The
INSTITUTE of MARINE ENGINEERS

Founded 1889. Incorporated by Royal Charter, 1933.

Patron: HIS MAJESTY THE KING.

SESSION 1938

Vol. L. Part 12.

President: Sir E. JULIAN FOLEY, C.B.

'Loded' Cast Irons.

READ

By H. J. YOUNG (Member).

On Tuesday, December 13th, 1938, at 6 p.m.

CHAIRMAN: MR. A. F. C. TIMPSON, M.B.E. (Vice-Chairman of Council).

Synopsis.

A REVIEW of the cast irons employed generally for cylinder liners, piston rings and other purposes on internal-combustion and superheated steam engines during the past quarter of a century. A precise practical definition of the description "all-pearlitic" cast iron. The decisive effect of this structure upon service results of otherwise similar cast irons. How it has caused marine engineers to confine themselves to irons of low silicon-content. The types, applications to date and future possibilities of all-pearlitic machinable grey irons of high silicon-content stabilized by high-chromium, namely, 'Loded' irons. A consideration of a relation between wear, as induced by force, heat, corrosion and oxidation, and the qualities of the ultimate superficial skin presented by various cast irons under service conditions.

This paper introduces a new range of high-duty grey cast irons, suitable for cylinder liners, pistons rings and other important engineering castings, and known as 'Loded' irons.

The privilege of this platform is valued because the author, as a non-member, read his first paper here in 1921, and he has been associated with The Institute and the practical side of marine engineering ever since.

There exist difficulties of "language" between engineers and metallurgists; hence, this launching of 'Loded' irons is being done on ways of simplicity designed to render the subject generally intelligible.

Introductory

'Loded' irons may be manufactured with any iron-foundry's normal appliances, but metallographic control is essential. They form an extension of that group of machinable metals known as grey cast irons made in refractory or metal moulds, stationary or moving. Their structure is all-pearlitic. They are usable in the as-cast condition without heat-treatment.

In the above-mentioned paper in 1921 the author said: *At great expense it seems quite an easy task to make improved metal, but if applied science is to justify itself in the world of cast iron it must produce the material at prices such as will enable our castings to command the markets here and abroad.* His belief in the fundamental truth of this has never been shaken, which probably explains why 'Loded' irons are not unduly costly materials.

The description of grey cast iron given in that same paper serves excellently to quote as an approach to the present matter:—

> "Grey cast iron is a very high carbon steel cut up by and surrounding innumerable plates of graphite, that is, a matrix of steel containing many spaces filled with graphite".
>
> "A practical object lesson is obtained from a large propeller casting, blades and boss complete, weighing eleven or more tons. In practice, the molten metal flowing to the tips of the blades is almost chilled and, therefore, the tips are very hard and brittle and contain but little free carbon. A short distance from the tip, this cooling is less severe and more carbon is released, with the consequence that the metal is grey but rather hard. Half-way up the blade the section is greater, hence the metal will be normal and perfectly grey and machinable. At the root of the blade, where it joins the boss, the cooling will be extremely slow and, therefore, the iron has time to free itself almost entirely from combined carbon and, when cold, is found to be full of large graphite".

Considering this, it is obvious that the quality of the iron varies from being hard and white at the tip of the blade to soft and grey at the root. Equally, it follows that somewhere up the blade the metal will be in its best condition, namely, not too hard and white and not too soft and grey. It will be just right. It will be all-pearlitic, but *only round about the one section where the rate of cooling suited the particular quality of iron used for casting the propeller.*

It is this "just right" point which is so momentous. Each grey iron—no matter its quality—wears better, when at this all-pearlitic point. It does not cause all grey irons to be equal; merely each to be at its best.

The Meaning of All-pearlitic Structure.

Fifteen years or so ago, the Lanz Perlit process brought to prominence the fact, now fully accepted, that all-pearlitic structure is vital to the performance in service of grey cast iron. The difference between striving fully to accomplish something by sheer intent and more or less approaching it now and again, so to speak, empirically, was not appreciated in those days when it was contended that iron "mainly pearlitic", "substantially pearlitic" or "more or less pearlitic" was the same as all-pearlitic iron. The fallacy of this contention is hard to illustrate in the case of iron but a purchaser of bars of pure gold would find no difficulty in appreciating it.

