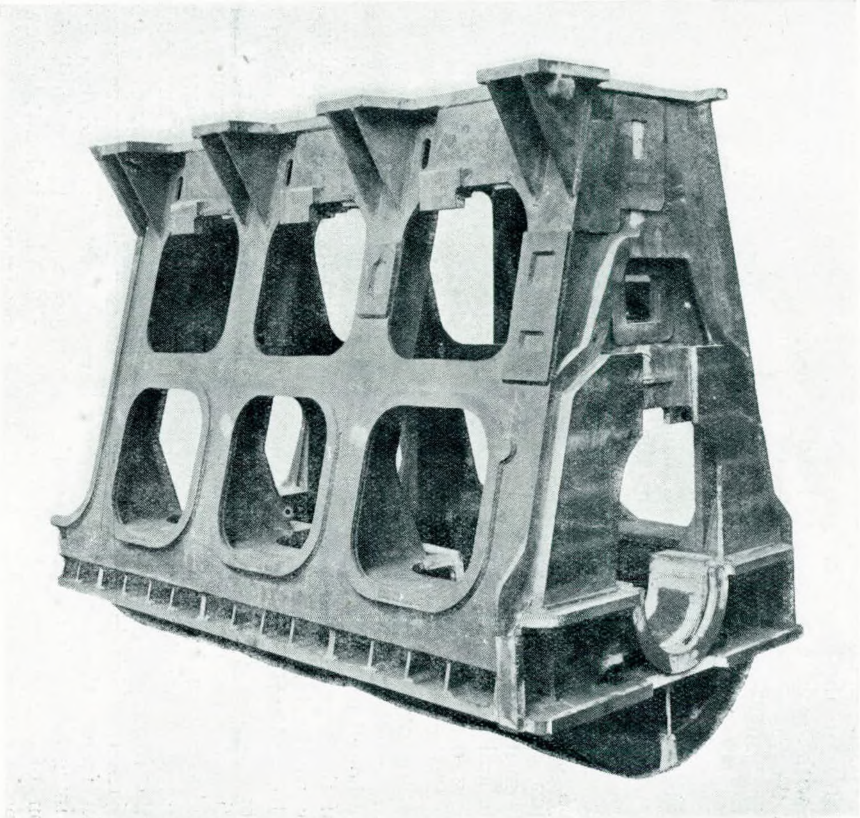

Fig. 7.—Finished half frame showing after end.

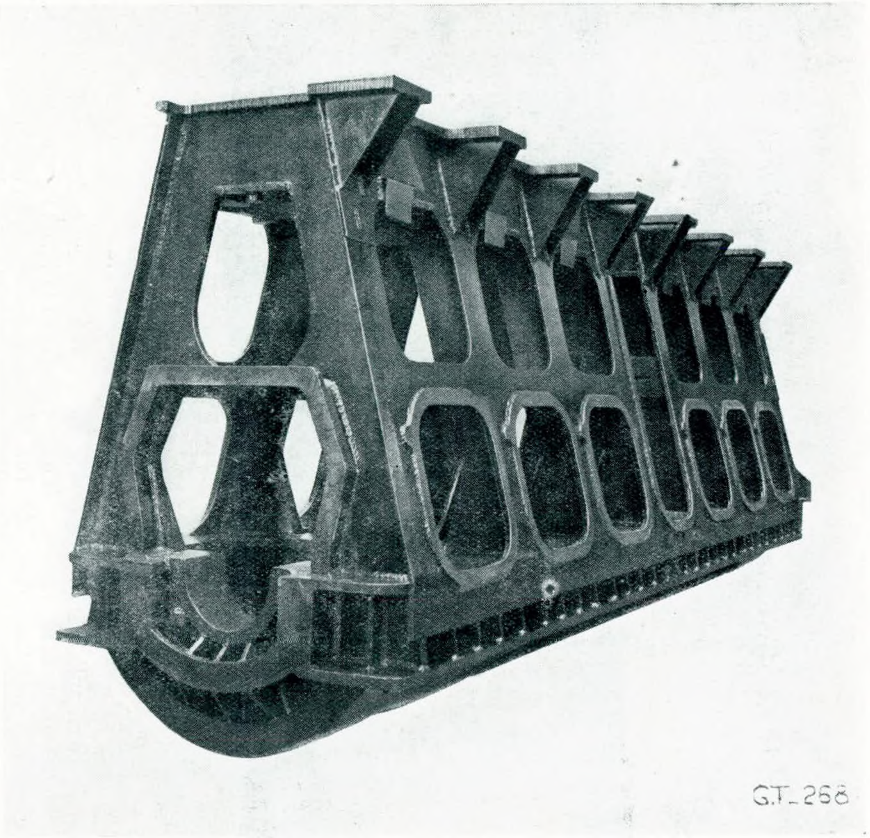

Fig. 8.—Finished complete frame showing the two halves bolted together.

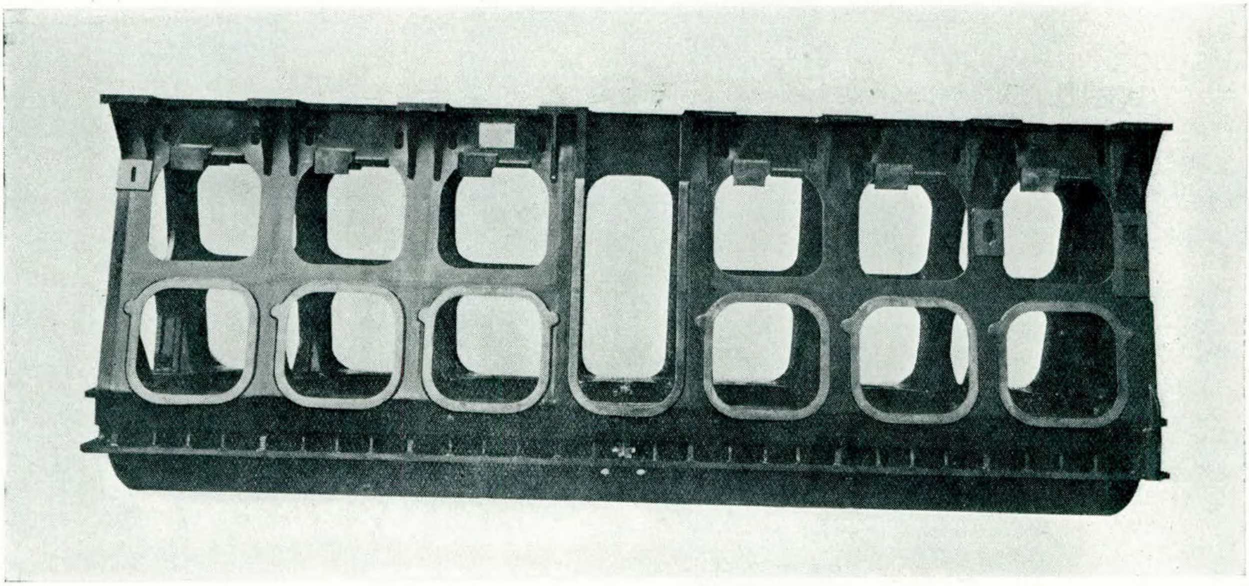

FIG. 9.—Front view of complete frame.

shaft from the ship is accomplished through the forward end after uncoupling at its centre. The outline of the crank-shaft in lifted position for removal is shown in Fig. 4. By this means the crank-shaft can be got out without disturbing the structure of the vessel above the engine, which is necessary in the case of these engines as previously constructed with separate columns and bedplate, as owing to the restriction imposed by the column feet there is insufficient room to clear the crank-shaft.

The advantage of the complete sling frame having eliminated all horizontal bolted joints will be appreciated, as it leads to great rigidity of the structure under working conditions. Figs. 5, 6, 7, 8, and 9, show these frames in different stages of construction. Fig. 5 shows the main sling frames in course of erection, in which the cylinder head bolt plate is seen in its position below the top girder of the frame, and the crank-case diaphragm plate in position. Fig. 6 shows the completed half frame and illustrates the facings of the central joint. Fig. 7 shows the completed half frame and the facings at the after end. Fig. 8 shows the two halves of the frame bolted together. Fig. 9 shows a front elevation of the complete frame.

We come now to the larger twin screw set, illustrated in Fig. 10, and whilst in principle precisely the same form of construction has been used, a number of variations in the general appearance of the upper part have been introduced. These consist of the arrangement for the housing of the cylinder liner and the formation of the upper portion of the water jacket, which in this design is a part of the main frame, the formation of the camshaft bearings integrally with the frame-work, and the elaboration of the design to permit of welding being properly carried out.

The water jacket and liner seating are illustrated in Fig. 11, which also shows the transmission of the load from the cylinder head bolts to the top girder of the sling frame and to the side plates by metal to metal contact and not through the welding, which has been purposely omitted from the drawings. The arrangement of the camshaft bracket is illustrated in Figs. 10 and 12, from which it will be seen that the bracket is formed from an extension of the main frame and cut solid from the main frame plate, the journals and webs being welded on in the approved manner. The decision to make these bearings integral with the main frame arises from the fact that it gives a better access for welding of the liner housing to the horizontal plates, owing to the absence of large seatings on which separate camshaft brackets would be bolted.

Good access to the interior welding of the upper part is provided by cutting away the useless parts of the cylinder head bolt seating plate and the top of the liner housing, and also a portion of the outer side plate. No part of the material thus cut away would transmit load, and would therefore be redundant, whilst its removal has greatly facilitated the work of welding.

Fig. 12 shows the main frame with bearing welded in and the extension for the camshaft bearings. By reference to Figs. 10 and 12 it will be seen that the main frames are of the sling type, each cut from a single plate. All the main bearings and ribs, together with any seatings or facings, are welded to the main frames before general assembly is commenced. Counting from the top the first horizontal plate is called the cylinder head bolt plate and receives the upward pull of the bolts (*see* Fig. 10). This plate is located below the top girder of the sling frame.

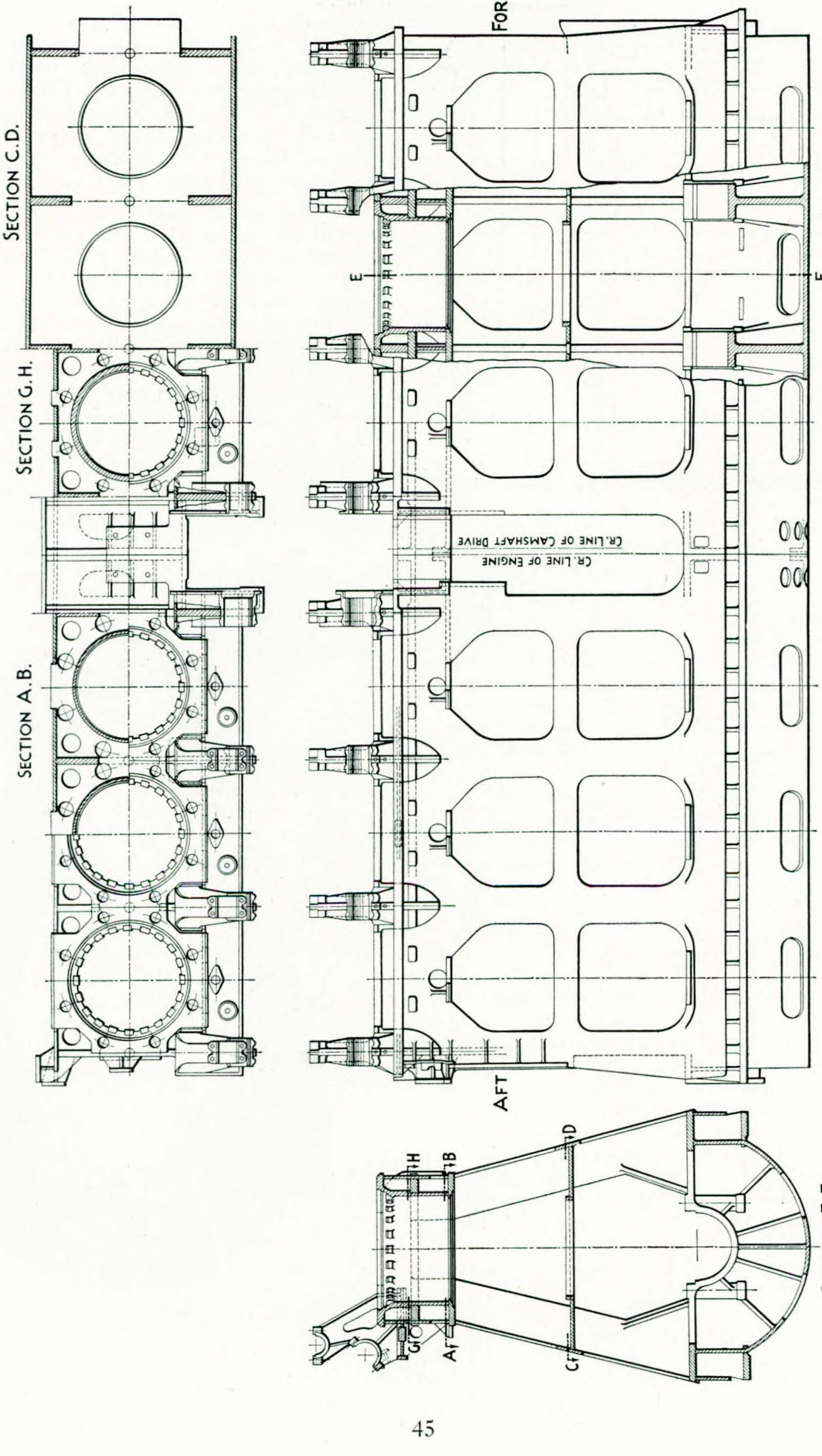

Fig. 10.—Line drawing of front elevation, end elevation and sections.

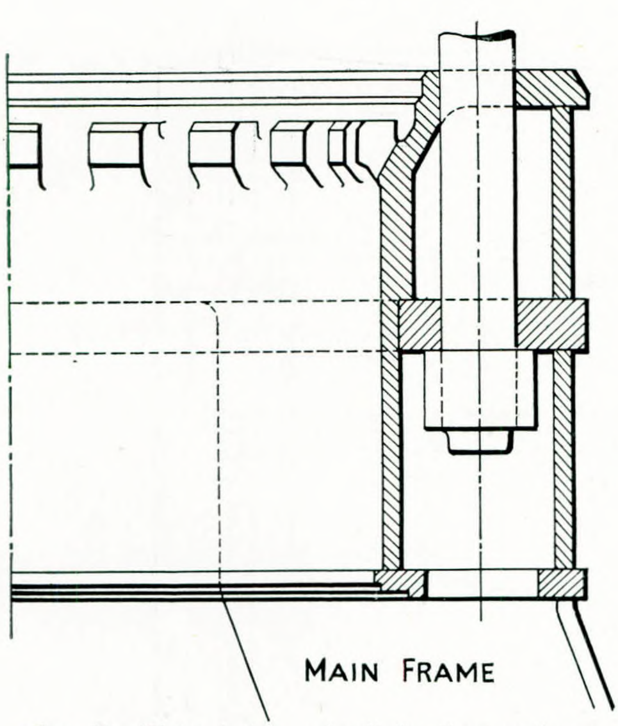

FIG. 11.—Water jacket and cylinder liner seating.

The next horizontal plate acts as a longitudinal cross girder, and carries on its underside the seatings for the separate water jacket and the timing gear brackets, and its upper side provides a seating for the liner housing tube. The lower horizontal plate is the diaphragm plate of the crankcase, and is provided with rings for the location of the lower ends of the cylinder liners. All these horizontal plates are cut from one piece, they are slotted at the sides to fit over the main frames, and are threaded through the frames and passed into position. (This process and the whole erection will be shown by a model which will be assembled at the meeting).

After these horizontal plates are in position and welded, the sump plate is located and welded, together with the top members of the bedplate portion and the brackets above the engine seating. The side plates, back and front, are then located and completely welded to all the frames and horizontal plates. The outer edges of the engine seating brackets are then welded to the lower part of the side plates through the space where the seating plate is finally located, and the welds attaching this to the brackets and upper edge to sump plate are made through the open gap between the lower edge of the side plate and the top face of the seating.

The next operation of importance is the assembly and welding of the cylinder liner seatings. Finally the camshaft bracket ribs and oil tray are fitted and welded in.

The same engine frame, when made in cast steel with through bolts, requires in all 60 steel castings and 16 through bolts to complete the frame, all of which 76 pieces have to be machined and bolted together, as compared with two pieces in welded steel bolted together in the central bay. The welded engine frame could just as readily have been constructed in one piece, but it was decided to make it in two pieces to facilitate heat treatment and machining. There is, of course, a vast difference between the amounts of machining and fitting in the two types.

All the seating faces of the various parts which are bolted to the engine frame are attached to those parts by welding, a sufficient machining allowance being provided. Fig. 10 illustrates a number of seatings which are required for the control gear, etc. The main bearing and bearing bolt housings are illustrated in Fig. 13. The upward pull of the bolts is taken on cross-bars which are passed through slots in the frame. The welding of the main bearing journal to the frame is shown in the drawing. These large welds are built up in a series of small runs, the radial webs being welded on afterwards.

FIG. 12.—Main sling frame with bearing welded in and showing the extension for the cam shaft bearings.

All frames when completed are submitted to a heat treatment consisting of heating up to 650° C., and maintaining that temperature for one hour for every inch of thickness of the thickest plate used, and then cooling off in still air. No difficulty has been experienced in carrying out this treatment, and no deformation has taken place.

Some auxiliary Naval engines have been fitted with steel frames and are illustrated in Figs. 14 and 15. These are three-cylinder 75 b.h.p. engines, and the frames are of the complete sling type in which the top girders of the main frames stand above the liner seating plate. The water jackets are separate and renewable and are made of galvanized steel.

The frames are perhaps remarkable in that whilst the main sling frames are ½in. thick the outer plates are only $\frac{3}{16}$in. Under test these engines were quite steady when running at maximum revolutions of 800 per minute.

The frame of another small eight-cylinder engine of 320 b.h.p. is illustrated in Figs. 16, 17, and 18. This is of the same general type as the small set shown in Fig. 14. The easy variations in general design of the frame to suit the engine-makers' designs are well illustrated in these two small engines.

It has been found possible in all these designs to construct the welded steel work in such a manner that the various details of fittings and moving parts have not had to be altered from the original designs of the engines. This is an important advantage when considering a change over from castings to steel weldings for an existing design of engine.

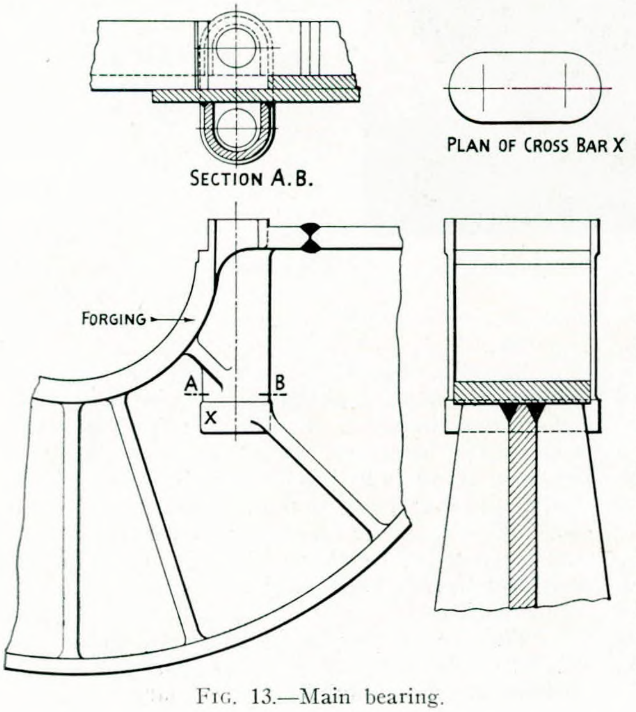

FIG. 13.—Main bearing.

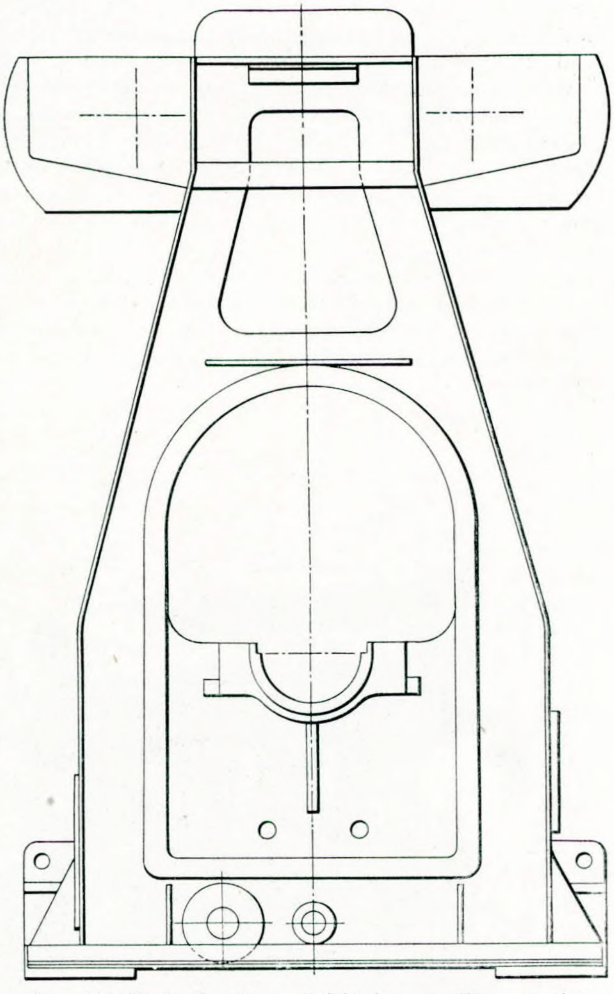

FIG. 14.—End elevation of 75-b.h.p. auxiliary engine.