The subject is overwhelmingly important to engineers. For instance, if an iron in its all-pearlitic condition in a cylinder liner gives, on an automobile engine, a wearing rate of 1 thou. per 7.000 miles, it will, beyond any manner of doubt, give no such figure when the iron is *but very slightly on the wrong side* of the all-pearlitic point; instead, experience shows that the result would probably be 1 thou. per 3,000 miles or less. It is astonishing how very critical to service performance is all-pearlitic structure.

Since the introduction of internal combustion, engineers have become accustomed to tolerances and limits embodying decimal places only. They have had reason to know that big effects, for better or for worse, are brought about by extraordinarily small causes. The delicacy of the all-pearlitic point in grey iron will be demonstrated by a series of rough sketches.

The All-pearlitic State Defined.

When a specimen of carbon-free iron (which may contain both silicon and manganese) is polished, etched and examined under a microscope, there is visible only the faint outlines of the iron (ferrite) crystals. In common parlance there is nothing to be seen, and the view will be like Fig. 1.

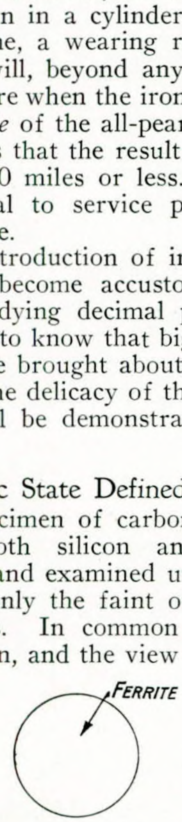


Fig. 1.

Cast iron, however, contains much carbon. If, therefore, the carbon-free iron (of Fig. 1) is melted and, say, 3·2 per cent. of carbon combined with it, there results *molten* iron containing as much carbide as the 3·2 per cent. of carbon can form.

Very *slowly* cooling this carbide-containing molten iron to a cold solid allows time for the whole of the carbon to "un-combine" itself. Hence, the final result is a piece of ferrite or carbon-free iron (just as Fig. 1) only having flakes of graphite within it, like carraway seeds in a cake. Fig. 2 shows this effect, namely, ferrite plus graphite.

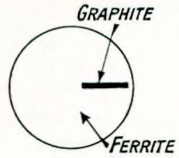


Fig. 2.

A slightly quicker rate of cooling gives barely time for the above process to be completed. consequently some of the carbon remains combined. The result is slightly less carbon-free iron (ferrite), slightly less graphite, together with a small amount of a new constituent in the shape of iron with carbide combined with it. The latter is a natural lamellar body which, having a "pearly" appearance,

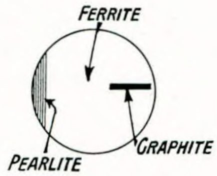


FIG. 3.

was christened pearlite. Fig. 3 demonstrates the entry of a little pearlite (see also Fig. 9).

Still faster cooling means still less time for graphite to form. Fig. 4 is the result, namely,

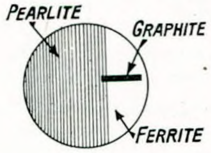


FIG. 4.

more pearlite with less ferrite and graphite (see also Fig. 9).

It will be noticed that a state of affairs is approaching when, by slightly quicker cooling, there will be but a minute trace of ferrite left. This is

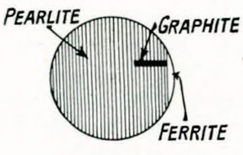


FIG. 5.

shown in Fig. 5. Even a trace of ferrite prevents the iron exhibiting good wearing properties.

The next stage is attained when the iron is quite full of pearlite. Fig. 6 is theoretical all-

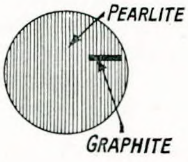


FIG. 6.

pearlitic grey iron, containing nothing but pearlite plus free graphite flakes (see also Figs. 10, 14 and 16).