As regards weight, generally there should be a saving of about 60 per cent. in comparison with cast iron and not less than 10 per cent. in comparison with cast steel. The weight of the main frames is controlled by the permissible amount of elastic stretch under the primary load. This can only be fixed by the designer and as a result of some experience. For example, the elastic stretch under the load of the columns of the engine illustrated in Fig. 10 is 0.007in., and therefore if it had been decided to permit a stretch of 0.014in. the columns would have been of half the weight. The actual unit stress on the columns is low, so that it is not altogether a matter of factor of safety, but rather of permissible elastic stretch under load which controls the scantlings of the main frames.

In marine oil engines where sea water is used for cylinder cooling it is not advisable to have the water jackets formed as a part of the engine frame, owing to the possibility of serious corrosion taking place. The provision of separate renewable water jackets is therefore necessary.

In the large Naval engines described in this paper, the renewable parts of the cylinder liner water jackets are made from galvanised steel, and this practice has proved satisfactory. In smaller engines the problem of design presents some difficulties owing to the generally restricted space available. A design which has been produced by the Author to overcome these difficulties in small engines has necessitated a variation in the construction of the upper part of the frame, whilst retaining the sling frame construction (*see* Fig. 19). This variation consists in lowering the top girder of the sling frame below the level of the cylinder head seating, instead of having it extending above this level as shown in Figs. 14, 16, 17, and 18.

The heavy top plate into which the top end of the liner was seated and in which the cylinder head studs were screwed is now lower down, but, as before, below the top girder of the sling frame. The separate water jacket extends to the top face of the frame and carries the seating for the top of the liner. On the water jacket there is a shoulder which rests upon the top face of the cylinder head bolt plate, and below this the water jacket extends down to the lower end of the cylinder liner.

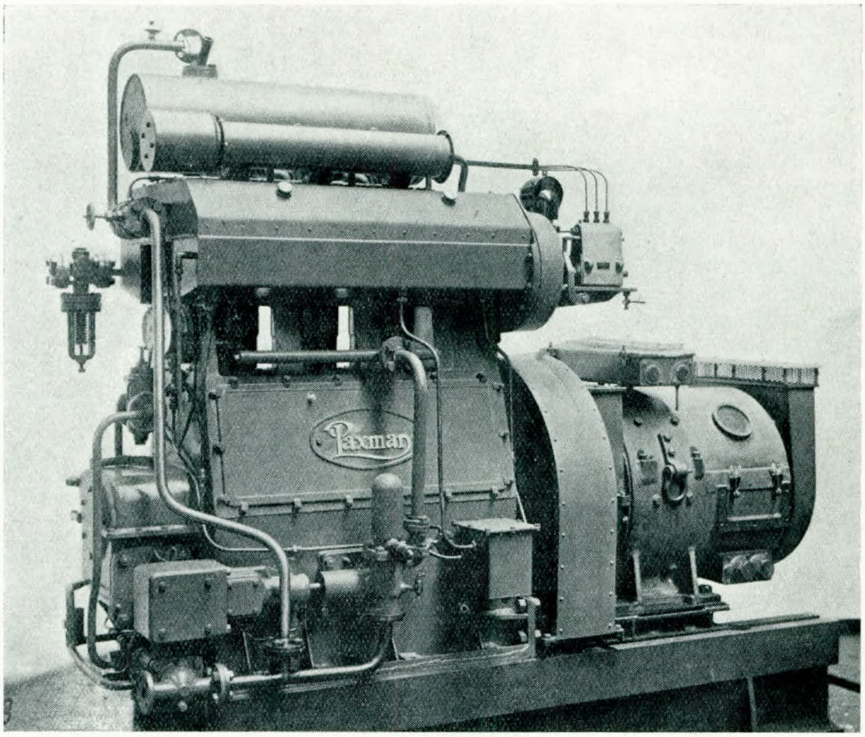

FIG. 15.—Photograph of completed 75-b.h.p. engine and generator.

In place of cylinder head studs, bolts are shown passed up from underneath. It will be observed that the tightening of these bolts holds the head, liner, and water jacket hard down on the bolt plate, and that the compression ignition load is transmitted to the top girder of the sling frame by metal to metal contact as in the other designs. The water entry and exit are shown as bosses for pipe connections, but if the method of conveying the water from the jacket to the cover is by means of a number of small passages, this is easily arranged. The passage of such bosses through the horizontal plates is provided for by cutting suitable gaps. In this arrangement the top of the frame is covered by a light steel plate welded on, which may carry any facings required, or may be machined all over.

In the usual designs of frames having through bolts and castings, the removal of the crank-shaft for renewal or repairs can as a rule only be accomplished by the complete dismantling of the engine, and this is frequently accompanied by the removal of some of the upper structure of the ship, all of which causes considerable expense. The use of a frame which permits of the crank-shaft being withdrawn from one end appears to have distinct advantages. Generally in the Merchant Service this would necessitate an opening in the forward bulkhead of just sufficient size to pass the shaft through, and this could be arranged when designing the bulkhead.

An alternative method is suggested in which short columns are fitted in the frames as illustrated in Fig. 20, which would enable the crank-shaft to be removed from the front of the engine. The crank-shaft is lifted a certain height and bars are laid across below the main journals on which to roll the shaft out. The position of the crank-shaft near the end of its outward movement is shown in the diagram.

By either of these methods the dismantling of the cylinders, camshafts, etc., is avoided, and of the two the removal of the shaft from one end appears to be more advantageous owing to the absence of all bolted joints in the frame, and its rather cheaper construction. There is, of course, nothing new in the idea of removal of the crank-shaft from the end or through the side, both methods having been used in the past, usually on small engines.

The point which it is desired to emphasise is that by the use of the types of frames here described, the crankshafts of large main and

FIG. 16.—320-b.h.p. auxiliary engine. View before outer plate is fitted.

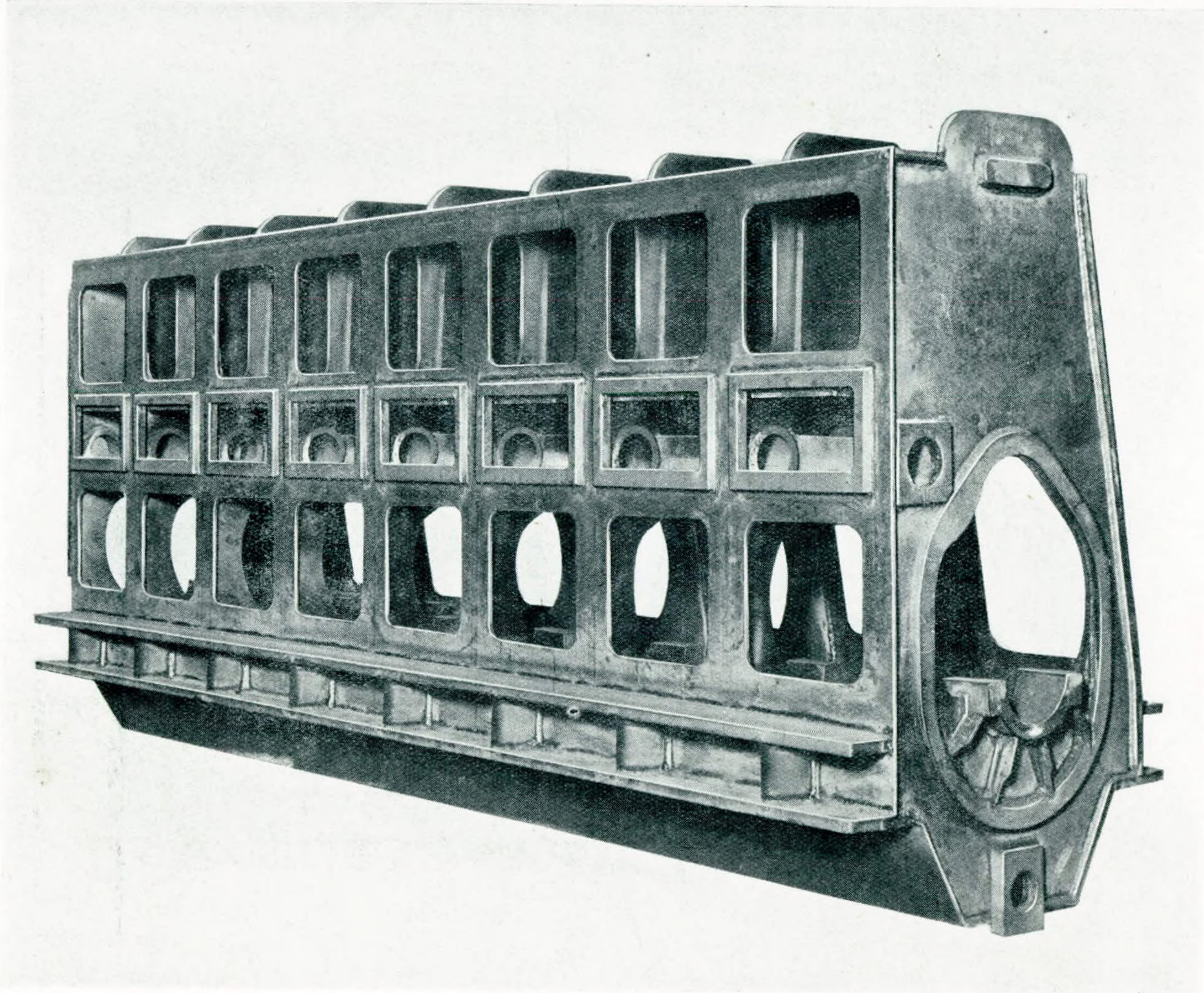

FIG. 17.—320-b.h.p. auxiliary engine. Front of completed frame.

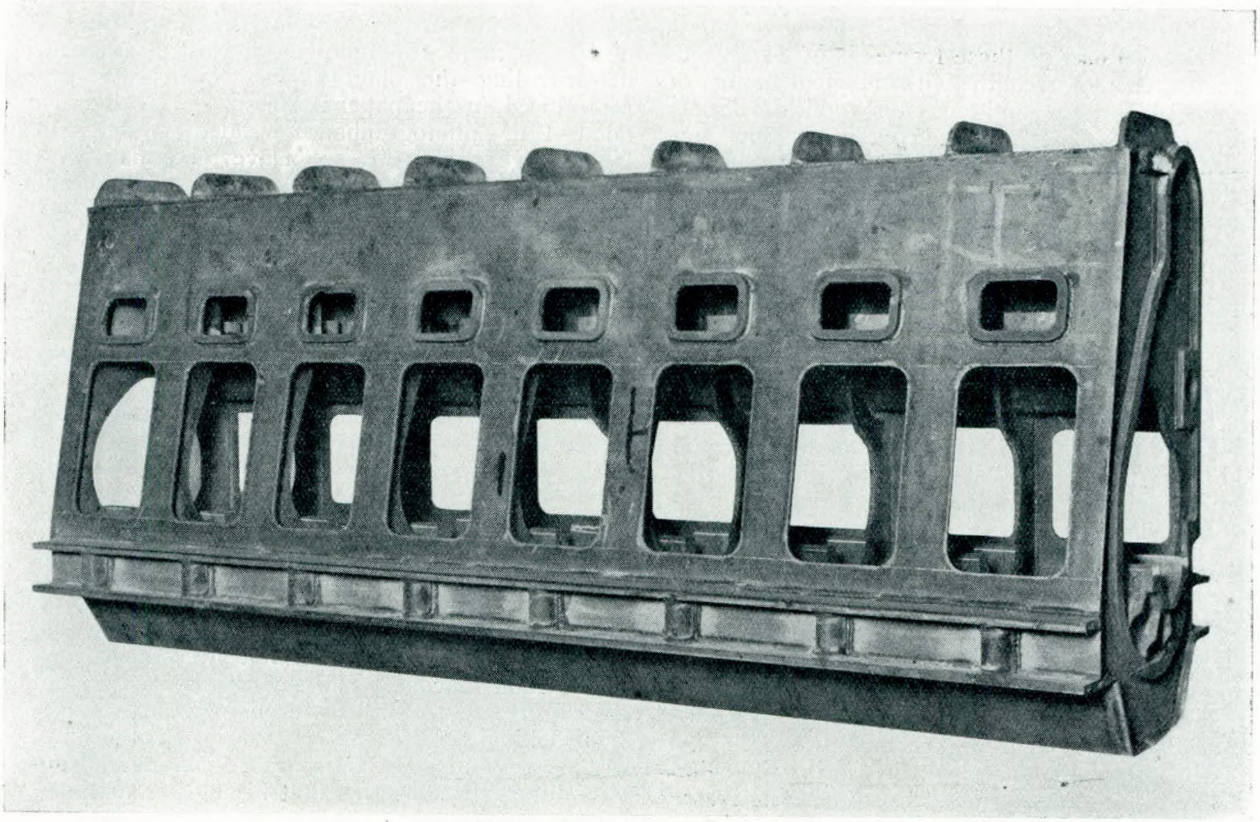

FIG. 18.—320-b.h.p. auxiliary engine. Back of completed frame.

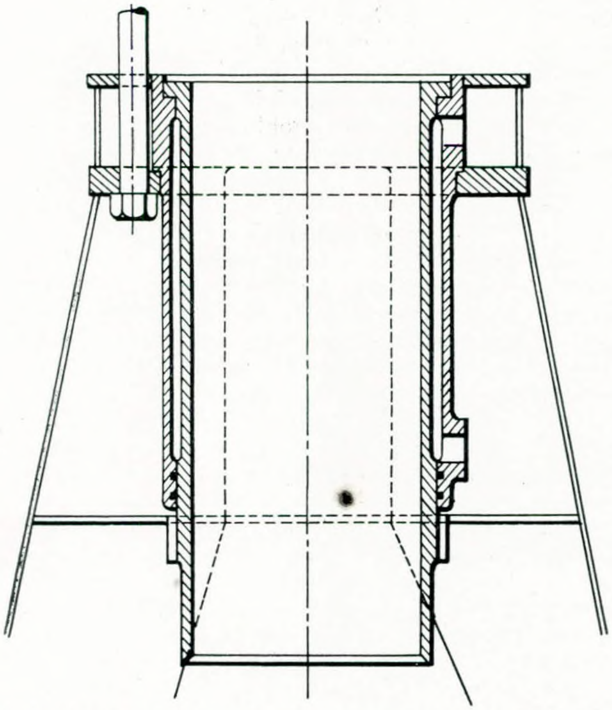

FIG. 19.—Combined sling frame and separate cylinder water jacket.

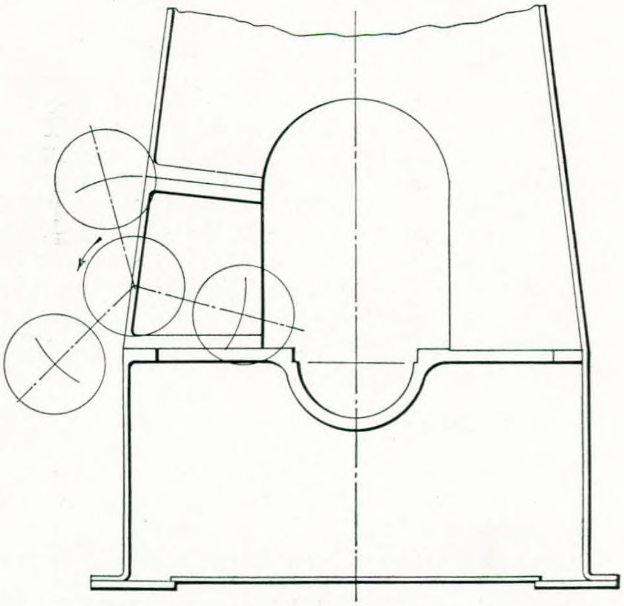

FIG. 20.—Line drawing illustrating removal of crankshaft from front of engine.

auxiliary engines can be more readily and economically removed.

The steel used in these frames is of 24/28 tons ultimate tensile strength with a yield point of around 14/16 tons and an elongation of 25 per cent in 8in. The carbon content is low, not exceeding about ·15 per cent. This quality of steel is, therefore, excellent for electric arc welding, and electrodes are used which give approximately the same physical properties as the parent metal.

The Author takes this opportunity of thanking the Naval Authorities for permitting him to give the description of the Naval engine frames. He also desires to thank the following for their assistance in providing the photographs which have been reproduced in the paper: Messrs. Peter Brotherhood, Ltd.—photographs of welded columns and large sling frames; Messrs. Davey, Paxman & Co. (Colchester) Ltd.—photographs of three-cylinder engine frame; Messrs. G. A. Harvey & Co. (London), Ltd. and Messrs. J. & H. McLaren, Ltd. —photographs of eight-cylinder engine frame.

## DISCUSSION.

**The Chairman (Mr. J. Hamilton Gibson, O.B.E., M.Eng.)** said that there was no doubt that welding as recognised engineering practice had come to stay. They were all, of course, more or less familiar with the smith's ancient method of fire welding, but modern welding by oxygen flame and the electric arc was a highly scientific process which, after many years of research work and against much opposition and prejudice, had arrived at a stage when it was properly regarded as thoroughly reliable if carried out with the usual safeguards of supervision of the work, inspection and testing.

Mr. Stevens had concentrated on an ingenious method of building-up or fabricating engine frames of steel plates and bars by which, as they had heard, a very considerable saving in weight was obtained. There was, of course, increased reliability as compared with cast frames, and in addition there was no question of putting in a lot of work on a casting and then finding that it was a "waster". The practice of welding such structures, in his opinion, was bound to extend.

Later in the discussion the Chairman remarked that the engine frame construction advocated by Mr. Stevens would be subjected to two distinct stresses. First, the primary stresses due to the work which the engine was called upon to do, which put the columns into tension, seemed to be quite straightforward, and he assumed that Mr. Stevens had so designed the framework, by interlocking the parts, that these stresses did not pass through the welds. The second set of stresses, i.e. racking and seaway stresses, were of a different kind and would, of course, come on the welds, which must be of the highest quality.

**Dr. S. F. Dorey** (Vice-President), opening the discussion, said that the paper that evening had been on a subject which might ultimately play a very important part in marine engineering. Mr. Stevens undoubtedly had given very careful attention to this new method of manufacturing frames for engines, and his paper would be of use not only to marine engineers but to land people.

Dr. Dorey thought, however, that the main aim of this proposition should be not to cheapen construction but the production of a superior frame for the purpose intended, which might offer possible future economy. Mr. Stevens' method of construction would, of course, give a reduction in weight, and provided reliability was kept a first consideration this was a desirable advantage. The shipowner looked for a reduction in weight, which was so much less for the ship to carry, but such reduction in weight should not necessarily mean a reduction in cost. The saving in weight would afford the shipowner the economy for which he was looking.

One point about the author's claim regarding reduction in weight was that his figures of 60 per cent. reduction for cast iron and 10 per cent. for cast steel frames suggested that it was possible to have cast steel construction 50 per cent. lighter than cast iron. Dr. Dorey thought that 35 to 40 per cent. could well be claimed for this method of construction.

Mr. Stevens had quite rightly shown that this method of construction should be applied in a manner which would ensure the stresses in the welds being reduced to a minimum, which was a step in the right direction. To illustrate that point Dr. Dorey suggested that even the most fervent enthusiasts of welding might pause to consider whether it would be advisable to weld the whole of the construction to the hull of the vessel itself. Mr. Stevens, in fact, might consider a method whereby he might be able to incorporate the structure which was the subject of his paper in the hull proper, for instance by using welding instead of holding-down bolts. Dr. Dorey thought that such a proposal would cause general consideration of whether welding had not its limitations. After all, experience of breakdowns indicated that failure was generally caused at points of stress concentration, and even with the best of welding he thought that it would be found that there were innumerable places where concentration of stress was likely to arise if the welds were subjected to fluctuating stresses. The best method of construction would therefore appear to be to weld only those portions necessary for stiffness.

Dr. Dorey had had an opportunity of considering a number of the proposals put forward, and had found that the designed stresses were in the main very low and also that the columns and sections proposed were quite suitable for the work intended. There did appear, however, to be rather a lack of rigidity from the point of view of fore and aft thrust and the effective tying of columns, and in more than one case it had been found necessary to increase the fore and aft stiffness.

Mr. Stevens claimed that the welds were all of secondary importance, but Dr. Dorey suggested that the fitting of the side plates to the engine introduced stresses which were not necessarily of secondary importance; in fact, they were of prime importance. Mr. Stevens also maintained that they were not subject to cross shear, but he thought it would be found that in frames of this construction fitted to the main engine of a ship there were considerable possibilities of cross shear taking place.

Was Mr. Stevens able to adapt his method of construction to the crosshead type of engine of, say, 3,000 h.p.?

Dr. Dorey was quite in agreement with the author regarding heat treatment which, wherever possible, was most essential. It would possibly be found difficult to anneal or heat treat the bigger structures, but it might be done in sections. Where it proved to be impossible, multi-run welding might be resorted to. The author had stated that all frames when completed were submitted to a heat treatment consisting of heating up to 650° C. and maintaining that temperature for one hour for every inch of thickness of the thickest plate used, and—an interesting point—that no distortion had been experienced. Dr. Dorey presumed that this applied to the smaller type of construction, not, for instance, to a structure 20ft. long by 9ft. high in one piece. Had the author tested the material which had been subjected to treatment at 650° C., and was any spheroidisation found which could be attributed to using this temperature? Also, had the author tried using temperatures of 570° to 600° C? Particulars regarding the rate of cooling would also be of interest.

Dr. Dorey was in full agreement with regard to the material used by the author, and desired to emphasize the view that a high tensile steel was not called for in this method of construction. It could be used where reduced weight was specially required, but rigidity was the most important factor to bear in mind. Besides, increased troubles would arise through the welding operation with high tensile steel. A good quality low carbon steel with which they were all familiar and soft iron electrodes producing ductile welds would be found to give the most satisfactory results.

To sum up the views of Lloyd's Register of Shipping regarding this method of construction, so long as the proposals put forward were satisfactory, no exception would be taken to them. At present the construction was regarded as novel, and special attention must be given not only to the design but to the methods of construction and the electrodes to ensure that they were satisfactory; extended trials afterwards were also necessary. In fact, where the welds were subject to fluctuating stresses, a guarantee of one or two years might be considered necessary by purchasers. It took a period of time to find out whether any cracking had ensued due to the racking stresses, etc., caused by heavy weather at sea. Unlike the insurance companies, Lloyd's Register had no premiums to consider and were only anxious to ensure that the job was satisfactory. They were in a unique position compared with most other classification societies, insurance companies and government institutions, inasmuch as they were dealing with propositions coming in from all parts of the world and were thus able to keep in contact with all developments in different classes of welding. He thought it well also to mention here that the classification societies in no way wished to hinder progress in engineering, and if the proposition was a sound one they were prepared to accept it.

**Mr. E. P. Paxman** (Messrs. Davey, Paxman & Co. (Colchester) Ltd.) said that his Company had had a certain amount of experience in building engine frames of the construction put forward by Mr. Stevens. They had built small engines for marine use and engines for locomotives up to 400 h.p., and in every case the frames had been entirely satisfactory. Their reason for using this type of frame in marine engines was lightness, and in locomotives it was adopted for stiffness.

Dr. Dorey asked if they were quite certain about end thrust and rigidity. A shunting locomotive which they had built had given no trouble whatever in the two and a half years it had been at work, and in a shunting locomotive the end stresses were extremely high, much higher than would occur in marine work. There was nothing peculiar about the framework, but the construction and the sections of steel used were such that the stresses were low; in fact they were generally found to be much lower than was considered safe.

When using a ductile material such as mild steel one naturally kept on the safe side, and this was done to keep down elongation. The average saving in frame weight was 45 per cent. as compared with cast iron and through bolts, and the design was fairly light to start with.

The cost of the frames in every case considerably exceeded the cost of comparable iron frames, probably due to the small number made and the large amount of hand working and welding.

It had been found advisable to lighten the frame and side plates as much as possible by cutting away material which was not wanted for load carrying, because this gave good access for welding. This seemed to limit the application to small engines, because the welder could not get the electrodes where he wanted them.

In the majority of engines the water jackets were not formed by the main framework, but separate solid-forged steel sleeves were fitted round the cylinder liners and inserted bodily into the frame with them. By this means there was no water in contact with the welded structure itself. This had a three-fold advantage. Firstly, it avoided any corrosion of the welds or of the steel plating and permitted the use of sea water for cooling purposes; secondly, it greatly reduced the weight of water in the engine itself and ensured brisk circulation; thirdly, it avoided having to make the framework itself unnecessarily heavy merely to withstand test pressures in the water jackets on flat surfaces, as would be the case if the whole frame formed the water space.

**Mr. R. E. Strub** (Member) said that it was well known that welded structures of the kind presented in the paper were an entire success, and as far as was known no one had had reason to regret their adoption. In the face of this, it was difficult to find a line of criticism. There was one point, however, which he thought should be referred to, and that was the subject matter of the second paragraph on the first page, where it was mentioned that "the main feature of the designs to be described consists in the fact that the primary load due to compression and ignition is not transmitted through the welding, but is carried by steel members themselves". It had already been mentioned by Dr. Dorey that it was probably doubtful that the stresses due to the ignition were so prevalent as to overshadow every other consideration. Calculation showed that the main stresses due to the ignition were inferior in some instances to the stresses due to the so-called inner couples. This remark applied more to multi-cylinder engines, and therefore to marine engines in the first instance, since the propulsion engine and the marine auxiliary must have a minimum number of cylinders, the former for reversing and the latter for reasons of balance.

These inner couples in multi-cylinder engines were shearing the welds connecting the main bearing frames with the outer skin. The author would find that considerable stresses were set up in some of the engines he had illustrated that evening, and very rightly the author relied on the welds to carry those stresses. It was not clear why the necessity to avoid stresses being carried through welds should be described as a main feature and why special elaborate means should be provided to attain this end. It would be more in keeping with the confidence the author placed in the welds if he carried all the major loads through them, and not only part of them as he did at present.

The makers of marine high-pressure boilers led very high stresses through the welds, and relied in a similar manner to builders of Diesel engines in steel, upon the workmanship. Welding had been so developed that the designer could safely accept specific figures on elongation, Izod and tensile of the weld. These figures were comparable with the figures obtained in the parent metal when the latter was mild steel, and stood each in a certain ratio to the figures obtained in low tensile steel.

The principle of avoiding any ignition stresses being carried through the welds led to the design of the girder plate which was being carried as a sling above the top plate to which the cylinder heads were fixed. This sling necessarily led, in the speaker's opinion, to inconvenience in other respects. The multi-cylinder engine of to-day had to be built as short as possible for reasons of torsional vibrations and to reduce the inner couples. This tendency of shortening the engine was very clearly brought out in the modern ratios of the bore over the distance between bearings. Ten years ago the ratio 1·8 was not uncommon, to-day the ratios went down to 1·25. This meant that every fraction of an inch on top of the cylinder head was precious. For the accommodation of the cylinder heads with the sling plates the engine would necessarily have to be lengthened.

Had the author developed any method of checking the distortion of the whole of the framework after welding? In the experience of the speaker's firm this could quite easily be done by putting a check plate along the main bearings before welding. This plate was dowelled into each of the main bearings. The criterion as to whether the whole structure had deformed during the welding process was that the check plate lifted off without an effort after the whole of the structure had been welded. It would be interesting to hear whether the author made use of a similar device.

**Mr. G. R. Grange** (Messrs. Alexander Stephen & Sons, Ltd.) said that his firm had recently been responsible for the building of two steam engines with welded frames.

The first thing that occurred to the speaker on reading the paper was that Mr. Stevens' design necessitated the withdrawal of the crank shaft from the end. He was not too sure of that method, because when engines were used for auxiliary purposes on board ship the usual method was to have two engines on each side of the ship with their generators between them. That would necessitate spacing them far apart for withdrawing the crank shaft in the space between the two engines. When considering main engines and the withdrawal of the crank shaft fore and aft, great difficulties presented themselves. Aft there was the thrust block and tunnel, and forward there might be oil tanks. The whole arrangement would be spoilt. For main engines the old method of withdrawing the crank shaft upwards still held the field. Fig. 4 showed a crank shaft in position for withdrawal, but it was a six-throw crank shaft and for an eight-cylinder unit the space would have to be much larger.

Due to the large hole which was necessitated in the centre to withdraw the shaft, the stresses were carried round by a circular path and were, therefore, thrown on the fillet welds between the front and back plates and columns; moreover the maximum stress would occur nearest the engine centre line where there was a minimum amount of material. Fig. 20 showed an alternative method of withdrawing the crank shaft from the front of the engine, but this necessitated carrying the main stresses through bolted joints.

When his Company first considered this question two years ago they were of Mr. Stevens' opinion that the stresses between the cylinders and main bearings should not be carried through welds. The result was a design shown in Fig. 21. Two heavy "H" beams were used as the basis of the design. The webs of these beams were split and the outer flange bent outwards. Latticed members were then welded into place and the two columns thus formed were tied together by cast-steel distance pieces forming the main bearings and cylinder supports and a cast-iron guide section. The stresses from the cylinders were carried in a straight line by the inner flange of the "H" beam. The design was put forward as an alternative solution of the problem of designing a fabricated frame with none of the main stresses carried through welds. Two engines of this type were now at sea, and the engine frames showed no sign of distortion or oil leakage.

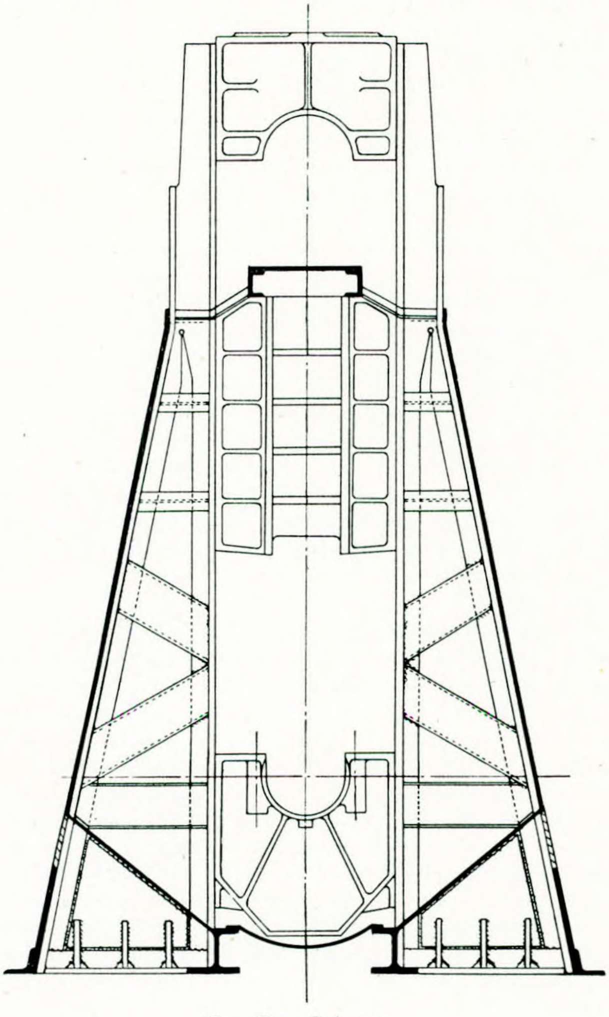

FIG. 21.—Columns.

**Mr. H. N. Pemberton** (Lloyd's Register of Shipping) said that in the design put forward by Mr. Stevens they were encountering something of which they had had very little experience, and he thought it possible that in two or three years' time some of these welded engines might be giving a little trouble. The surveyors would no doubt have to don their oilskins and get inside the engines to see the welds.

In the case of land installations where there was a rigid foundation for the engine, the conditions were not so severe, but when an engine of considerable height was put into a ship the stresses which might be imposed upon it in heavy seaways were incalculable, and he wondered what the effect was going to be on such an entablature as had been shown that evening. He did not think that Mr. Stevens or anyone else could tell, for the simple reason that it had not yet been experienced.

He felt that they should be concerned with obtaining intensive rigidity of the structure and not with reduction of weight, a point which was always advertised about these designs. A construction which was not going to affect the safety of the ship must be aimed at, and the question of reduced weight and scantlings must be very carefully considered.

Mr. Stevens had mentioned a weight reduction of 60 per cent. in comparison with cast iron, and stated that the "weight of the main frames is controlled by the permissible elastic stretch under the primary load". Mr. Pemberton thought that 60 per cent. was a somewhat optimistic figure. From purely theoretical considerations, weight reduction should be inversely proportional to the elastic modulus of cast iron compared with mild steel—slightly modified to allow for the difference in the specific gravity of these two materials. He thought that the proper basis was to allow no greater elastic stretch than would be obtained in a normal cast-iron structure, and in these circumstances it would be found that a weight reduction of the order of 30/35 per cent. could be expected.

In view of the figures given by Mr. Stevens, was it to be assumed that he would allow twice the elastic stretch in a mild steel structure than he would get in cast iron? If this assumption were correct, had Mr. Stevens considered the effect of such an allowance on the nature and magnitude of the stresses in the moving components of the engine, such as the crank shaft, connecting rods, etc.? With the scantlings of these components already reduced to a minimum, Mr. Pemberton thought that the degree of flexure allowed in a welded engine entablature was a matter of primary importance.

Dr. Dorey had mentioned the question of the fore and aft bracing of this particular engine and had pointed out that, whereas Mr. Stevens claimed, and rightly so, that the majority of the welds were of secondary importance, one very important weld was that which attached the side plate to the framing, because it was that plate which gave the fore and aft stiffening. Mr. Pemberton was rather perturbed at the holes in the side plates from the point of view of whether the stiffness was there or not.

In regard to the welding, very little had been said about it, and Mr. Stevens' design rather indicated a lack of faith in the reliability of fusion welds to withstand the very light stresses due to the primary loads. Mr. Pemberton thought that much greater use could be made of fusion welding, provided the welding was carried out under conditions which were known in the welding industry to provide the highest class of joint.

Mr. Pemberton added that in his view a design in which the welds were called upon to take a proper and safe share of the loading would prove to be a more economic proposition than that put forward by Mr. Stevens. The best positions for the welds would be found by a study of the moments of the forces existing in an engine structure under working conditions. It was, however, essential that the permissible flexure in a mild steel entablature should be kept as small as possible.

**Mr. Stanley E. Evans** (Messrs. Murex Welding Processes, Ltd.) said that it should be appreciated that Mr. Stevens had put in several years of hard work converting people to his views, and also it should be remembered when criticising supposed weaknesses that most of the engines had been designed for Admiralty service. From this fact alone, i.e. that they had been accepted by the Admiralty, he thought it could be taken that they did not err on the side of weakness.

Both the representatives of Lloyd's Register of Shipping had referred to what might happen in the future, but Mr. Stevens could give some information regarding what had happened under service conditions to the work already produced.

The speaker could not subscribe to the view that welds should be considered of secondary importance, and he was glad to note that in recent structures Mr. Stevens was using welds for primary stress.

Diesel design in this country lagged behind that of America, where there was no hesitation in putting welds in direct tension or of applying subsequent heat treatment.

Another point was that it was necessary to obtain welds of good contour. It had been pointed out that secondary stresses should be avoided, but no information was offered as to how this should be done, although Dr. Dorey did suggest using multi-run welds. In American designs it had been found necessary to use welds of concave shape, which could only be obtained by expert workmanship. He would like Mr. Stevens to give his opinion of the present standard of workmanship as regards welding in this country.

**Mr. H. J. Vose** (Vice-President) said that they were bound to have failures at first with new things, but those failures must be overcome. One of the most important points in Mr. Stevens' proposals was that the welds were not considered in the construction. Mr. Vose would like the author to alter that and say that the welds would be considered in the construction. In the case of an engine 8ft. or 9ft. high the longitudinal stress would not come into the problem very much, but in a big marine engine of a height of say 20, 30 or 40ft. very considerable longitudinal stresses would exist at various parts. Concentration of stress would occur at points where changes of section took place, and in a big engine the entablature, in his opinion, might break down. He had himself seen failures in big marine engines due to concentration of longitudinal and transverse stresses largely brought about by change of section, and he suggested that Mr. Stevens might consider provision for changes of section and for stresses coming on the weld. Bad weather must bring stresses on these various joints and this would have to be provided for. Welding had come to stay so that it was not a question of the goodness or badness of the welds (these were assumed to be good), but one of making the welds so that they would stand the stresses which might be imposed upon them.

Mr. Stevens spoke about the steel used. Mr. Vose would be in favour of a low carbon content steel, the lower it could be the better for the structure. This would give a quantity of metal sufficient for rigidity and would afford a better chance to weld it. The temperature of the annealing would not present difficulty. Stead's curve for normalising steel was the best criterion for this class of work. Mr. Vose, however, doubted whether it would be any advantage to normalise after welding. A few years ago he had been concerned with the testing of two fabricated steel chests to about 3,600lb. pressure per square inch. At that time he certainly was in favour of annealing the chests after they were fabricated. One of the chests was annealed and the other was not, and strange to say it was the latter which gave the best results in the tests. Unless there was an annealing furnace available (and it would have to be very big for large marine work) with suitable recording and regulating instruments, he doubted very much whether any advantage by annealing would be obtained.

**Dr. S. F. Dorey** interposed at this stage of the discussion to say that he hoped his remarks had not conveyed any sense of alarm. Mr. Stevens had advanced on right lines by getting his experience on small engines and extending it to larger ones. Dr. Dorey considered that Mr. Stevens' method of construction was good, and his remarks were offered as points to be borne in mind by makers of welded structures.

Some large welded engines, e.g. the Doxford engine, lent themselves well to this type of structure, and there were several large two-stroke cycle double-acting engines, plans of which had already been examined, which would have welded construction. So far as Mr. Stevens' construction was concerned, Dr. Dorey felt quite satisfied with the way it had been developed.

**Mr. R. Morton** (Member) said that it should be recognised that the welded frame and developments in welding generally were inevitable. Up to the present a great deal of prejudice against welding had prevailed, but it should be remembered that resort to its use had frequently had to be made, particularly in repair work. There had been many repairs to boilers and Diesel engines which, but for welding, would have meant big renewals.

A notable point was that on a very well-known solid-injection engine the main cylinder fuel pipe, which was subject to a working pressure of 8,000lb., was connected to its tail-piece (perhaps to keep the size within reasonable limits) solely by being butt welded, and had to stand a test pressure of 16,000lb. per square inch. Mr. Morton thought that after a good deal more welding had been carried out, with the consequent increase in skilled workers, much of the present prejudice would disappear.

He thought that it would be very interesting if a welded structure on a large scale were made and tested in all ways to destruction for the purpose of finding out how much the welding was stressed and what was its reaction. This no doubt had been done in a small way. He also thought that the welded frame engine should be supported so that its actual use could be ascertained. In the future, welded frames might give the means of increasing the limited power which at present was obtainable by the use of the Diesel engine.

On the proposal of **Mr. W. A. Christianson** (Member), seconded by **Mr. C. J. Hampshire** (Member), a very cordial vote of thanks was accorded to the author.

## THE AUTHOR'S REPLY TO THE DISCUSSION.

The Chairman, Dr. Dorey, Mr. Vose and Mr. Pemberton mentioned longitudinal, racking and seaway stresses, and the author was of opinion that ample provision had been made in those engines already built and that no difficulty would be found in providing the necessary stiffness for engines of 20, 30 or 40ft. high.

The author might mention one interesting test he carried out when considering the question of the engine seating in the region of the holding-down bolts. A full-size section of the bedplate was made covering the portion of the box-shaped side member of the seating and containing one holding-down bolt, which in this case was 1in. diameter. The combination was then pulled in a testing machine, the top member of the bedplate being held above and the tail of the bolt below. The bolt yielded at 13 tons load and broke under the thread at about 16 tons, whilst no effect could be discerned on the welding of the section of bedplate and seating. Other tests had been made of right-angle connections.

The Chairman mentioned the question of "waster" castings and undoubtedly these appeared with distressing regularity in both cast iron and cast steel. In welded steel parts of good workmanship there were no rejects from faults in material either of the plates or of the welding.

The author was in full agreement with Dr. Dorey's remarks on the main aim of his propositions being to produce a superior frame, and reliability had been the first consideration when fixing scantlings. No weight cutting had been attempted, but owing no doubt to the method of construction a definite reduction of weight had automatically resulted.

Regarding Dr. Dorey's remarks on the welding of the engine frame to the seating in place of the usual holding-down bolts, the author was of opinion that in view of the frequent occurrence of broken holding-down bolts and defects in the seatings themselves, there would be a better distribution of the stresses if the seating and engine were designed to be welded together. This would mean a scrapping of old ideas and the development of a general welded design which would not interfere with the lining up of the shafting. Whether this could be done was a matter for consideration.