As the metal cannot be "more than full" of pearlite and still quicker cooling will give a little more carbide, this excess must then remain as *free*

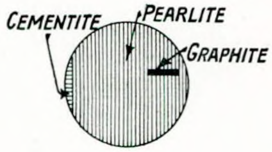


FIG. 7.

carbide. shown in Fig. 7 (see also Figs. 14 and 15) and called cementite. Fig. 7 together with Fig. 6 represent the author's definition of all-pearlitic iron as aimed at in practice, namely, iron either on, or on the *safe* side of, the theoretical all-pearlitic point.

As cooling is expedited so does the amount of

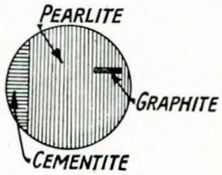


FIG. 8.

free carbide (cementite) augment, as seen in Fig. 8. Instantaneous chilling of the molten metal would produce the final stage, namely, white iron containing neither graphite nor pearlite.

The diagrams have shown the gradual approach to the all-pearlitic point and how iron like that in Fig. 5, *although very nearly all-pearlitic,* contains traces of ferrite which profoundly impair the wearing qualities of the iron and which cannot be guarded against save by constant metallographic control in the manufacturer's works.

On the other hand, it is impracticable unfailingly to produce metal true to Fig. 6. Attempts to work on such lines must result often in getting iron like that in Fig. 5, on the *wrong* side, the bad-wearing side, of the all-pearlitic point, and having to scrap the castings rather than permit them to go into service to harm the prestige of the product by the inferior performance.

Fig. 7, however, is on the *right* side, because a little cementite does not detract from the service performance of the metal. Getting too much cementite means trouble in the machine shops, which is far preferable to bad results on the engine. All-pearlitic iron is always on, or on the safe side of, the all-pearlitic point.

It will be patent to everybody that the production of a cylinder liner or any important part is not a question of making good castings which will machine at high speed with heavy feed. Instead, success, both technically and commercially, depends upon not having failures under service conditions.

In early work on 'Loded' irons, castings frequently were made too cementitic, with resultant difficulties in the machining; but the fault was on the right side, the irons lived to be tried again. Had the fault been on the wrong side, the ferritic one, the machine shops might have been delighted but the user of the engine would have said that his one trial of 'Loded' iron was one too many.

There is an additional and purely metallurgical point, which engineers can neglect. Cast iron contains phosphorus as phosphide of iron. No matter how much phosphide there may be present, the iron itself, which surrounds the phosphide (Fig. 11), is in no way debarred from conforming to the desired all-pearlitic structure. For example, iron containing, say, 2·0 per cent. of phosphorus can be as all-pearlitic as iron containing 0·2 per cent. Of course, the higher the phosphorus the more iron used to form the phosphide, leaving less ferrite to form pearlite, with the anticipated result that the combined carbon content of low phosphorus all-pearlitic iron is higher than that of high phosphorus all-pearlitic iron. This is common metallurgy. It is to be observed also that the author employs the term ferrite to include iron containing in solid solution silicon, nickel, manganese, etc., and the term cementite to include free carbides of any composition.

The author suggests that an engineer assimilating the example of the propeller, cited at the beginning of this paper, will have no difficulty in seeing that all-pearlitic iron occurs at some place in every blade for reasons set out in the diagrams. In fact, Figs. 2 and 3 depict the metal at the root and Fig. 8 the iron near the tip, with Figs. 2 to 8 representing progressively the material from root to tip of the blade.

Silicon Control.

It has been demonstrated that the degree of the pearlitic state is altered by the rate of cooling. This degree, however, depends upon the silicon-content of the iron being used. The higher the silicon the faster may be the cooling rate, so that foundries use more silicon for thin and light castings than for thicker and heavier ones.

Silicon-control is limited in the case of light castings because they chill so easily, thereby becoming difficult to machine. This accounts for the poor-wearing qualities associated so often with light castings of thin section, because a foundry on very competitive repetition work has necessarily to base its control upon a machinability test, and cannot aim at all-pearlitic iron.

Silicon-content of All-pearlitic Irons.