As regards fore and aft stiffness, this had been carefully considered and provided for, and no lack of rigidity had been observed. Mr. Paxman had given his view on that subject.

As regards the importance of the welds, what the author claimed was that in these designs they were of secondary importance with reference to the primary load due to compression and ignition, and that they were not used to carry or transmit this load in cross shear.

Regarding engines of the crosshead type, the methods of construction could be adapted to one of 3,000 b.h.p. or up to any power, dimensions or type.

Heat treatment had been applied to all the frames illustrated, including the structure 20ft. long by 9ft. high which was treated in two halves. The steel so treated had been in every case tested by the Admiralty officials and had been found to have retained its original physical properties.

Dr. Dorey's remarks on the views of Lloyd's Register of Shipping were encouraging.

Mr. Paxman had dealt with the question of stiffness and the severe longitudinal stresses which occurred regularly in the 400 b.h.p. engine of a shunting locomotive. The engine had been running about five years.

Mr. Paxman expressed the opinion that difficulties in getting at the welding rather limited the methods for small engines, but these difficulties could be overcome by careful design and some very small engines had been designed where all the welding was easy to get at.

Regarding Mr. Strub's remarks on the stresses due to inner couples, the author would point out that in all the engines so far constructed and running, no difficulties or breakdowns had occurred.

Mr. Strub had referred to welding in use in high-pressure boilers, but a moment's consideration showed that the conditions of stress were not the same as those in a Diesel engine. In boilers there was a constant load in one direction only, whereas in engines there were loads varying from maximum intensity to zero and frequently reciprocating.

Regarding Mr. Strub's objection to the girders of the sling plates standing above the engine, if he would look at some of the designs it would be seen that the condition was optional. As to checking the distortion of the framework after welding, this had been done, but not quite in the same manner as Mr. Strub described.

Mr. G. R. Grange had criticised the proposals for removing the crank shaft from one end, but the author considered that engine room arrangements could be made for this system, both for main and auxiliary engines, to the advantage of the engines and to the reduction of repair costs.

With reference to the clearance required to draw the shaft, the author could not agree that the stresses in the columns were thrown upon the welding of the front and back plates. The columns were designed to carry the stresses without reference to or assistance from the side plates. In spite of the size of clearance hole required to draw the crank shaft, the engines described were the same dimensions across the seatings as the multi-member through-bolt engines they displaced. If in any particular case it was not possible to adopt monobloc frames, then the design details of the multi-member welded steel frames would still be such that no primary stresses were transmitted through the welding.

It should be observed that, as there were no patterns, designs could be constantly altered to suit varying conditions without increasing the cost of the frames. Mr. Grange's illustration of the welded frames for steam engines which his Company had evolved was interesting, but the author was disappointed to see so much of the framework still produced as castings, and he urged Mr. Grange to eliminate castings altogether. From the drawing it appeared that the castings for cylinder entablature and main bearings were bolted to the steel columns with bolts in cross shear, and the author thought that this arrangement would not be satisfactory for an oil engine. The use of standard rolled sections for this class of work was not generally satisfactory.

Mr. Pemberton's doubts regarding the condition of the welding after two or three years might be somewhat modified when he learnt that the first twin-screw set of submarine columns had been in commission since 1931 and that last year a complete examination was made and all welds were found perfect. Incidentally it should be noted that these engines were heavily loaded.

Regarding Mr. Pemberton's remarks on elastic stretch, the author would certainly not allow twice the elastic stretch in a steel structure as obtained in a cast-iron one. Actually in practice iron castings had as a rule a large amount of redundant metal (frequently there on account of moulding considerations) so that the author contended that his estimate of 60 per cent. was not without foundation.

Regarding Mr. Pemberton's remarks on the holes in the side plates, those in the welded design shown were actually smaller than in the multi-member frame they displaced. In addition, all the corners of the holes had been provided with a large radius instead of being square at the bedplate level, and in the region of the diaphragm plate. In connection with the important welding attaching the side plate to the main frames, the practice was to make the two fillet welds of a combined greater strength than the thinner of the two plates, which in this case was the outer plate. The author did not understand Mr. Pemberton's reference to the "very light stresses" due to the primary load. The primary load on one cylinder line of the engine illustrated in Fig. 10 was 112 tons, and the author was definitely of opinion that owing to the fact that half this load was momentarily imposed on one frame on alternate sides, a purely welded attachment would not give the security against failure that he attained by his methods. A further consideration was that, in his opinion, very large welds should be avoided as far as possible so as to get away from the consequent distortion and welding stresses.

Regarding Mr. Pemberton's suggestion that a design in which the loads were transmitted through the welding would prove a more economical proposition than the author's methods, he would point out that the welding was the more costly part of the job and, therefore, the design with least welding would be the most economical. Dr. Dorey, however, had said that he "thought the main aim should be not to cheapen construction, but the production of a superior frame for the purpose intended".

The author expressed his appreciation of Mr.

Evans' preliminary remarks. Regarding performance under service conditions, the welded steel marine engine frames had been entirely satisfactory. Previous to their manufacture, the author had designed and made a column for an engine which had a primary load of 120 tons. This had been constantly at work, frequently heavily overloaded, for a period of five years, without showing any signs of weakness.

Regarding the quality of welding, the author could vouch for its excellence on these frames. The Admiralty requirements as to ability and test had been fully met, and the appearanc of the welding was all that could be desired.

The author specified welds of convex shape, particularly those which were single or double run. His experience was that such welds were less liable to fracture along their centre on cooling and, moreover, they were easier to produce than concave welds. Multi-run welds should be used for all places where the welding was greater than $\frac{1}{4}$in. or $\frac{5}{16}$in. fillet, and the use of larger electrodes than 8 gauge was not favoured. The use of larger electrodes necessitating higher ampère values and resulting in greater local heating was not in his view suitable for this class of work, where the tendency to distortion must be kept to the lowest point.

Regarding Mr. Vose's remarks about failures, the author wished to emphasize that his designs were produced with the idea of avoiding failures and so far none had occurred. The welds had all been very carefully considered in the construction and every weld had been made to dimensions as designed.

Like Mr. Vose, the author had also seen failures in castings due to concentration of stress at changes of section, probably helped by internal stresses in the castings themselves caused by those same changes of section.

With regard to normalising, the author had made many important parts of machinery in welded steel, not normalised, and there had been no failures. The author's view was that the decision to normalise any welded steel structure rested on the question of complication, i.e. if simple it should not be normalised, but if complicated it should. He was also strongly of opinion that in many cases normalising need not be carried out if the structure was such that the welds could cool down naturally and without restraint, and this should be regularly aimed at by a careful study of sequence of welds.

It was not possible to comment on the fabricated chests which Mr. Vose mentioned without knowing to what temperature the chest was heated and the rate of cooling. Any annealing (as distinct from normalising) which reduced the tensile strength of the plates should in no case be permitted, hence the safeguard specification of 680° C. as the upper limit for the heat treatment of the frames.

Mr. Morton laid particular stress on the prejudices which existed against welding. The author had had to fight this prejudice for many years, but had now the satisfaction of seeing it practically disappear.

He once made a certain part of machinery in welded steel which was to be tested to destruction. It was heated up to a red heat and plunged half in water twice, tested several times to 1,000lb. hydraulic pressure and severely hammered whilst under that pressure. This treatment having failed to cause a fracture, the part was finally taken to a powerful hydraulic press and crushed.

# INSTITUTE NOTES.

## FORMATION OF AN EDUCATION GROUP.

As announced in the "Notices" pages in the February Transactions the Council are taking steps to form an Education Group, comprising Members who may be either directly engaged in an educational capacity or specially interested in matters concerning the education of Marine Engineers of all ages and at all stages of their training. The notice is repeated this month, and an early response by those interested will expedite the convening of a meeting to further the objects for which this group is being formed.

## ELECTION OF MEMBERS.

List of those elected at Council Meeting held on Monday, February 25th, 1935.

**Members.**

James Irvine, 1, Thomson Terrace, Montrose, Scotland.
James Kirk, 69, Kelvinside Avenue, Glasgow, N.W.
Thomas John Averell Morrison, c/o Messrs. J. G. Kincaid & Co., Ltd., Engine Shop, East Hamilton Street, Greenock.
John Watson Noble, M.V. "Highland Patriot", Royal Mail Lines, Ltd., Royal Mail House, Leadenhall Street, E.C.3.
Robert Alexander Melville, 31, Thomson Terrace, Rossie Island, Montrose.
Thomas Percy Palmer, 8, Micheldever Road, Lee, S.E.12.
Roman Emil Strub, 3, Pemberley Avenue, Bedford.
Alexander Watt, Asiatic Steam Navigation Co., Ltd., Lyons Range, Calcutta, India.

**Companion.**

George Richard Green, Wickham, Falmouth, Cornwall.

**Associate Members.**

William John Chandler, s.s. "Gambhira", c/o B.I. Engineers' Club, 15a, Kyd Street, Calcutta, India.

Gordon Thomas Collier, 23, Welsford Avenue, Stoke, Devonport.

Leslie John Fulford, 131, South Lane, New Malden, Surrey.

Arthur Norman Gandy, 10, Windsor Terrace, South Gosforth, Northumberland.

Edward Clarence Parfitt, Netherven, Garrison, Barbados, B.W.I.

Thomas William Ross, 2, Crawford Street, Seaton Carew, Co. Durham.

**Associates.**

Guru Prasad Das, 3, Lovelock Place, Ballygunge, Calcutta.

Samuel McEwen, Gillevray, Leyton Green, Harpenden, Herts.

**Transfer from Associate Member to Member.**

George Robertson Kirk, 11, Cliftonpark Avenue, Belfast.

**Transfer from Associate to Associate Member.**

William Helge Cowell Nicholas, 16, Palmer Avenue, Willerby, near Hull.

Alexander Clark Macneill, 374, Langlands Road, Glasgow, S.W.1.

**Transfer from Student to Associate.**

Spencer Oliver Grant, Strathspey, Park Road, Shenfield, Essex.

## ADDITIONS TO THE LIBRARY.

### Purchased.

Department of Scientific and Industrial Research. Report for the year 1933-34. H.M. Stationery Office, 3s. net.

King's Regulations and Admiralty Instructions (Amendments K.R. 12/34, 13/34, and 14/34. H.M. Stationery Office, 3d. net each.

Department of Scientific and Industrial Research, Technical Paper No. 2 on "A Study of the Boundary Lubricating Value of Mineral Oils of Different Origin". H.M. Stationery Office, 9d. net.

"Notes on the Grants to Research Workers and Students". H.M. Stationery Office, 2d. net.

List of the Principal Acts of Parliament, Regulations, Orders, Instructions, Notices, etc., relating to Merchant Shipping issued prior to the 1st January, 1935. H.M. Stationery Office, 6d. net.

### Presented by the Publishers.

"The Lubrication of Compression-Ignition Oil Engines". The Gargoyle Technical Series. Messrs. Vacuum Oil Co., Ltd.

"Parsons 'Simplex Unit' System of Geared Turbines for Cargo Boats". with Report on the Shop Trials. The Parsons Marine Steam Turbine Co., Ltd.

"Great Ship Builders or the Rise of Harland & Wolff", by J. Gordon Peirson. A. H. Stockwell, Ltd., 29, Ludgate Hill, E.C.4, at 1s. 6d. net.

"Some New Heat-Treatable Nickel Non-Ferrous Alloys". The Mond Nickel Co., Ltd.

Britsh Electrical and Allied Industries Research Association. Sub-Committee J/E: Joint Committee: Steels for High Temperatures. Arrangements proposed by the National Physical Laboratory for subjecting steel specimens to the combined influences of stress and corrosion in superheated steam. Bibliography of literature on the behaviour of steels at high temperatures, furnished by "The Engineering Index Service".

The following British Standard Specifications:

No. 32-1935. Steel Bars for the Production of Machined Parts for General Engineering Purposes. (Suitable for automatic, semi-automatic and turret lathes).

No. 587-1935. Motor Starters and Controllers (Excluding liquid starters and controllers and single-phase A.C. Models).

British Corporation Register of Shipping and Aircraft: Register of Ships, 1935.

Diesel Engine Users Association:—

"Some New Developments in High-Speed Oil Engines", by P. Belyavin.

Supplement to Specifications for Lubricating Oils for Use on Heavy-Oil Engines.

Transactions of The Institution of Civil Engineers, Vol. 237, Part I, 1933-34, containing the following papers:—

"Impact of Wheels on Roads", by Aughtie, Batson and Brown.

"The Reconstruction of the Empress Bridge over the River Sutlej on the North Western Railway, India", by Watson.

"Training-Works in connection with the Shortening of the Empress Bridge over the River Sutlej", by Macrae.

"The Working Fluid of Internal-Combustion Engines", by David.

"Equipment for Handling Phosphate Rock at Nauru and Ocean Island", by Bentham.

"Hammer-Blow Impact on the Main Girders of Railway Bridges", by Foxlee and Greet.

"Moving-Load Stresses in Short-Span Railway Bridges", by Gelson.

"Uniform Flow in Alluvial Rivers and Canals", by Lacey.

"The Water Supply of Kano, Northern Nigeria", by Gourley.

"The Respective Merits of Roads and Railways for Colonial Development", by Spiller.

Transactions of The Institution of Mechanical Engineers, Vol. 127, 1934, containing the following papers:—

"Gas Works Practice", by Birks.

"Liverpool and the Atlantic Ferry", by Austin.

"The Green Plant as Agricultural Engineer". Thomas Hawksley Lecture by Keeble.

"The Operating Temperatures of Cast Iron and Aluminium Pistons in a 12-inch Bore Oil Engine", by Baker.

"Force Fits and Shrinkage Fits in Crank Webs and Locomotive Driving Wheels", by Coker and Levi.

"The Work of the Alloys of Iron Research Committee", by Desch.

"The Embrittlement of Low-Carbon Steel", by Lea and Arnold.

"The Work of the William Froude Laboratory, with a Bibliography", by Johnson.

"The Evaluation of Coal with particular reference to Small Coal for Steam Raising", by Grumell.

"The Part Played by Mechanical Excavators in World Progress", by Bone.

## *Additions to the Library.*

"The Evolution of Design", by Gibb.
"Engineering Contracts", by Plevin.
"The Development of Inventions", by Gledhill.
"Bauer-Wach Exhaust Steam Turbines", by Crossley.

"Schools, 1935", 12th Edn. Truman & Knightley, Ltd., 61, Conduit St., W.1, 740pp., 2s. 6d. net, post free 3s. 3d.

That twelve editions of this work have now been issued is very definite support for the publishers' claim that it is the most useful and comprehensive guide obtainable to the scholastic facilities of Great Britain. It has been brought up to date, and we can unhesitatingly recommend it to any of our Members anxious to obtain information regarding a suitable school for the education of his children.

"Riveting and Arc Welding in Ship Construction", by Commander H. E. Rossell (CC), U.S.N. Simmons-Boardman Publishing Co., New York. Distributed in this country by Messrs. Crosby Lockwood & Son, Ltd., 210pp., illus., 12s. 6d. net.

In this very useful book comparison has been made between riveted and welded joints as used in the construction of United States warships. The early part of the book discusses riveting work, both oil-tight and watertight, the design of riveted joints and special features of riveting practice. This section contains little new information but affords an interesting survey of standard riveting practice.

The second half of the book deals with welded joints and the three chapters of which it consists cover the "Design of Welded Joints", "Special Constructional Design Problems" and "Practical Considerations". The thorough manner in which Commander Rossell covers the ground included in his discussion of metallic arc welding renders this book one which will be regarded as of special value to draughtsmen and designers who are anxious to obtain the most up-to-date methods of tackling welded designs.

One section—Chapter 2—is particularly valuable as it gives quantitative methods for evaluating stresses in welded joints taking account of complex stresses. While this section is rather theoretical in treatment it is well worth careful study.

"The Theory of Vibrations for Engineers", by E. B. Cole, M.Sc. Crosby Lockwood & Son, Ltd., 263pp., 115 illus., 15s. net.

The author in writing this book has performed a very useful service in bridging the gap between pure mathematics and the application of mathematics to important problems in engineering design. The careful explanations of the physical meaning of mathematical equations should do much to clarify the principles involved.

The writer feels, however, that a good deal of extra information could have been included to help still further the engineer engaged on design work. Such information may be summarised briefly as follows:—

(1) Harmonic analysis of indicator cards for—
    (*a*) steam reciprocating engines;
    (*b*) petrol engines;
    (*c*) heavy oil engines, single and double acting;
    (*d*) air compressors.
(2) Notes dealing with propeller damping.
(3) Details of the principles involved in the design of the "dry friction" Lanchester dampers and in the design of damped and undamped dynamic vibration absorbers.

Mention is made on page 70 of the elasticity of crank shafts and in this connexion the writer believes it would have been helpful if both Major B. C. Carter's and Dr. Geiger's formulæ had been included so that these could be directly applied. Estimation of engine damping factors has not been included; no doubt the author feels that so little is known at present about this subject that the problem of estimating stress should not be attempted. It will be realized how vitally important it is to the engineer engaged on design work to be able to predict stresses set up at critical speeds within the running range. Information affecting engine damping is therefore of great importance. Where stresses are of a high magnitude, damping due to elastic hysteresis may become appreciable. In the case of engines, however, other damping forces are at work which limit the stresses at resonance.

Knowledge gained in recent years regarding both vibration and fatigue properties of materials has done much towards elucidating the causes of failures which hitherto were obscure, and it is the reviewer's opinion that this book is well worthy of careful study by engineering students.

"Second Year Engineering Science—Mechanical", by G. W. Bird, Wh.Ex., B.Sc. Sir Isaac Pitman & Sons, Ltd., 236pp., illus., 5s. net.

This book, by the author of several well-known textbooks on mechanics and machine design, is intended to meet the needs of students preparing for the second year (S.2) of the National Certificate Course. This standard, whilst varying slightly in different parts of the country, is maintained at a fairly uniform level by the requirements of the examining bodies. It may be said that this book will more than meet those requirements.

The author has adopted a new, or rather unusual, method of attack. Whilst preserving a logical sequence of exposition, he has endeavoured to link up the principles, ofttimes shrouded in mystery, with modern practice. For example, the chapter on friction, which in many cases having stated the "Laws of Friction" deals with the inclined plane and a profusion of $\cos \theta$, in this book discusses plain and roller bearings and the effect of lubrication. There is also an excellent chapter on belting and gears. Whilst the purist may decry this "practical" mechanics, there is no doubt that to many students the association of ideas will prove decidedly advantageous. Approximately half the book deals with mechanics plus a little hydrostatics and hydraulics, the other half dealing with engines and boilers. A very useful introduction to the slide rule is also given.

Wherever examples of modern engineering practice are shown, they are in general modern, but the reviewer would suggest the substitution of a modern Yarrow boiler for the type illustrated on page 146.

There are many worked examples and examples to be worked, and the reviewer was impressed by the freshness of outlook displayed throughout the text. The illustrations are exceptionally clear and well lettered. A small misprint occurs on page 26 where $O$ is written for $\theta$ (second paragraph).

Reviewing books is not an easy task. One has to avoid prejudice and be fair and candid. This is a point not always appreciated by authors and publishers. In this case the reviewer, in order to avoid prejudice, allowed a second-year student to review the book independently. His criticism was "that he could follow the work on mechanics, but he enjoyed the heat engine section immensely". Allowing for the immaturity of the student's mind, the reviewer regards that as an endorsement of his own views. Mechanics is notoriously a hard subject to grasp, but Mr. Bird has gone a long way in this book to make the pursuit easier. Incidentally, the untimely decease of the author is greatly to be deplored.

## JUNIOR SECTION.

### The Lubrication of Marine Engines.

A well-prepared and informative paper on the above subject was delivered by Mr. E. R. Chamberlain (Student) at a meeting of the Junior Section on Thursday, February 14th, 1935, under the Chairmanship of Mr. H. R. Tyrrell, B.Sc. (Associate). The author dealt fully with the special problems associated with the lubrication of steam reciprocating engines, turbines, and Diesel engines for main propulsion, also of machinery other than main engines, including refrigerating machines. He followed with a discourse on the principles of lubrication, the physical and chemical testing of lubricants, and the storage of lubricants on board ship.

A number of interesting points were raised by speakers in the subsequent discussion, and the author replied to the complete satisfaction of his questioners.

A vote of thanks to Mr. Chamberlain was accorded with enthusiasm on the proposal of Mr. E. W. Cranston (Associate).

# ABSTRACTS.

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

## BOARD OF TRADE EXAMINATIONS.

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

| Name. | Grade. | Port of Examination |
|---|---|---|
| **For week ended 7th February, 1935:—** | | |
| Livingstone, Robert L. | 1.C. | Glasgow |
| McArthur, Walter | 1.C.M. | " |
| McDowall, John | 1.C.M. | " |
| Gifford, Harry | 1.C.M.E. | " |
| Ingram, Harry | 1.C.S.E. | " |
| Fowler, William L. | 1.C. | Newcastle |
| Peek, Edward R. H. | 1.C. | " |
| Stonehouse, Robert W. | 1.C. | " |
| Smith, James C. | 1.C.M. | " |
| Waterston, John W. | 1.C.M. | " |
| Eyres, Geoffrey M. | 1.C.M.E. | " |
| Jones, Arthur D. | 1.C.M.E. | " |
| Hetherington, William C. | 1.C.M.E. | " |
| Herridge, Maxwell C. | 1.C.M.E. | " |
| Fletcher, Gardner C. | 1.C. | Liverpool |
| Keenan, George | 1.C. | " |
| Robertson, James W. G. | 1.C. | " |
| Randles, Benjamin R. | 1.C.M.E. | " |
| **For week ended 14th February, 1935:—** | | |
| Thomas, Thomas G. | 2.C. | Cardiff |
| Tibbles, Robert H. | 2.C. | London |
| McIntyre, Andrew D. | 2.C. | Glasgow |
| McKnight, Robert E. R. | 2.C. | " |
| Wilson, William | 2.C. | " |
| Thomson, George L. | 2.C.M. | " |
| Jefferson, Norman | 2.C. | Newcastle |
| Johnson, David M. P. | 2.C. | " |
| Storey, James | 2.C. | " |
| Boll, Clement | 2.C.M. | " |
| Wandless, Joseph A. | 2.C.M. | " |
| Mason, Philip W. | 2.C. | Liverpool |
| Wheeliker, George H. | 2.C. | " |
| Downey, Joseph | 2.C.M. | " |
| Nevison, Walter | 2.C.S.E. | " |
| **For week ended 21st February, 1935:—** | | |
| Brown, John W. | 1.C. | Newcastle |
| DuCros, William C. | 1.C. | " |
| Black, William A. | 1.C.M. | " |
| Gane, Gilbert R. | 1.C.M. | London |
| Gunnell, John J. | 1.C. | " |
| Carson, Henry | 1.C. | Liverpool |
| Qualters, Francis J. | 1.C. | " |
| Simpson, John | 1.C. | " |
| Kirk, George R. | 1.C.M. | " |
| Roberts, R. J. | 1.C.M. | " |
| Knight, Ervistus | 1.C. | Cardiff |
| Morgan, Josiah L. | 1.C. | " |
| Ogram, George E. | 1.C. | " |
| Dewar, Robert | 1.C. | Glasgow |
| McCutcheon, John | 1.C. | " |
| Kirkpatrick, David | 1.C.M. | " |
| Martin, Thomas | 1.C.M. | " |
| Rennie, William | 1.C.M.E. | " |
| Stewart, John F. | 1.C.M.E. | " |
| Calderhead, Raymond C. | 1.C.M.E. | London |
| Gillan, Donald | 1.C.M.E. | Newcastle |
| Freeman, John R. | 1.C.M.E. | Liverpool |
| Sowden, Frederick J. | 1.C.M.E. | " |
| James, Thomas G. | 1.C.M.E. | Cardiff |
| Pollard, Charles | 1.C.M.E. | " |
| **For week ended 28th February, 1935:—** | | |
| Whittet, Thomas | 2.C. | Glasgow |
| Leaf, Albert R. | 2.C. | Liverpool |
| Hannah, Lloyd | 2.C.M. | " |
| Smart-Dalgleish, John G. C. | 2.C.M. | " |
| Graham, Evan G. T. | 2.C. | Newcastle |
| Harrison, Nicholas W. | 2.C. | " |
| Clements, George | 2.C.M. | " |
| Thomson, George K. | 2.C.M. | " |
| Abraham, Leslie T. | 2.C. | London |
| Davidson, Patrick D. | 2.C. | " |
| Leigh, Henry J. A. | 2.C. | " |
| Cockburn, Matthew | 2.C.S.E. | Newcastle |

## Modern Marine Switchboards.

Multiple Motor Starters.

Electric Control Gear in the "Dorset".

"Journal of Commerce", 7th February, 1935.

In this ship the whole of the auxiliary machinery is electrically driven, the generators being controlled and the power distributed by a main switchboard supplied by the General Electric Co., Ltd., and built at Witton; this switchboard also embodies a G.E.C. plural starter equipment for all the engine-room motors. All the electrical equipment was installed by the Sunderland Forge and Engineering Co., Ltd.

The main switchboard is of the flat back type, built up of 17 slate panels, which are bevelled and finished in polished black enamel. Four panels control one 220kW. and three 300kW. direct current generators, which supply power at 220 volts. On the left of the generator panels are arranged four feeder and two battery charging panels, while on the right are the seven plural starter panels.

Protective Relays.

On each generator panel are mounted a triple pole line-contact circuit breaker, ammeter, shunt regulator, and the necessary protective relays. The line-contact circuit breakers are equipped with shunt trips and overload trips, and are rated to carry 1,000 amps. and 1,500 amps. for the 220kW. and 300kW. sets respectively. Protection is given against reverse current, while two time delay relays are provided. These relays operate at predetermined intervals, which are adjustable up to 5 and 10 seconds respectively, so that in the event of a sustained overload, certain of the less important circuits are cut out. If the overload still persists all but the essential circuits are cut out after a further interval. Should this not relieve the overload, the generators are then isolated from the switchboard by the operation of the overloads on the circuit breakers and the battery takes over the supply to all essential circuits. Two sector voltmeters mounted on a swinging bracket indicate the generator and busbar voltages.

The feeder panels control the supply to air compressors, winches, refrigerating plant and galley equipment, each panel being arranged to control two circuits and carrying two double pole line-contact circuit breakers. The capacities of the breakers range from 400 to 2,500 amps, protection being provided against voltage failure and overload. Ammeters are provided in each circuit, and along the bottom of the panels are fitted 25 double-pole knife switches and Handguard fuses, which control various lighting and auxiliary circuits. These circuits range in capacity from 50 amps to 200 amps. Provision is made whereby certain of these circuits can be supplied from the battery in the event of an emergency.

### Battery Control.

The panels at the left hand end of the switchboard control the charge and discharge of a 110-cell battery, which is split into two 55-cell sections. On these panels are mounted a 400-amp. line-contact circuit breaker, which controls the incoming supply from the main bus-bars, a triple-pole change-over contactor, voltage relay, ampere-hour meter, and the necessary voltmeters and ammeters. From the panels a supply is provided through two 200-amp. knife switches with Handguard fuses to the steering gear equipment, and to the secondary busbars which feed certain of the lighting circuits and essential auxiliaries.

Normally the load is carried by the main generators, the change-over contactor being in position for charging the battery, the two sections of which are connected in parallel. An alarm bell, which operates in conjunction with the ampere-hour meter, gives audible warning when the battery is fully charged, provision being made for transferring the battery on to trickle charge by opening two single-pole knife switches.

Should the voltage of the busbars fall below a predetermined figure, the voltage relay operates and the change-over contactor isolates the panel from the busbars, at the same time connecting the two sections of the battery in series and enabling it to take over the supply to the steering gear equipment and other essential lighting and auxiliary circuits. Immediately the busbar voltage is restored, the voltage relay again operates and transfers the load back to the main generators, the two sections of the battery being automatically re-connected in parallel and put on charge.

Of the seven plural starter panels, that at the extreme right hand end of the board carries two motor-operated drum type starters, one of which serves as a standby, a seven-pole change-over switch being provided to connect either of the starters in service. Provision is also made for emergency operation by hand. On the remaining six panels are mounted the contactors for starting 18 motors, ranging from 5 to 60 h.p.

### Multiple Motor Starters.

With this system it is possible to start all the motors through one starter. For this purpose each motor is provided with a control unit, which is mounted near to the machine. This unit embodies "stop" and "start" push buttons, shunt regulator, ammeter, isolating links and pilot lamp. Each of these units starts its machine through the drum starter on the main switchboard, this drum making one complete revolution at each start. In order to give a longer starting period for the larger machines, the motor driving the starter is provided with two independent field windings. One of these is a light shunt winding, so designed that the starting time is short and suitable for the smallest machines. The second winding acts in conjunction with the first, and is connected across the starting resistance. When starting the larger machines, the sustained voltage drop across the resistance energises the winding and strengthens the motor field, giving a proportionally longer starting period.

The resistance is designed to have a total ohmic value high enough for the smallest machine, while the later steps are of ample section to deal safely with the starting current required by the largest machines.

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## First Marine Mono-tube Super-pressure Boiler.

"The Engineer", 15th February, 1935.

The first order for a marine type mono-tube extra high-pressure boiler has been placed with Sulzer Brothers by the Rotterdam Lloyds. It is to be installed on the single-screw steamship "Kertosono", which has five Scotch type boilers, one of which is to be replaced by the new boiler. The ship has a double casing turbine and a new high-pressure turbine is to be introduced between the high-pressure and low-pressure casings.

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## Diesel-geared Tug.

"The Engineer", 15th February, 1935.

An order for an unusual type of paddle tug has been placed with the Ardrossan Dockyard, Ltd. The vessel can best be described as an independent paddle-wheel heavy oil engined tug, propelled by two main oil engines, each coupled to the paddle wheel through a clutch, patent flexible coupling, and a geared reduction gear, this method being considered preferable to the Diesel-electric system. The tug has been designed for towing two 300-ton lighters on the river Euphrates.

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## Conversion of the "Siantar".

"The Marine Engineer", February, 1935.

The Rotterdam Lloyd fleet consists nowadays of modern motor vessels; not all of them are new ships, however, since several of their older units have been converted from steam to Diesel drive. In this class comes the "Siantar", converted during 1934. The old propelling plant consisted of single-screw steam turbines developing 3,000 s.h.p., and giving the ship a speed of 12 knots. The new machinery comprises two De Schelde-Sulzer two-stroke cycle double-acting oil engines driving the single propeller shaft through Vulcan fluid couplings and single-reduction gearing. The cylinders are 530mm. by 760mm. stroke, the engine speed being 215 r.p.m., which is reduced to 98 r.p.m. at the propeller.

The new power is 7,000 s.h.p., which gives a speed of 15½ knots. The consumption of fuel oil when the ship was propelled by the turbines developing 3,000 s.h.p. was 36 tons per day, while now the daily consumption of the oil engines developing 7,000 s.h.p. is no more than 31 tons. Alterations to the hull were necessary when the increased power was adopted, a new stern lengthening the vessel by 30ft. and giving finer lines to the run.

The original dimensions of the ship were 433ft. by 57ft. 6in. by 37ft. 4in., with 30ft. draught. The old electric generating sets comprised two steam turbo sets by Clarke, Chapman & Co., Ltd., and one small Diesel set. Of the four old cylindrical boilers two have been retained for producing steam for the auxiliary generators; at sea a waste-heat boiler used in connection with the main engines produces the necessary steam.

The calculated weight of the new propelling installation is 439 tons, while a slow-speed (98 r.p.m.) engine directly connected to the propeller would have weighed 610 tons — neither weights including the shafting.—*Journal de la Marine Marchande,* September 13, 1934.

### The Elimination of Vibration.

"The Motor Ship", March, 1935.

A considerable literature is being built up around the subject of torsional vibration and ship vibration generally, and belief is growing that the solution of the problems relating to it are capable of exact mathematical analysis. On the other hand, a well-known superintendent engineer remarked recently that the building of a vibrationless ship was still largely a matter of luck!

Two books on torsional vibration have just been published, and the paper on "Ship Vibration", read on 22nd February by L. C. Burrill before the North-East Coast Institution of Engineers and Shipbuilders, was largely concerned with the problem so far as it bears a direct relationship to oil-engined vessels.

There is no doubt that more confidence will be felt in the reliability of calculations relating to ship vibration and torsional vibration if it can be demonstrated that the theoretical results are borne out in practice. As Mr. Burrill mentioned, it is very difficult, as a rule, to confirm theoretical data in the case of cargo ships, since the trials seldom are run with the vessels in a loaded condition.

The author of the paper has established a method of dealing with changes of loading and draught in order to overcome this difficulty to some extent, but this cannot carry the same weight as direct confirmation of theoretical anticipations on official trials.

If shipbuilders and shipowners would co-operate, more information could be obtained, for it is not always out of the question to arrange for a cargo-ship's trials to be carried out in a loaded condition. Passenger liners can, in most instances, be loaded down to their normal draught, whilst with tankers, the fully laden conditions can be obtained with the greatest ease. Mr. Burrill suggests that records of criticals for actual vessels, taken as part of a trial-trip routine, would be valuable, as enabling the designer to know approximately the range of revolutions liable to give trouble for any proposed ship. With this we are fully in agreement.

An interesting point is brought out by the author in showing that whereas vibration is to be expected at normal Diesel engine revolutions in tankers below 400ft. in length, the criticals of large tankers above this length are more likely to coincide with the lower revolutions per minute usually associated with steam reciprocating engines. As practically all motor tankers now built for normal long-distance voyages have a measurement of over 400ft. in length, the problem of vibration in them seems, therefore, scarcely to arise.

### Circulation in Boiler Tubes.

"Shipbuilding and Shipping Record", 7th February, 1935.

In the operation of water-tube boilers it is very desirable that a uniform speed of circulation should be maintained through all the tubes. If, as a consequence of their proximity to the hot furnace gases, the circulation is very rapid in the front rows of tubes, there is a tendency for stagnant steam to gather in the rear tubes with the result that grooving or pitting occurs, this being followed by overheating and corrosion. The provision of one or two rows of tubes immediately adjacent to the furnace of larger diameter than the remainder tends to overcome the tendency for excessive circulation to occur in the front rows, but it introduces obvious disadvantages of a mechanical nature. As an alternative, a system has been developed in the United States whereby, by the use of what are termed restrictors in certain tubes and of central cores in others, the effects of stagnation have been satisfactorily overcome. The restrictors which take the form of orifices are placed in the ends of the lower rows of tubes, while cores in the form of round rods are placed in the upper tubes, the effective cross-sectional area of which is thereby reduced to about one-half. The reduced circulation in the lower tubes combined with the limitation of effective area in the upper ones ensures a vigorous annular flow which effectively sweeps the stagnant steam from the tube walls.

### Automatic Tube Expander.

"Shipbuilding and Shipping Record", 7th February, 1935.

When the tubes of a boiler, condenser or any other form of tubular heater or cooler are secured to the tube plate by the simple process of being expanded in position, there is always the risk that excessive pressure may lead to cracking or at least to molecular deterioration of the material of the tube which sooner or later may lead to failure. In order to eliminate the risk of over-expansion, an automatic tube-expanding machine has been developed in Germany in which as soon as the desired degree of expansion has been attained, the pressure is relieved. The expander is of the usual form consisting of three steel rollers which are rotated against the interior surface of the tube by a slowly-advancing slightly-conical shaft, the shaft being driven by an electric motor. The end of the shaft adjacent to the motor carries a system of toothed wheels which drive the sleeve nut used for giving the slow forward movement of the shaft. This mechanism is, however, so designed that as soon as the tube is tightly pressed against the hole in the tube plate, the resistance to the forward movement of the shaft causes the nut to move backwards, disengaging a coupling and stopping the rotation of the nut. Owing to the continued rotation of the shaft, it now moves in the reverse direction, thus releasing the pressure on the expanding rollers. A powerful spring is used to control the movement of the nut and equilibrium is thus established between the compression of this spring and the pressure exerted by the rollers on the tube.

### Long-range Gun Fire.

"The Engineer", 8th February, 1935.

On 23rd March, 1918, Paris experienced for the first time a bombardment with high-explosive shells, which had been fired from a gun mounted in the forest of St. Gobain on the German front at the unprecedented range of 75 miles. These shells were 8·28in. in diameter, weighing 330lb., and fitted with long hollow ogival heads. It has been calculated that the muzzle velocity of the gun was 5,000 foot-seconds, or nearly 1 mile per second, and that the velocity of arrival of the shell was 2,626ft. per second. The velocity of arrival of the shell being over double that of sound in air, it was impossible to hear it coming. In the course of its flight the shell passed into the stratosphere, the highest point of its trajectory being 24 miles above the earth's surface, or four times the height of Mount Everest.

There is no reason, other than difficulties of manufacture, why guns should not be constructed for a much higher muzzle velocity even than this, to throw shells to a much greater distance with considerable accuracy.

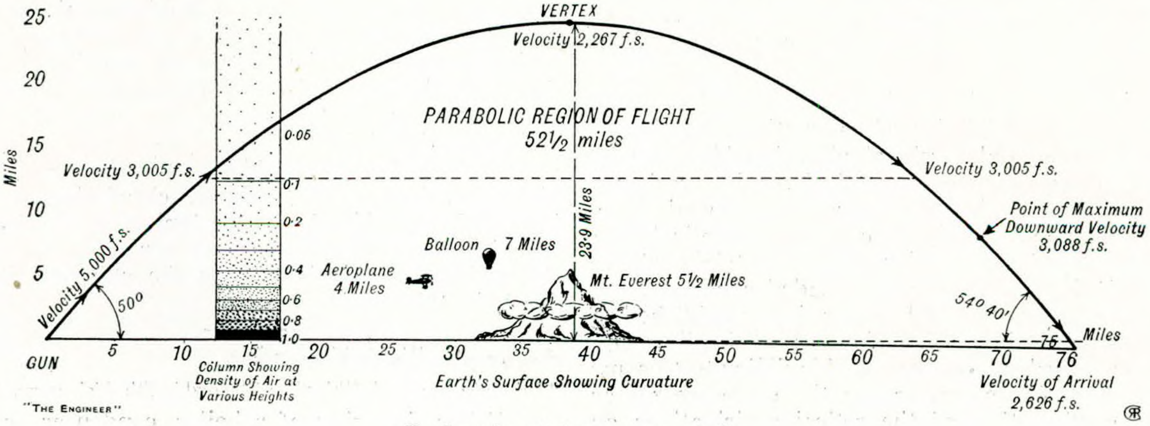
Three-quarters or more of the trajectory would be practically in vacuo, where no disturbing influences would deflect the path of the shell.

### High-pressure Boiler Troubles.

"Engineering", 1st March, 1935.

The water available for steam boilers invariably contains impurities in greater or less degree, even when it is for the most part returned condensate, the impurities being of different natures, scale-forming or corrosive. The prevention, or at least the minimising of scaling and corrosion, has long been a matter of concern to boiler engineers and owners, and many methods, scientific and "rule-of-thumb", elaborate and simple, some successful and others faulty, have been devised and adopted to provide relief. The reports of boiler insurance companies and of Board of Trade inquiries into explosions show what serious consequences may follow if the measures employed to protect boilers from troubles on the water side are inadequate, unsuitable, or carelessly applied.

A boiler is nothing less than an autoclave in which chemical and physical phenomena of considerable complexity take place. These affect the quantity and nature of the solids that may be thrown down, often being deposited on the heating surfaces, and interposing undesirable resistance to the flow of heat with a resultant rise in the temperature of the metal. They also influence the liberation of gases and acids which may lead to



Trajectory of long range shell.

corrosion, and the formation of compounds which, with the accompaniment of mechanical stress, may cause the metal to crack.

Substances added to the water to cure some of these ills form products which give rise to troubles of their own, and still more "dopes" are required to counteract these in their turn, and so on.

The knowledge resulting from research and experience with waters at former pressures and temperatures is by no means adequate to deal with the chemical and physical problems met with in the advanced designs of to-day, in which both high temperatures and pressures introduce complexity, while the metal itself is much nearer the danger point. The late Mr. J. Anderson, of Milwaukee, was, we believe, one of the first engineers to draw attention to these problems, and to place on record his experiences of the troubles met with. They were described in a very interesting paper he contributed in 1928 to the proceedings of the Institute of Fuel.

It has been pointed out that damage traceable solely to conditions of water flow occurs only in tubes in which the water descends and which are exposed to heat, and the theory is advanced that if the velocity of the rising steam bubbles is identical with that of the downward water in which they are immersed, the bubbles will be stationary, and may thus remain in contact with one part of the tube for an appreciable time. Overheating, dissociation of the steam, and corrosion of the tube follow in due course. The inference is that in high-pressure boilers, in none of the tubes in which water descends should steam generation be permitted. This trouble, too, is therefore curable. The conclusion of the German report of 1931 was that "the operation of high-pressure boilers is to-day free from objection. There is no fundamental connection between corrosion and high pressure as such".

It is significant that much of the discussions at recent meetings was directed, not to the question of care of the boiler, but to that of "carry-over", or purity of the steam.

Carry-over is detrimental to the superheater, where it may lead to overheating due to internal deposits, and has also become a matter of serious concern to turbine engineers, as it may lead to rapid diminution of power output. Mr. Anderson, in 1928, cited a case of turbine output being reduced from 6,500kW. to 4,000kW. in three days as a result of the deposit of feed treatment chemicals on nozzles and blading. Mr. H. L. Guy last month referred to a turbine, the output of which was reduced from 50,000kW. to 40,000kW. in a month due to this cause, and spoke of an attempt to overcome such a possibility by the design of a boiler in the steam drum of which a scrubber had been fitted to clean the steam before it entered the main.