Iron castings of the all-pearlitic class, invariably are low in silicon-content. This inducement towards low silicon is furthered by reason of the fact that the structure of very low-silicon irons is more stable, when subjected to elevated temperatures, than that of higher silicon irons.

Lanz Perlit irons have the lowest silicon of all, often only 0·5 per cent. and seldom going beyond 1 per cent. All other irons of all-pearlitic type contain silicon ranging from about 0·9 per cent. to 2 per cent., but more often under 1·75 per cent.

Chromium-content of All-pearlitic Irons.

Sometimes a little chromium is present, generally accompanied by about double the amount of nickel; so that an all-pearlitic iron for heavy work may contain 1 per cent. silicon, 1 per cent. nickel and 0·5 per cent. chromium; for lighter work the silicon is increased to about 1·5 or 1·75 per cent. Seldom is as much as 0·75 per cent. chromium present.

The above figures apply throughout the world where all-pearlitic irons are manufactured; equally to the author's own work for twenty-five years.

The 'Loded' Iron Process.

Thinking over these things the author gave attention to the factors rendering the higher end of the silicon scale utterly unusable by the manufacturers of all-pearlitic irons. Out of this came the 'Loded' iron process which, departing altogether from the low-silicon range, can employ any silicon-content from 2·5 per cent. up to, say, 7 per cent. Many castings, for example, have been made with silicon of 4·5 and 5·5 per cent. These contents are stabilized by high chromium, often from 1 per cent. up to 4 per cent. or more, adjusted to the silicon chosen and the section of the castings concerned, and an all-pearlitic structure ensured. Suppose a cylinder liner of normal all-pearlitic iron contains 1 per cent. of silicon, then the same liner in 'Loded' iron may have at least 1·5 per cent. more silicon and, if desired, 4 per cent. more and over, the all-pearlitic iron being attained by chromium to an amount from 1 per cent to, say, 2·5 or 3 per cent. No matter what silicon-content is used to-day for any all-pearlitic iron, a 'Loded' iron can be substituted containing much more silicon. The same applies to chromium-content. In other words, 'Loded' irons are made all-pearlitic, although containing high chromium and high silicon—both conducive to great stability under heat—and, at the same time, retain the bearing metal properties common to grey cast iron and the wear-resisting properties peculiar to all-pearlitic structure.

A new range of engineering irons thus becomes available for use and research. The silicon and chromium may be replaced wholly or partly by nickel, copper, molybdenum and manganese. Also, 'Loded' irons lend themselves to having small amounts of rarer elements, such as tungsten, vanadium, titanium and so on; in other words, they do not prohibit the use of any minor addition which may be fancied.

Nickel, etc. in 'Loded' Irons.

Nickel in 'Loded' irons is interesting in that it appears to give the beneficial effects observed in the case of ordinary irons, such as, increased perfection of castings, overcoming edge-chill, troubles with sudden changes of section, etc. The author often incorporates from 0·5 to 1·5 per cent. of nickel in 'Loded' irons, replacing a little of the silicon.

Similarly, molybdenum is often used by him, in place of some of the chromium, to promote toughness.

Lanz Perlit and the 'Loded' Iron Process.

Valuable types of 'Loded' irons may be those made under Lanz Perlit conditions where preheated sand or refractory moulds are employed. The established advantages of Lanz Perlit iron may well be enhanced by incorporating the principles of the 'Loded' iron process. The chromium-carrying possibilities of iron so made are not without interest. Moreover, the Lanz Perlit method has such good effects upon ordinary irons that it would appear attractive to obtain them in 'Loded' irons of very different range and properties.

Centrifugally-cast 'Loded' Irons.

'Loded' iron can be cast centrifugally. It requires no alteration of the normal centrifugal process; the commonly employed die temperatures and speed of production remain unchanged. There is no need for delayed cooling in the dies or for any after-treatment whatsoever. The plant is switched over from ordinary iron to 'Loded' iron without varying anything save the molten metal, which is melted in the same furnaces in the same manner.