In certain systems of water treatment, such as those employing colloids, the prevention of scale-formation depends upon the solids separated from the water being in the form of non-adherent sludge. It is clear that the tendency to foam and prime, and the increase of carry-over will be marked when such systems are adopted. Again, a sludge of this description may settle into a deposit during periods when the boiler is banked, and may subsequently arrest circulation by partially blocking up tubes, thus leading to eventual failure. It should be generally recognised that the proper place for water treatment is not the boiler, and that treatment prior to entry is the correct practice.

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## Welded Steel Gear Wheels.

"Engineering", 28th December, 1934.

Welding as a constructional method in mechanical engineering has now reached such a stage that work of very large dimensions, e.g. alternator stators, condenser-shells, bedplates, etc., put together in this way, have become common. We have illustrated many such examples in these pages from time to time. It will be noticeable, however, that the structures cited above are stationary, and it is not generally known that rotating parts carrying heavy torque loads are now being constructed by welding. Messrs. David Brown & Sons (Hudd.), Limited, Huddersfield, for instance, have devoted a good deal of attention to the welded construction of large spur gear wheels used in drives of various sorts. The basic reasons for this development have been twofold. Very large wheels are, as a rule, required for particular units, that is, they are not used in quantities. In consequence, a large part of the cost is due to the operations of pattern-making and moulding, whilst, if they are of steel there is always a risk of hidden blow-holes, etc. The other primary reason for the adoption of welding lies in the speed in which a large wheel can be produced in the case of a hurried replacement due to a breakdown.

As far as we know, the welded steel gear wheel had its origin in this country, and has already settled down on fairly definite lines. In a large wheel constructed by Messrs. Brown for a breakdown job, which, incidentally, was delivered on the site in four days from the receipt of the order, the arms were made from rolled steel joists of standard section. These were welded to a hub made from a forged steel bar, the junction of the arms with the hub being stiffened with quadrantal pieces of plate between the arms and on the centre line of the joists, so that there was virtually a continuous web at the centre of the wheel for about a quarter of its diameter. The rim was formed from a strip of medium carbon steel rolled to shape and stiffened by a central vertical welded web. This web was cut away where the arms joined the rim and, again, formed, with the web of the joists, a continuous ring. The wheel was welded up with the rim joint left open in order to avoid initial stresses. This joint was welded last. It runs straight across the face. No difficulty was experienced with it in cutting the teeth. These may be either spur or helical, as required. There is practically no limit in diameter for welded wheels of this type in the direction of large sizes. With small welded wheels it is often simpler to use a single plate web instead of arms. For building-up large wheels, if suitable rolled sections for the arms are not readily obtainable, two or three such webs suitably cross-braced can be used.

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## Draughtsmanship.

"Engineering", 15th February, 1935.

The drawing-office is accustomed to receive from the shops more kicks than compliments, and often develops in consequence a protective armour-plate of indifference which successfully repels both curses and useful criticism. "What's the use of telling 'em?" the shops are apt to ask—an attitude to be regretted, for a large and important part of the draughtsman's education can come from no other source. It is instructive to consider what features should reasonably be expected to characterise shop drawings.

Correct proportioning, of course, there must be for strength and appearance. What looks right to the engineer does not usually err seriously. In the general lines of design some attempt at pleasing the eye is demanded. There is no reason why engineers should not be artists in their own sphere. Draughtsmen cannot go far wrong in following the precept of Nasmith, of steam-hammer fame. "The most direct path to your objective", said he, "is the most artistic as a rule".

In the early stages the sales department may put in a spoke or two about talking points. These should not be accepted if they add appreciably to cost without a corresponding efficiency. It verges on commercial dishonesty to increase the selling price simply to help the salesman, e.g., fitting ball bearings where plain are fully adequate; using nickel steel or forgings instead of malleable castings, and so on. In this matter it is essential that the objections raised to such a course are sound. For example, plain bearings may be perfectly right so far as speed and pressure are concerned, but unequal wear affects spindle alignment and, perhaps, machine efficiency. Adjustment may not be easy, and the presence of oil unwanted, so that altogether ball bearings may really be preferable.

Clear dimensions are a first duty. Good, though not inflexible, rules are the use of inches up to 24in.; diameters to be given on a circle rather than an elevation; no repetition in different views. Need it be said that such notes as "This dimension is important", "Easy fit" and the like, have no business on drawings? What is easy to one man's touch is tight to another. The proper thing is to give the required tolerance, making it always as great and not as small as the work allows. Breaking points should be selected and suitably prepared, so that an accidental overstrain does not financially wreck the machine. Accessibility is important to those details which, sooner or later, will require maintenance attention. Handwork is eliminated wherever possible, because of the costliness and the difficulty of estimating this in the rate-fixing office. Especially to be avoided, unless absolutely necessary, is the lazy man's instruction, "To be marked off in position". This always means double work at least, and is, of course, fatal to interchangeability.

This point brings us to essentially shop features in the design, features on which comments in the works are often harsh, rather than kind. Lack of room for a good spanner-hold is common. How foolish to skimp such a matter. A quarter of an inch too much is so very different from an eighth too little. So simple a thing, too, as drilling is worth attention. Without real cause, there ought not to be on the same elevation holes ranging from $\frac{3}{8}$in. to $\frac{3}{4}$in. in sixteenths, calling for several changes of drill, each taking time and adding to the cost of jigs. Variations in diameter should be kept down to a reasonable number, and in studs or screws sixteenths not used beyond $\frac{1}{2}$in. Long holes and blind tapped holes also run away with time, but perhaps of all these the greatest robber is the supposed clear bolthole, $\frac{1}{32}$in. large, when it gets to the erector. The draughtsman, conscientious fellow, thinks he has erred, if at all, on the easy side. But if there are four, eight or twelve holes, sometimes 6in., 12in., or 24in. apart; if further they are marked off, and not jig drilled, then how many of the centres will be to a $\frac{1}{64}$in.? And what a to-do the erector has with his round file, probably putting up and taking down the detail repeatedly. How slovenly, too, does the collection of drawn holes look when finished. A $\frac{1}{16}$in. clearance is not in the least excessive for a recognised clear bolthole up to $\frac{7}{8}$in. diameter, increasing beyond that diameter if erection is to proceed smoothly.

Some draughtsmen are lavish with taper pins. Without doubt, a well-fitted taper pin is a good job, but very often it is a better job than is needed. One has only to analyse the erector's work to find that it can be ten times as costly as a screw or bolt. There is the assembly of the two parts, the holding together while drilling, by hand probably, the careful reamering for fear of getting too big for the pin, the repeated trial of the pin and, when done, a detail that is almost certainly not interchangeable afterwards.

The machine shop greatly appreciates requests for advice on means for holding cumbersome details while machining, and it is generally easy to provide suitable lugs or bosses for such a purpose. A closed case from which the cover, on a split bearing, must be lifted to measure the inside faces is objectionable designing, and two opposite bores are reduced in cost if made alike, meeting any slight difference in spindle diameter by the bush. Dog-clutches are much more easily milled with an odd rather than an even number of teeth.

Such points could be multiplied almost indefinitely, but perhaps enough has been said to indicate lines which lead to approximate perfection. Alas! which one among us can lay equal claim to the mathematical mind, the artistic eye, the ingenious mastery of movements, and the shop knowledge which cements all together? In the general draughtsman one can only expect a reasonable compromise, but as regards the last of the four virtues there is a deep well of advice available in the works, if he will but draw upon it.

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## Preheating and Combustion.

"Engineering", 8th February, 1935.

In his Memorandum for the year 1929, the Chief Engineer for the Manchester Steam Users' Association remarked that "in the modern high-pressure, high-efficiency boiler the economiser is disappearing and its place is being taken by air preheaters", the argument being that the greater the temperature of the furnace, the greater is the rate of heat transmission by radiation. The day of the economiser is, however, far from ending, though such a development might have been expected from a literal interpretation of the sentence quoted; at the same time, air preheating is attracting very considerable notice. The effect of furnace temperature upon radiation is complicated, being not only proportional to the fourth power of the absolute temperature of the gases composing the flame, but also a function of the pressure of the gases and of the thickness of the radiating layers; the effect is further complicated by the presence of solid particles of carbon, so that the total radiation is the sum of the "luminosity radiation" due to the solid particles and the radiation due to carbon dioxide and water vapour in the flame, all of which are good radiators. As an indication of the order of magnitude of one of these factors, it may be mentioned that Dr. Schack, in his well-known analysis of the subject, has shown that an increase in the temperature of an infinitely thick layer of water vapour, from 1,200° C. to 1,400° C. over three selected wave-bands increased the amount of radiation by nearly 50 per cent., the equivalent figure for an infinitely thick layer of carbon dioxide being very little less, as compared with an increase in the total radiation of a perfect black body (to which the solid particles would more nearly approximate) of some 70 per cent.

In the course of its work, this subject, in one of its phases, has been taken up by the United States Bureau of Mines, which has recently published in its Bulletin No. 378 an account drawn up by Mr. P. Nicholls of an investigation on "Underfeed Combustion, Effect of Preheat, and Distribution of Ash in Fuel Beds". This covers studies of the underfeed type of fuel bed, and deals with the effect of preheated air on both underfeed and overfeed types of fuel bed, as well as treating of other matters which we do not propose to deal with at the moment. The investigation neglects anything that may occur after the gases have left the fuel bed, and deals only with the conditions in the bed itself, and although the experimental methods employed do not exactly represent industrial practice, the investigation brings out points of considerable interest.

Referring first to the "overfeed" fuel beds in which the fuel is fed from above, the paper refers to the practical objections that are raised against preheating air to a high temperature on the ground that clinker troubles increase while the cost of upkeep of stoker parts also tends to rise. Possibly, these difficulties, it is suggested, might be obviated by the use of a small quantity of steam with the air; since water vapour is an exceedingly good radiator, the presence of water vapour resulting from the combustion of water gas might be advantageous. The view is taken in the report that the introduction of heated air is advantageous as a means of increasing the temperature of the fuel bed itself, and Mr. Nicholls considers to be detrimental—anything—for example, endothermic reactions resulting from the formation of carbon monoxide or the water gas reaction—which will tend to reduce its temperature. The correctness of this view, however, is open to question. A high temperature in the interior of the fuel bed is largely useless, since the heated material there is screened from the boiler surfaces by the fuel lying above it, while the combustion of gases above the fuel bed will so increase the effective radiating and convecting powers of the furnace as a whole that the overall efficiency of heat transfer will be raised considerably.

For most of the experiments recorded, coke was used in order to avoid difficulties due to caking. In considering combustion phenomena, it should be realised that a boiler furnace is little different in degree from a gas retort. Too rapid heating will cause the coking of the coal to be effected so quickly that the plastic properties of any good coking coal, while between the temperatures of 400° C. and 450° C., will cause greater resistance to the flow of air with preheated air than with unheated air, unless the fire is disturbed more frequently.

In general, the effect upon the reactions in an overfeed fuel bed of preheating the air to temperatures between 80° F. and 800° F. is to cause a far more rapid disappearance of oxygen and a more complete conversion of $CO_2$ into CO; at 800° F., oxygen disappears, according to this investigation, at 1·25in. above the grate, as compared with 5in. with air at 80° F. and 2·25in. at 400° F. The combustion of CO above the furnace increases the radiating temperature of the gases. The temperature of the fuel itself also rises, as would be anticipated, and preheating, therefore, both adds heat to the furnace and accelerates the chemical ractions taking place therein; since the gases leave the fuel bed at a higher temperature, combustion of volatile matter from the coal should clearly be more easily effected.

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## Corrosion in Refrigerating Plants.

By W. Nolcken.

"Ice and Cold Storage", January, 1935.

In the publication of the Department of Scientific and Industrial Research *Report of the Food Investigation Board for the year 1933,* on page 222, the short article "Corrosion in Refrigerating Plants" advances a theory which, in the writer's opinion, may be viewed from a different angle. It is reported that "it was observed that the sides of the piston of methyl-chloride plants had patches of the surface covered with a film of copper, while the piston heads and diaphragms had a coating of a thin brown deposit.

### Calcium Salts.

"The trouble was not confined to one particular plant. Some of the deposit was dissolved in acid and the flame-colour test applied. The characteristic colour of calcium was observed. This suggests that calcium salts are the cause of the corrosion. The deposit of copper is then accounted for by the fact that the copper pipes would be attacked by the calcium salt, and the compound formed would be carried on to the iron piston and react there, depositing copper. On inquiry it was ascertained that this make of methyl-chloride machines utilizes a drying tube containing calcium chloride to remove the traces of moisture from the methyl-chloride, so this could account for the presence of calcium. It was suggested as a remedy that a silica-gel drier be used instead of calcium chloride".

Whereas it is not surprising that the delicate flame coloration test revealed traces of calcium on the piston of a machine to which a calcium chloride drier had been fitted, the conclusion that the calcium chloride was responsible for the observed corrosion and copper deposition inside the compressor appears to be a little hasty.

Corrosion and copper-plating in methyl-chloride compressors were known to refrigerating engineers long before the now popular method of dehydrating the refrigerant with calcium chloride had come into use. To-day, after years of almost universal application of this system, it is well known that both copper-plating and corrosion can be completely arrested by it, especially so if a small quantity of calcium oxide be added to the chloride. Needless to say, the chemicals must be anhydrous to start with and of reasonable purity, also there must be a sufficient quantity to deal with all the water in the system without formation of the hexahydrate ($CaCl_2\ 6H_2O$) or worse still, partial dissolution and slipping through the filter.

It is suggested in the report that the calcium salt had attacked the copper pipes, and "the compound formed" had been carried round to the piston, depositing copper on it. It is usual for the filter body to be made of copper or copper alloys and if this was liable to be attacked by calcium chloride, as suggested, there would have been traces left on the inner surface of the filter body, which could not have escaped the notice of the service engineer. It is difficult to imagine what compound could be formed from anyhdrous calcium chloride interacting with metallic copper in an atmosphere of methyl chloride. Surely, no such reaction could take place without water being present as well. With water in the system reactions leading to copper deposition and corrosion of iron parts do take place, but the presence of calcium salts is not essential.

The equation: $CH_3\ OH + HCl = CH_3\ Cl + H_2O$, expresses the equilibrium between methyl alcohol, hydrogen chloride, methyl chloride and water. Elimination of the products on either side of the equation will cause the reaction to proceed to finality in that direction. Thus, methyl alcohol treated with sodium chloride and sulphuric acid is completely converted into methyl chloride, and again, methyl chloride yields methyl alcohol quantitatively when treated with KHO at 100° C.

### Methyl Chloride.

Accordingly, a certain proportion of the water present in a methyl chloride refrigerating plant will, in course of time, produce hydrochloric acid. High pressures favour the formation of acid from water, and low temperatures tend to inhibit it, the reaction being endothermal. Removal of the acid results in further conversion of water into acid, according to the law of mass action. Corrosion of steel and iron parts results from the presence of free hydrochloric acid in the system, but copper-plating does not take place so long as the inner surface of the copper tubing is clean. In American practice, particular attention is paid to the internal finish of the copper piping, but the same cannot be said for pipes manufactured in this country.

Had the pipes of the copper-plated compressor, referred to in the report, been examined, no doubt red cuprous oxide ($Cu_2O$) would have been found on the inner surfaces, resulting from heating the metal to below red heat in air. Possibly, also, a greyish-green powder would have been noticed—apparently a mixture of hydrated oxychlorides. The fact that cuprous chloride is fairly soluble in methyl chloride accounts for the readiness with which the oxide interacts with the acid and for the subsequent deposition of copper on the steel piston.

Admittedly, there are other ways by which corrosive agents may find their way into the system, such as from fluxes used for soldering the joints, from pickling solutions used for the treatment of castings, from impure packing or jointing material or unsuitable lubricating oil, etc. It will be found, however, that with no water in the system very little, if any, damage is done, whereas water alone is quite capable of causing corrosion, and in conjunction with oxydized copper tubing produce copper deposition on the steel or iron parts. Effective elimination of the water usually cures all other "chemical" troubles in the machine, and it is in connexion with this question that information regarding the efficacy of silica-gel as compared with calcium chloride would be much appreciated. The writer's own limited experience with silica-gel driers fitted to "Servel" methyl chloride machines has not been very successful.

In the first place, these driers had to be fitted in the suction vapour pipe, between the compressor and the evaporator, whereas calcium filters are preferably fixed in the liquid pipe, between the expansion valve and the condenser or liquid receiver. The first intimation of the presence of water which the refrigerating engineer experiences, generally takes the shape of a partial or complete "blockage" at the expansion valve. Methyl chloride combines with water into a solid hydrate $CH_3Cl\ 6H_2O$, which is stable below −7·3° C. (18·86° F.) at 760mm. pressure. At this temperature the saturated vapour pressure of methyl chloride is 28·2lb. sq. in. abs., and at atmospheric pressure its boiling temperature is −10° F. approximate.

The dissociation pressure of the hydrate is therefore well below the saturated methyl chloride pressure, and dissociation cannot take place outside the region of high superheat of the vapour inside the compressor and in its immediate vicinity. Formation will take place wherever there is liquid with the vapour, as in the evaporator, and especially in the condenser and liquid pipe. Within this pipe the liquid is usually subcooled well below saturation point, especially near the cold expansion valve. Here, then, are the most favourable conditions for the formation of hydrate crystals. These are carried along by the liquid towards the expansion valve, which "filters them off" when they accumulate, eventually causing the so-called "ice blockage". Admittedly, ice blockages can and do occur in other places of the system, but most frequently they are met with in the expansion valve.

Considering that it is imperative to keep the refrigerant in circulation while dehydrating it with calcium chloride or silica-gel, it is advisable to fix the filter in the liquid line in order to keep the expansion valve clear from blockages during the operation. Also, this pipe being the place where the highest concentration of water is likely to be found, one naturally prefers to fit the filter here, rather than in the suction pipe.

Calcium chloride will absorb very nearly its own weight of water before it is completely "gone", i.e., has formed $Ca\,Cl_2\ 6H_2O$, when further addition of water results in dissolution. It is not advisable to let things reach this stage. The congruent melting point of the hexahydrate is 86·36° F., at which temperature it deliquesces. Its dissociation pressure at this point will be 0·25″ Hg., approximately 0·223 at 85·56° F. in equilibrium with the $\beta$ modification of the tetrahydrate, and 0·271 at 85·64° F. when in equilibrium with the $\alpha$ tetrahydrate.

### Filter and Charge.

It is therefore advisable not to carry the dehydration beyond the tetrahydrate stage, when 64·8 per cent. of the initial weight of calcium chloride is absorbed in weight of water. For all practical purposes it is safe to estimate the absorptive capacity of a filter as equal to half the weight of the charge. I believe it will be found that this compares very favourably both in weight and bulk with silica-gel filters of equal absorptive capacity.

With reference to the degree of dehydration which can be reached with either material—I believe the figure for freshly activated gel is fairly high. The limit of calcium chloride is approximately 0·0021 grams $H_2O$ to the litre, which is ample for all practical purposes.

It would be interesting to know whether the recommendation to use silica-gel in place of calcium chloride for the purpose of eliminating water from methyl chloride machinery has been carried out, and if so, what advantages or inconveniences of the one system over the other have been observed in praxis?

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## Trial Results for a Modern Steamship.

"The Marine Engineer", February, 1935.

In a recent issue of this paper we published a short illustrated article on the single-screw cargo steamships "Kirkland" and "Merkland", of about 2,450 tons deadweight capacity, which have been built for the Leith, Hull, and Hamburg Steam Packet Co., Ltd. (James Currie & Co., managers). The "Kirkland" was built by the Caledon Shipbuilding and Engineering Co., Ltd., and the "Merkland" by Barclay, Curle & Co., Ltd. Each vessel is propelled by a triple-expansion engine having cylinders 15in., 25in. and 41in. in diameter by 33in. stroke. In each case the engine has been built by Barclay, Curle & Co., Ltd., and is provided with Andrews & Cameron special cam-operated triple-opening, balanced, separate-type slide valves for all cylinders and is designed to work with a fairly high degree of superheat. It will be recalled that steam is supplied from two coal-fired boilers provided with the Howden system of forced draught; the auxiliary machinery is arranged to give a high economy. Since our previous article was published we have received from Barclay, Curle & Co., Ltd., trial particulars relating to the "Merkland", and as these are of such general interest they are summarised below in tabular form.

The "Merkland" and her sister ship, it may be remembered, is 260ft. long by 40ft. breadth moulded by 18ft. 6in. depth moulded to upper deck. The gross tonnage is 1,360 tons and the net tonnage 630 tons. On trial the draught forward was 17ft. 6in., and aft 19ft. 3in., giving a mean value of 18ft. 4½in. The corresponding displacement was

### TABLE I.—LOADED TRIAL. MEASURED MILE, SKELMORLIE. HIGH WATER AT GREENOCK 2.48 P.M.

| | | | PRESSURES, lb. per sq. in. | | | | | Superheat at Engine Stop Valve | MEAN PRESSURES, lb. per sq. in. | | | | HORSE-POWER. INDICATED | | | | | | Apparent | | CUT OFFS. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Run. | Time of Observation. | Revs. per Min. | Boiler Steam. | Main Steam. | M.P. Receiver. | L.P. Receiver. | Vacuum, in. | ° F. | H.P. | M.P. | L.P. | Mean Referred. | H.P. | M.P. | L.P. | Total. | Time on Mile, M. S. | Speed in Knots. | Slip, per cent. | $D^{\frac{2}{3}} \times V^3$ I.H.P. | H.P. | M.P. | L.P. | Engine Stop Valve. |
| Down | 11.51 a.m. | 88 | 190 | 125 | 27 | 2 | 26 | 36° | 61·3 | 22·8 | 7·97 | — | 159 | 166 | 154 | 479 | 7—21 | 8·16 | — | — | 21·9″ | 18·2″ | 23″ | 3/16″ Open |
| Up | 12.13 p.m. | 90 | 190 | 125 | 32 | 2 | 26·5 | 21° | 60·0 | 21·24 | 7·2 | — | 159 | 156 | 142 | 457 | 6—21⅘ | 9·429 | — | — | 21·9″ | 18·2″ | 23″ | 3/16″ Open |
| Mean | — | 89 | — | — | — | — | — | — | — | — | — | 23·9 | — | — | — | 468 | — | 8·795 | 4¾ | 358 | — | — | — | — |
| Down | 12.34 p.m. | 102 | 190 | 165 | 53 | 7 | 26 | 26° | 80·7 | 31·0 | 10·65 | — | 240 | 258 | 238 | 736 | 6—38½ | 9·034 | — | — | 21·9″ | 18·2″ | 23″ | 7/16″ Open |
| Up | 12.55 p.m. | 100 | 195 | 150 | 43 | 5 | 25·75 | 34° | 72·8 | 29·88 | 8·80 | — | 214 | 244 | 193 | 651 | 5—49 | 10·315 | — | — | 21·9″ | 18·2″ | 23″ | ⅜″ Open |
| Mean | — | 101 | — | — | — | — | — | — | — | — | — | 31·2 | — | — | — | 694 | — | 9·674 | 7½ | 321 | — | — | — | — |
| Down | 1.17 p.m. | 107 | 197 | 185 | 75 | 10 | 25·5 | 43° | 89·3 | 34·84 | 12·15 | — | 280 | 305 | 286 | 871 | 6—20 | 9·473 | — | — | 21·9″ | 18·2″ | 23″ | 9/16″ Open |
| Up | 1.37 p.m. | 109 | 198 | 180 | 65 | 8 | 25·5 | 43° | 84·4 | 31·96 | 11·18 | — | 270 | 284 | 268 | 822 | 5—25 | 11·077 | — | — | 21·9″ | 18·2″ | 23″ | ½″ Open |
| Mean | — | 108 | — | — | — | — | — | — | — | — | — | 35·6 | — | — | — | 847 | — | 10·275 | 8¼ | 314 | — | — | — | — |
| Down | 2.3 p.m. | 110 | 198 | 185 | 67 | 10 | 25·5 | 45° | 92·5 | 36·0 | 12·95 | — | 295 | 324 | 313 | 932 | 6—9 | 9·756 | — | — | 21·9″ | 18·2″ | 23″ | ⅞″ Open |
| Up | 2.25 p.m. | 116 | 200 | 190 | 67 | 12 | 26·5 | 52° | 93·8 | 37·2 | 13·35 | — | 320 | 352 | 341 | 1,013 | 5—11½ | 11·557 | — | — | 21·9″ | 18·2″ | 23″ | Full Open |
| Mean | — | 113 | — | — | — | — | — | — | — | — | — | 38·1 | — | — | — | 973 | — | 10·657 | 9 | 307 | — | — | — | — |

| | | | | | | | | | | | TEMPERATURES, °F. | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Heater. | | | | Above Air Heaters. | | Below Air Heaters. | | Air Passages. | | | | | Boiler Stop Valve. | | | Conditions. | |
| | | | | | | | | | | | | | | | Port Boiler. | | Star'd. Boiler. | | | | | | | |
| Run. | Air Pressure at Fan. | Circ. Inlet. | Circ. Outlet. | Main Exhaust. | Condensate. | Feed Pump. | 1st Stage. | 2nd Stage. | Stokehold. | Funnel Base. | Port. | Starboard. | Port. | Starboard. | Port. | Star'd. | Port. | Star'd. | Furnace Entrance. | Port | Starboard. | Pyrometer in E.R. | Tide | Wind. |
| Down | 1¼″ | — | 82 | 121 | 105 | 108 | 190 | 240 | — | 338 | 200 | 206 | 360 | 365 | 284 | 299 | 286 | 294 | 306 | 415 | 425 | 420 | Against | With |
| Up | ¾″ | — | 84 | 122 | 106 | 110 | 190 | 241 | — | 341 | 203 | 206 | 364 | 368 | 285 | 299 | 286 | 295 | 307 | 420 | 430 | 405 | With | With |
| Mean | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| Down | 1¼″ | — | 84 | 122 | 110 | 115 | 190 | 241 | — | — | 207 | 208 | 375 | 368 | 287 | 287 | 286 | 294 | 308 | 420 | 430 | 410 | Against | Against |
| Up | 1⅛″ | — | 86 | 123 | 112 | 117 | 195 | 240 | — | — | 206 | 208 | 378 | 369 | 289 | 287 | 287 | 292 | 308 | 420 | 430 | 420 | With | With |
| Mean | — | 58 | — | — | — | — | — | — | 80 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| Down | 1″ | — | 85 | 128 | 119 | 120 | 195 | 250 | — | — | 207 | 209 | 377 | 369 | 287 | 287 | 283 | 290 | 310 | 425 | 440 | 430 | Against | Against |
| Up | 1″ | — | 86 | 128 | 120 | 122 | 190 | 240 | — | — | 209 | 214 | 381 | 377 | 290 | 290 | 283 | 289 | 311 | 425 | 440 | 430 | Slack | With |
| Mean | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| Down | ⅞″ | — | 85 | 128 | 120 | 124 | 195 | 250 | — | — | 211 | 214 | 389 | 378 | 289 | 293 | 280 | 289 | 311 | 435 | 445 | 432 | Slack | Against |
| Up | 1″ | — | 85 | 125 | 119 | 124 | 190 | 240 | — | 344 | 214 | 215 | 373 | 375 | 285 | 291 | 280 | 287 | 311 | 435 | 450 | 440 | Sack | With |
| Mean | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |

### TABLE II.—COAL CONSUMPTION TRIAL. FIRTH OF CLYDE. ENGINE STOP VALVE FULL OPEN.

| | | PRESSURES. | | | | | | | Superheat at Engine Stop Valve | MEAN PRESSURES, .lb. per sq. in. | | | | INDICATED HORSE-POWER. | | | | CUT OFFS. | | | | | DYNAMO. | | AIR PRESSURE Port Boiler. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Boiler Steam. | | | | | | | | | | | | | | | | | | | | | | | | |
| Time of Observation. | Revs. per Min. | Port. | Star'd. | Boilers. | Main Steam. | M.P. Receiver. | L.P. Receiver. | Vacuum. | ° F. | H.P. | M.P. | L.P. | Mean Referred. | H.P. | M.P. | L.P. | Total | H.P. | M.P. | L.P. | Feed lb./hr. | Feed lb./ i.h.p./hr. | Volts. | Amps. | Port. | Star'd. |
| 3.10 p.m. | 105 | — | — | — | — | — | — | — | — | 83·1 | 32·4 | 11·4 | — | 256 | 278 | 263 | 797 | — | — | — | — | — | — | — | — | — |
| 3.30 p.m. | 107 | — | — | — | — | — | — | — | — | 88·6 | 33·2 | 10·62 | — | 278 | 291 | 250 | 819 | — | — | — | — | — | — | — | — | — |
| 3.50 p.m. | 105 | 198 | 195 | 195 | 188 | 65 | 9 | 27·12 | 44° | 86·5 | 33·2 | 11·75 | — | 267 | 285 | 271 | 823 | — | — | — | — | — | 107 | 33 | ½″ | ⅜″ |
| 4.10 p.m. | 108 | 198 | 195 | 195 | 188 | 65 | 10 | 25·75 | 44° | 85·0 | 35·2 | 10·62 | — | 270 | 311 | 252 | 833 | — | — | — | — | — | 106 | 33 | ½″ | ½″ |
| 4.30 p.m. | 106 | 200 | 200 | 200 | 190 | 65 | 10 | 25·5 | 52° | 88·7 | 32·4 | 11·92 | — | 276 | 281 | 278 | 835 | 17·8″ | 16·5″ | 18·2″ | 11,400 | 13·9 | 106 | 33 | — | — |
| 4.50 p.m. | 106 | 200 | 200 | 198 | 190 | 65 | 10 | 25·5 | 48° | 90·0 | 32·48 | 11·98 | — | 280 | 282 | 279 | 841 | — | — | — | — | — | — | — | — | — |
| 5.10 p.m. | 104 | 199 | 199 | 198 | 192 | 65 | 10 | 25·5 | 53° | 90·0 | 33·2 | 11·9 | — | 274 | 282 | 272 | 828 | — | — | — | — | — | 106 | 27 | — | — |
| 5.30 p.m. | 104 | 193 | 193 | 193 | 188 | 60 | 9 | 25·5 | 65° | 87·5 | 31·96 | 11·4 | — | 268 | 272 | 261 | 801 | — | — | — | — | — | 106 | 28 | — | — |
| 5.50 p.m. | 104 | 190 | 190 | 190 | 182 | 60 | 9 | 25·5 | 66° | 88·7 | 32·0 | 11·3 | — | 271 | 272 | 258 | 801 | — | — | — | — | — | 106 | 28 | — | — |
| 6.20 p.m. | 106 | 187 | 187 | 185 | 180 | 57 | 8 | 25·5 | 68° | 87·5 | 30·8 | 10·95 | — | 272 | 268 | 256 | 796 | — | — | — | — | — | — | — | — | — |
| — | 105 | — | — | — | — | — | — | — | — | — | — | — | 35·36 | — | — | — | 817 | — | — | — | — | — | — | — | — | — |

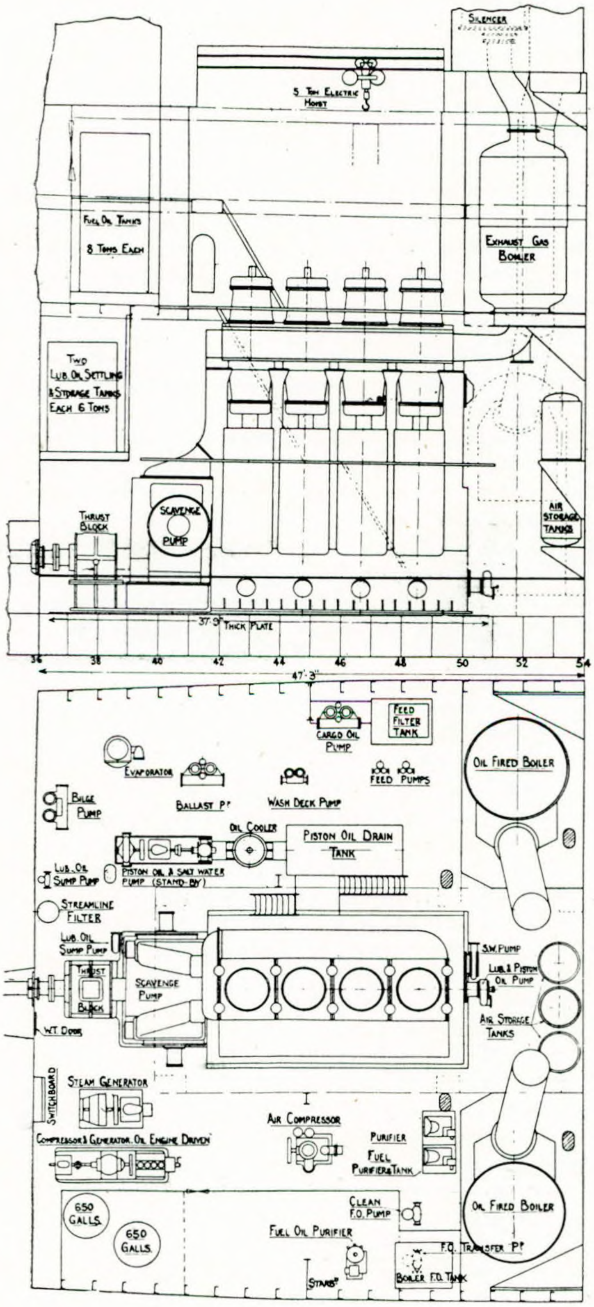
| | AIR PRESSURE. | | | | | | | | | | TEMPERATURES °F. | | | | | | | | | | | | | Coal Consumption | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Starboard Boiler. | | | | | | | Heater. | | | | Above Air Heaters. | | Below Air Heaters. | | Air Passages. | | | | | Boiler Stop Valve. | | | | |
| | | | | | | | | | | | | | | | | Port Boiler. | | Starboard Boiler. | | | | | | | |
| Time of Observation. | Port. | Starboard. | Circ. Inlet. | Circ. Outlet. | Main Exhaust. | Condensate. | Feed Pump. | 1st Stage. | 2nd Stage. | Stokehold | Funnel Base. | Port. | Starboard. | Port. | Starboard. | Port. | Star'd. | Port. | Star'd. | Furnace Entrance. | Port. | Star'd. | Pyrometer in E.R. | Boiler Efficiency. | lb./ i.h.p. hour. |
| 3.10 p.m. | — | — | — | 86 | 127 | 118 | 122 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 3.30 p.m. | — | — | — | 86 | 125 | 117 | 122 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 3.50 p.m. | ½″ | ½″ | — | 87 | 122 | 115 | 123 | 180 | 260 | — | — | 215 | 218 | 376 | 377 | 286 | 292 | 282 | 289 | — | 440 | 445 | 430 | — | — |
| 4.10 p.m. | ½″ | ½″ | — | 86 | 120 | 114 | 123 | 180 | 260 | — | — | 215 | 219 | 375 | 377 | 285 | 290 | 280 | 286 | — | 440 | 450 | 430 | — | — |
| 4.30 p.m. | — | — | 58 | 86 | 126 | 119 | 126 | — | — | 80 | 345 | — | — | — | — | — | — | — | — | — | — | — | 440 | 76% | 1·28 |
| 4.50 p.m. | — | — | — | 87 | 128 | 118 | 124 | 185 | 265 | — | — | — | — | — | — | — | — | — | — | — | — | — | 435 | — | — |
| 5.10 p.m. | — | — | — | 88 | 128 | 118 | 125 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 440 | — | — |
| 5.30 p.m. | — | — | — | 87 | 127 | 119 | 127 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 450 | — | — |
| 5.50 p.m. | — | — | — | 88 | 128 | 118 | 126 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 450 | — | — |
| 6.20 p.m. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 450 | — | — |
| — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |

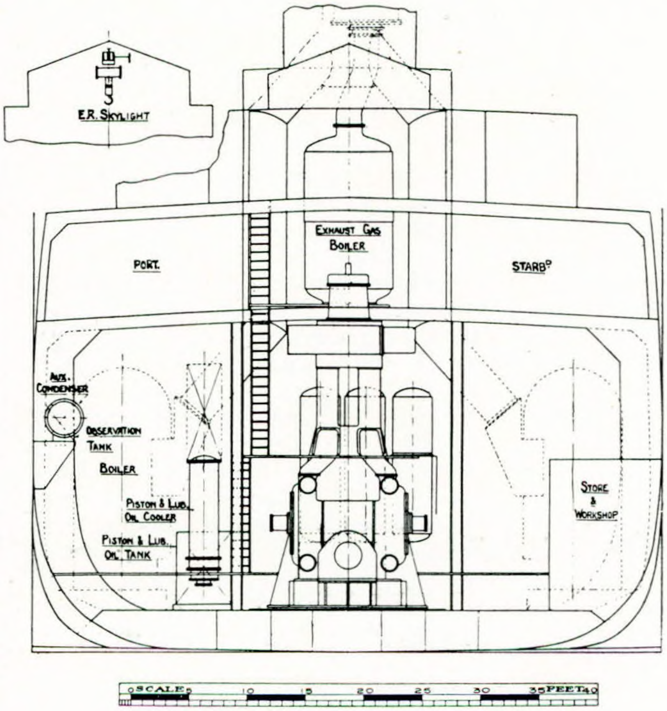
Coal analysis: fixed carbons 63·685 per cent.; Volatile matter 30·07 per cent.; ash 3·1625 per cent.; moisture 3·08 per cent.; sulphur 0·9675 per cent.; hydrogen 4·87 per cent.; Calorific value (gross) 14,364 B.Th.U.'s per lb. (net) 13,857 B.Th.U.'s per lb.

3,855 tons, giving a block coefficient of 0·708. The propeller is of manganese bronze and is a four-bladed right-hand solid-type screw, having an expanded surface of 48 sq. ft. and a projected area of 42 sq. ft. The diameter is 11ft. 10in. and the mean pitch 10ft. 6in.

The two single-ended main boilers are 11ft. in diameter by 11ft. 3in. long and each has a grate surface of 30ft. and a heating surface of 1,201 sq. ft.; the working pressure is 200lb. per sq. in. There is also a single-ended donkey boiler 9ft. 6in. in diameter by 8ft. long, this being arranged with natural draught to operate with a working pressure of 100lb. per sq. in.

The trials were run over the Skelmorlie measured mile. The wind was S.S.W.; force 5 on the Beaufort scale, rising to 6 during runs F, G and H in the following table. The sea during the trials was choppy. The first table, it will be observed, relates to the ordinary progressive runs over the measured mile, while the second table is concerned with a subsequent fuel-consumption trial, which was run the same day in the Firth of Clyde after the completion of the eight runs over the measured mile. The performance, both in respect of Admiralty constant and specific fuel consumption, is particularly good and all concerned should be congratulated upon an efficient vessel. We understand that the results obtained with the "Kirkland" are very much in line with those realised with the "Merkland", and for this reason it is not proposed to reproduce figures for the sister ship.





Engine-room plans of the "Silverlarch".

## Two Reconstructed Motor Ships.

Alterations to the "Silverlarch" and "Silverpine". New Richardsons-Westgarth Engines.

"The Motor Ship", March, 1935.

Among the numerous motor ships in the Silver Line are two of the slower class, the "Silverlarch" and "Silverpine", built in 1924 by Swan, Hunter & Wigham Richardson, Neptune engines of 2,000 b.h.p. being installed. Messrs. Stanley and John Thompson, the managers of the line, decided to bring the ships up to date by giving them a considerable increase in the speed and to modify the hulls.

We inspected the work in progress on the first ship last month, by the courtesy of Messrs. Joseph L. Thompson & Sons, who are carrying out the alterations at Sunderland. Seldom have there been more interesting and, perhaps, more intricate problems involved in a task of this character. The power is being doubled and the speed is to be 13½ knots instead of the 10-knot service figure sufficient 11 years ago.

The stern of each vessel is being entirely rebuilt on lines suitable for the faster speed, and although the length will be increased slightly, this feature is not a notable point. The new stern of the "Silverlarch" (the second ship is in its original state at the time of publication) is taking shape inside the old framing and (partly) plating. To inspect the transformation is to recognize an extremely ingenious and cleverly executed piece of shipbuilding procedure. Further than this, the high standard of workmanship apparent in such portions of the new structure as we examined reflected credit on the shipyard.

Remodelling the after end of the hulls and designing new propellers, together with streamlined rudders, is a major part of the contract, but it is important to note that a great deal of work is being carried out to the bedplate and girders. Among the modifications are the provision of four additional electrically welded deep-tanks for the carriage of edible oil.

The new engines for the "Silverlarch" and her sister ship are of the Richardsons-Westgarth double-acting airless-injection type, the output being 4,000 b.h.p. at a speed of 109 r.p.m. They are four-cylinder units, the cylinder diameter being 27½in. and the piston stroke 47½in. Welding is being applied to the construction of the bedplate and columns.

It will be appreciated that the appearance of the vessels will be greatly altered after their reconstruction and they will both resume their service this year. The auxiliaries on deck, which are driven by steam, are being retained. New donkey boilers are to be installed, and pumps will be required for dealing with the edible oil cargo. Accommodation is to be provided for 10 passengers in each ship.

## Lubricating Oil Economy in Diesel Installations.

By Eng. Lieut-Commander H. J. Nicholson, R.N., S.R., M.I.Mar.E.

"Gas Oil and Power", February, 1935.

In his opening remarks the author of the article under the above title in the January issue puts forward some sound arguments emphasising the importance of efficient lubrication in connection with Diesel engines. He refers to the "cost of lubricating oil", which, unfortunately, is too frequently the first consideration and may mean anything from 10d. to 4s. per gallon. The cost of *lubrication* is quite another matter and is the vital consideration; but sooner or later the persistent use of cheap lubricating oil will send the cost of lubrication sky high, when stoppages, repairs, and renewals are taken into account.

The keynote of ideal lubrication, once the correct grade of oil has been decided upon for a particular type of engine, is consistency in the quality and physical characteristics of the oil, and this cannot be maintained in products offered at ridiculously low prices. Furthermore, I would purchase lubricating oil only from those vendors who are prepared to offer the services of lubrication specialists. If proper care be taken in the application, storage, and treatment of the used oil by suitable filtration, a high-grade oil can be used at a cost of something between 5 and 7 per cent. of total running costs, without the risk of costly stoppages and renewals directly due to lubrication troubles.

Under the heading "Choice of Oil", the author offers some sound advice in recommending the user to follow the engine builders' instructions and to enlist the services of the oil company's technical staff. Under the same heading he makes other suggestions that are open to comment. He advocates that only two grades of oil be used for air injection engines, namely, one for bearings and power cylinders, and one for air compressor cylinders. This suggestion is quite good for the majority of land installations, but certainly not for marine engines of large power. For such engines it is usually necessary to employ in the power cylinders an oil of heavier body than the bearing oil.

For airless-injection engines, the author suggests the use of the oil throughout. I assume he refers to engines not fitted with a compressor for starting purposes, in which case such an arrangement is quite satisfactory for units of moderate power. He then states: "For cylinder lubrication, bearing oil which has been passed through the system and then carefully filtered is in extensive use nowadays", and endeavours to indicate the advantages that are to be obtained from this practice. The writer is in touch with a large number of Diesel engines, both land and marine types, and cannot recall a single instance where such a practice is employed. In the first place I do not believe that such a procedure would be endorsed by any engine builder; in the second place, it is definitely dangerous.

What does the author intend to convey by the expression "carefully filtered"? Usually oil from a Diesel engine circulating system contains carbonaceous material, the quantity increasing in proportion to length of service. Only the very best of filtering apparatus, such as the Stream-Line filter or one of the well-known makes of centrifuge, will remove this at all effectively, and even with such apparatus careful operation is necessary. When normal combustion is maintained in cylinders there is quite sufficient carbon formation to be objectionable, and to feed lubricating oil containing even a small quantity of free carbon in suspension is to invite trouble.

Carbon is by no means the only objectionable feature to be considered in the practice advocated. Very frequently oil in circulating systems is diluted with fuel to such an extent as to considerably reduce its viscosity. This contamination cannot be removed by ordinary methods of filtration, and to use such an oil for cylinder lubrication is to risk a seized piston, because the oil has not sufficient body to form and maintain the necessary protecting film. Furthermore, the oil must have sufficient body to assist in forming an effective piston ring seal.

Even if we assume that there is no fuel dilution and that perfectly clean oil is being obtained by filtration, i.e., there are no impurities either in suspension or in solution, there is still the problem of stuck piston rings resulting from gummy deposits to be considered. Oil in the circulating system of a Diesel engine is subjected to the influences of aeration, temperature, and mineral and metallic impurities, all of which tend to produce oxidation, a condition that even a high-grade oil cannot resist indefinitely. Although an oil that has begun to oxidise may still be quite suitable for further crankchamber service, it might, if used in this condition for cylinder lubrication, continue to oxidise rapidly because of its intimate contact during the compression stroke, with a mixture rich in oxygen, with very high temperatures, and with resultant impurities of combustion; hence the formation of gummy deposits. In view of these conditions, I would strongly advocate the use of unused oil for cylinder lubrication, to be fed by means of a first-class reliable mechanical lubricator. Such a lubricator should be capable of feeding closely controlled quantities of oil against pressure with absolute regularity.

Acidity.

The author of the article under discussion mentions certain physical characteristics in connection with suitable Diesel engine lubricating oils. Amongst these I regret to note he has raised the old bogey of acidity by stating that "the oil used should be a pure hydrocarbon, free from acids, fatty matter, wax, and lighter fractions. It should have no tendency to emulsify or corrode the metallic surfaces with which it will come in contact during service". The writer is unqualified to deal with this matter fully, not being an oil technologist; but as is fairly well known, modern methods of oil refining eliminate the presence of free mineral acids in a new oil.

A straight mineral oil suitable for Diesel lubrication and supplied by a reputable company will rarely have a total acid value exceeding 0·003 per cent. as $SO_3$. Usually, the standard content is below this figure, and in this condition there is no possibility of corrosion.

Petroleum acids may be present in the original crude or may be produced during distillation and refining, but it is far more likely for such acids to develop during circulation in the force-feed system, particularly when a low-priced oil of inferior quality is used. This is generally the result of oxidation. Petroleum acids are very weak in their action, and will not affect metals, except lead and zinc, and even these metals are not affected until a high degree of acidity has been attained. Before reaching this stage, however, the bulk of the oil would in all probability have sludged to such an extent as to make it unfit for further service.

The regular examination of samples from a Diesel lubrication system is very necessary, and should be made by an oil technologist. Some operators attach great importance to the acid value of such samples, but it is difficult to understand why this should be so in view of the fact that the acid value of a used Diesel engine oil is no guide whatever to the behaviour of the lubricating oil itself. This is explained by the knowledge that in almost every type of engine the lubricating oil very quickly becomes contaminated with fuel oil or with the products of combustion, a condition that at once destroys any significance the acid value may have in relation to the oil itself.

In his article, "H.W.B." stresses the necessity for oils of fairly high flash point, and gives 420° F. closed test as the minimum. This figure is approaching that for light bodied steam cylinder oils, which except for Diesel engines of the largest size and then only for cylinders, are unsuitable for circulating systems. A closed flash point of 420° F. would be unusual in oils having the viscosity and other physical characteristics mentioned by your correspondent. It is further stated that an oil having a fairly high flash point is necessary in order to reduce the vaporisation that goes on in Diesel engine crank chambers. Mineral oils will commence giving off the faintest trace of vapour at about 160° F., but the amount of such vapour does not become noticeable until a temperature approaching the flash point is reached. Obviously, any trace of moisture in the oil would produce a visible vapour, in which connection it is interesting to note that samples of used Diesel lubricating oil invariably reveal a moisture content.

I suggest that the amount of vaporisation is negligible, and that the so-called oil vapour often observed about an engine room is simply very finely atomised oil. Usually, a suitable high-grade Diesel crank chamber oil has a closed flash point between 380° F. and 400° F. The temperature in a crank chamber is in the region of 60° F. to 70° F. above the surrounding atmosphere, so that even in tropical countries the crank chamber temperature will be considerably below the flash points mentioned. Whilst appreciating that the temperature of the actual bearing surfaces is usually much higher than that of the oil returning from the bearings, it will not be high enough to cause vaporisation of the lubricating oil. Atomisation is produced by bleed-off from bearings under oil pressure, and is accentuated by carrying high oil pressures, a tendency far too marked in modern practice.

The article advocates a high-flash-point oil with a view to reducing the risk of an explosion in the crank chamber due to vapour which might be given off and become ignited by means of an overheated bearing. I suggest such an accident is almost impossible and is practically unheard of in ordinary industrial or marine Diesel practice. For such an explosion to occur, the first necessity is an explosive mixture of oil vapour and oxygen, the proportions of which are confined between very narrow limits and therefore difficult to obtain under working conditions in a crank chamber. If an explosive mixture were present, it would be necessary to have either a flame or a shower of sparks to cause ignition, and it is extremely unlikely that an overheated bearing would provide such means. A seized piston might do so, but almost invariably the engine would give due warning before such a stage was reached. In any case, an oil having a high flash point when new would offer little safeguard against possible crank chamber explosion, because in many instances the original flash point of the oil is appreciably reduced by fuel dilution after a comparatively short period of running. Numerous examples can be cited where, after a period of operation, the oil has been reduced in flash point (open test) from, say, 420° F. to 250° F., and yet has continued to give satisfactory service. The motor car engine is an illustration of the remote possibility of crank chamber explosions, it being not uncommon to find 20 per cent. petrol in the lubricating oil after a period of service. In this field seized bearings and pistons are by no means scarce, but I have never heard of a crank chamber explosion with such engines.

I agree with "H.W.B."' that the fitting of an extraction fan to a crank chamber can be beneficial, but I would suggest that the oil recovered from the cooler is the result of minute particles of oil in mist formation becoming sufficiently viscous on contact with the cold tubes to adhere to them, and then draining down to the sump. Another advantage of an extracter fan is to remove from the crank chamber gases resulting from piston blow-by. This, of course, applies to engines with the cylinders open to the crank chamber.

Under the heading "Contamination of Lubricating Oil", the author gives some very practical hints and sound advice. He considers the most serious form of contamination to emanate from sludge which drops down from cylinders, presumably the products of combustion passing the pistons, where cylinders are directly open to the crank chamber. To some extent this form of contamination does probably exist, but only in cases where pistons and rings are in poor condition, or where inferior or dirty fuel is in use. I suggest that most of the impurities in carbonaceous form are the result of free oil and oil mist coming in contact with the hot surfaces inside the pistons. This free oil or mist is the direct result of maintaining high oil pressures in the circulating system. On comparatively small engines running at high speed it is not uncommon to find oil pressures of from 30lb. to 40lb. per sq. in. creating excessive bleed-off from the bearings, thus filling the crank chamber with oil mist. In the majority of cases, 15lb. per sq. in. should be the maximum for large engines, while for smaller engines 5lb. per sq. in. is usually quite sufficient for all lubrication requirements.

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## Britain's Destroyer Fleet—Its Development and Growth.

By Frank C. Bowen.

"The Marine Engineer", March, 1935.

*Previous articles in this series appeared in our August and December, 1934, and February, 1935, issues.—Ed.* "M.E.".

The "Afridi" was the Elswick interpretation of the specification with a good bold forecastle and three funnels placed well apart, the first and second ones flat-sided. She had a displacement of 855 tons, but her speed was the most disappointing of the class, only 32·75 knots on trial, although in other respects she was most satisfactory. The "Cossack" was Cammell Laird's idea, with a displacement of 855 tons and considerably taller funnels than the "Afridi". She was a conspicuously good sea boat, and her trial speed was 33·1 knots. Then came the "Ghurka", from Hawthorn Leslie's, with a medium displacement of 870 tons and an appearance very much like the "Afridi". On trials she averaged 33·9 knots. With the "Mohawk", J. Samuel White & Company contrived to strike an original note. Her hull differed materially from the others, the high forecastle joining the side plating in a very sightly curve, while she had four funnels of which the foremost was considerably higher than the others in order to clear the bridge. Her displacement was 865 tons, and on trial she averaged 34·3 knots. Finally came the "Tartar", from the Thornycroft yard, such a striking vessel that she deserves special mention. She was the only one with a turtle-back deck, but the sheer of the hull under it was so sharp that it really amounted to a high forecastle with curved sides. Her displacement was 870 tons, and she was the fastest of the class by a considerable margin, her average on trial being 35·36 knots, while the best run on the measured mile was 37·4 knots, and she worked up to a world's record of 40·2 knots on passage, by striking a patch of water which just suited her. With only one boiler out of six in use, she could manage her 15 knots, and was an excellent sea boat. It may be mentioned that the "Tartar" was fitted with Thornycroft boilers, the "Mohawk" with

White-Foster boilers, while all the rest of the class had Yarrow boilers.

Contemporary with the first "Tribal" class was the first flotilla leader, a very remarkable vessel in many ways, which was, unfortunately, before her time, and perhaps too elaborate for her purpose. H.M.S. "Swift" was built by Cammell Laird & Co., at Birkenhead, with a displacement of 1,825 tons on dimensions 345ft. by 34ft. 1in.; her turbine engines were designed to develop 30,000 s.h.p. for a speed of 36 knots, while she mounted four 4in. guns and two 18in. torpedo tubes. To begin with, she had some difficulty in attaining her designed speed, but this was overcome, and eventually she did 39 knots at a spurt. Frankly, the service was not quite sure what to make of H.M.S. "Swift", for it was very certain that in torpedo craft it was numbers that really counted; and, in any case, her cost was prohibitive. A little time previously the "Scout" class had been built with what was regarded as extreme speed for cruisers, and it was not long before H.M.S. "Swift" was nicknamed "The Boy Scout". When the War came, however, she carried out some exceedingly useful work on the Dover Patrol.

Fine ships as they undoubtedly were, the destroyers of the "Tribal" class were terribly expensive, and also on the fragile side. The Russo-Japanese War, just ten years after the first destroyers had been commissioned, had opened up quite a new vista of their use, for the Japanese were particularly enterprising in their destroyer operations, and seemed to show, without a doubt, that the torpedo boat, as such, was quite obsolete, and that the destroyer had taken her place. Yet, while the "Tribals" were being built, the British Admiralty attempted to introduce a smaller class, known as the coastal destroyer, or unofficially as the "Oily Wads" or the "Bug Class", because they were all named after insects. The first dozen were built by White, Thornycroft and Yarrow, and, although they all had two slight funnels and a turtle-back deck like the older destroyers, their details varied with their builders, the average being about 220 tons with turbines of 3,750 s.h.p., designed for a speed of 26 knots, and 20 to 25 tons of fuel oil. Their armament was two 12-pounders and three 18-inch topedo tubes. There was something of an outcry at this retrograde step, and after the first dozen, the name Coastal Destroyer was quietly dropped, and First-class Torpedo Boat substituted, with numbers instead of names. But frankly, the three-screw arrangement proved itself to be quite a good one, and during the War these little boats, of which 36 were built, did excellent work in various spheres. It is highly probable that the next war will see a smaller, handier and less expensive type brought in after the destroyer.

While these little ships were being built the "Tribals" were still continued, two more being added in 1907. There were the "Amazon" by Thornycroft and the "Saracen" by Whites, having a displacement of about 970 tons, but otherwise with most of the features of the early "Tribals", except that the five 12-pounders were scrapped and replaced by two 4in. 25-pounder guns of an entirely new pattern, which were to settle the question of British destroyer armament for some years. In the following year five more were ordered, White, Denny, Thornycroft, Palmer, and Hawthorn Leslie building one apiece, and the White-built "Crusader" proving the fastest of the class, with a trial speed of 34·8 knots. Once again the builders had a very free hand in design, and the "Viking" was given no less than six funnels. Then a reaction set in, and in 1909 the 16 ships of the "Basilisk" class which were ordered were again a retrograde step. Oil-fuel supplies were then causing very serious concern in the Admiralty, as they have done more than once since, and in these ships it was decided to revert to coal and to limit their speed to 27 knots. They were also very much more heavily built than the "Tribals" which, remarkable ships as they were, had proved to be very delicate on knockabout service. Nine builders were commissioned and given great latitude, the displacement of the ships varying from 820 to 935 tons, although Yarrow boilers were fitted in all but the White boats, even those from Thornycroft's yard having Yarrow boilers. One great mistake in their design was the reintroduction of mixed armament; they were given one 4in. and three 3in. guns, backed by two 21in. torpedo tubes. The "Acorn" type (of 20 ships) was later ordered as an improvement on the "Basilisks", their displacement being from 750 to 800 tons. Once again the White boats were the only ones which were not fitted with Yarrow boilers, and two of the three built by the East Cowes firm proved the fastest of the class, the "Redpole", with 29·8 knots, and the "Ruby" with 28·3 knots. One particularly interesting innovation was that in the three ships built by John Brown & Co., of Clydebank, the "Acorn", "Alarm" and "Brisk", the Curtis turbine was tried for the first time in competition with the Parsons type. The armament of these ships was two 4in. guns, two 12-pounders and two 21in. tubes. At about that time the destroyer fleet had sustained a number of losses by stranding and collision, and the Navy was rather concerned at this break in their organisation. But Palmer's and Laird's had built several ships on speculation, and these were taken over to replace some of the losses. H.M. ships "Albacore" and "Bonetta" were the Palmer boats, built to rather original design as was usual with that firm, and had a displacement of 440 tons, with engines of 4,000 s.h.p. for a speed of 27 knots, but unfortunately only 43 tons of coal. Their armament was three 12-pounders and two tubes. H.M. ships "Stour" and "Test", built by Laird's, on the other hand, were practically the same as the "River" class, and fitted into the British organisation far better than the more interesting Palmers.

### High Speed of "Lurcher"

The 1910-11 programme was a very mixed one, although it was to produce greater uniformity than ever before. It consisted of three special boats of the "Lurcher" type, built to Yarrow design, with a displacement of 790 tons, a designed speed of 32 knots with Parsons turbines, and a new type of Yarrow oil-burning boiler. It may be mentioned that the "Lurcher" averaged no less than 35·34 knots for eight hours. Then came six ships built to the designs of their builders. Parsons, subcontracting the hulls to Hawthorn Leslie's, built the "Badger" and "Beaver", of 780 tons, having geared turbines and a speed of 30 knots, with 16,500 s.h.p. Thornycroft's built the "Acheron" and "Ariel", of 773 tons, designed for 29 knots, with 15,000 s.h.p., while Yarrow's built the "Archer" and "Attack", of 780 tons, designed for 28 knots, with 16,000 s.h.p. These boats were fitted with special superheaters, and on trial the "Archer" averaged 30·3 knots, and the "Attack" 30·6 knots. Finally, there were the 14 boats to Admiralty standardised design, built by eight yards. These had a displacement of 750 tons, a power of 13,500 s.h.p., giving a speed of 27 knots, and oil stowage of 130 tons. All the ships in the programme mounted two 4in. guns, two 12-pounders and two 21in. tubes, and in spite of the variety in their design they were practically identical in outward appearance with high forecastle and two short funnels.

Under the 1911 estimates the 20 three-funnelled ships of the "Acasta" or "K" class were built to Admiralty design, standardised with a displacement of 950 tons, an armament of three 4in. guns and four tubes, a speed of 31 knots and bunker tanks of 200 tons capacity. In the next year came the 20 ships of the "L" class, 807 tons and 31 knots speed, standardised as to their details but some having two and some three funnels. Their armament was the same as in the "K" class, but they were the first ships in which every name had the initial letter L, a system to which the Admiralty has since adhered to with successive letters. The 1913 programme consisted of 13 destroyers of the "M" class, built to Admiralty design, ships whose displacement of 1,200 tons, speed of 34 knots and armament of four 4in. guns and four 21in. torpedo tubes put them into quite a new class. There were also two special flotilla leaders, the first to be designed for the Navy after the "Swift", the "Lightfoot" being built by White's, and the "Marksman" by R. & W. Hawthorn Leslie & Co., Ltd.

### Seagoing Qualities.

Speed was only one factor in a destroyer's design; it had to be seaworthy enough to run down its quarry in any weather in which the torpedo boat dared venture out. During the 1894 manœuvres the "Havock" and "Hornet" went through a rough-weather test that was regarded as particularly severe, having to lay-to in the Bay of Biscay for 24 hours, and they withstood it very well. But they were not so satisfactory when they were driven at high speed against any sort of a sea, for in all the early boats the idea of a small target was made a fetish and greatly impaired their seaworthiness. They were all quick rollers; the average metacentric height with all weights and 20 tons of coal on board, was 2·48ft., the righting moment being a maximum at 46 degrees. Under helm at high speed they had a very big heel. Another fault of all early destroyers then was the tendency to flame at the funnel-tops which invariably betrayed them in night exercises. This was partially due to their design and the state of engineering development at the time, but also, it is to be feared, very largely due to faulty stoking. This, perhaps, was inevitable when an entirely new type of vessel was given to the Navy with so many different patterns of boilers for the stokers to learn to understand in a very short time.

The average dimensions of the 27-knot class were 200ft. by 19ft. beam by 9ft. maximum draught, the displacement varying from 280 to 320 tons with an average of 290 tons, although the "Conflict" was outstanding with 350 tons. The i.h.p. ranged from 3,850 to considerably over 4,000, their bunker capacity was about 60 tons, and their complement was generally 60 officers and men. They were hampered in their navigation by the very small and cramped fore-bridges which were provided. Their most economical speed was in the neighbourhood of 11 knots; their worst speed was about 23 knots, when they were most extravagant and often vibrated appallingly. Above that speed the vibration was very much less but always serious. They were divided into seven watertight compartments in addition to the machinery spaces, the bulkheads being unpierced, except the collision bulkhead, into which a small watertight door was fitted. An invariable feature was a turtle-back deck which was built over the forecastle, giving quite reasonable headroom to the mess deck below it, under which was a locker for the torpedo warheads and the forward magazine. There was a second mess deck between the forecastle and the machinery space. Abaft this were a small compartment for the dynamo, galley, fresh-water tanks, etc., then the petty officers' and engine-room artificers' mess, then a wardroom in which all the officers except the captain had to sleep on settees placed round the table with drawers under them. Finally there was the captain's cabin, stretching right across the ship, but rendered very uncomfortable by being placed over the propellers, and right aft there was the steering engine, engineers' stores, and the like.