Castings, known as Centricast 'Loded', are being tried as cylinder liners on fleets of commercial vehicles, motor boats, auxiliary engines, land units and so on. Results to date are encouraging and suggest that the skin of the iron, namely the working surface the metal takes unto itself, is uncommonly resistant to those influences leading to the final result known as wear.

Sand-cast 'Loded' Irons.

Several sand-cast qualities of 'Loded' irons are proving interesting to various trades. In the case of large cylinder liners, three qualities are being tried which may be classed as containing 3 to 3·5 per cent., 4 to 4·5 per cent. and 5 to 5·5 per cent.

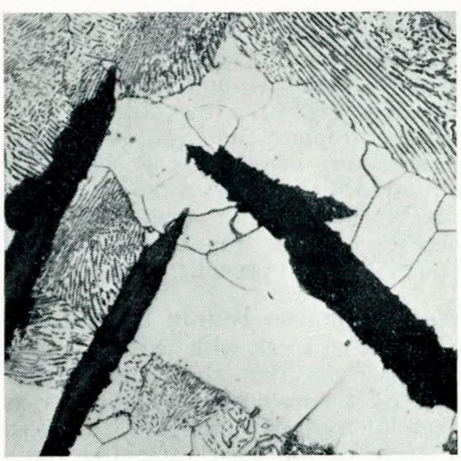


FIG. 9.—Less-than-all-pearlitic iron, namely, iron containing ferrite as well as pearlite (Figs. 3, 4 and 5). Magnification: × 400 diams.

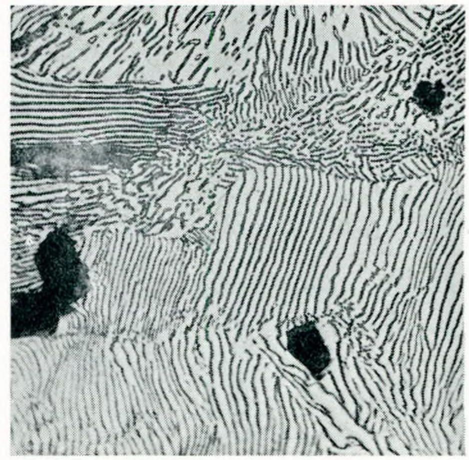


FIG. 10.—All-pearlitic structure (Fig. 6). Magnification: × 500 diams.

FIG. 11.—All-pearlitic iron containing high phosphorus. Magnification: ×400 diams.

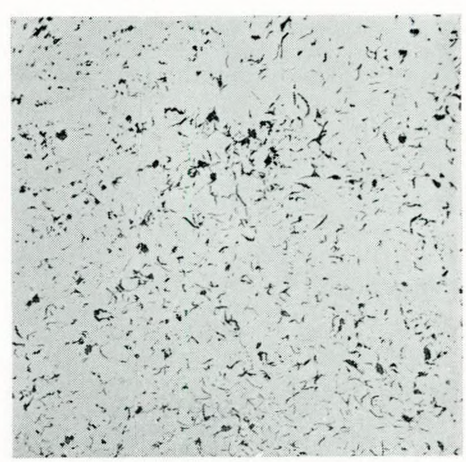


FIG. 12.—Sand-cast 'Loded' iron. Graphite at low magnification. Magnification: × 25 diams.

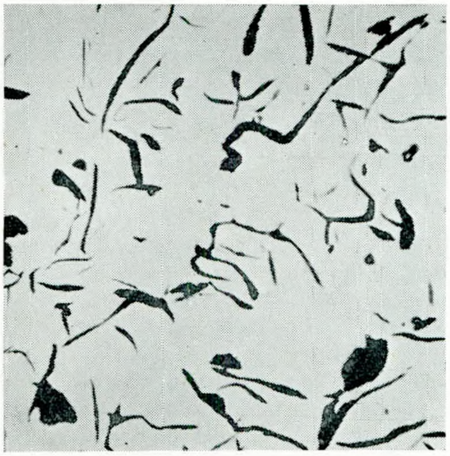


FIG. 13.—Sand-cast 'Loded' iron. Graphite at high magnification (same as Fig. 12).
Magnification : × 300 diams.

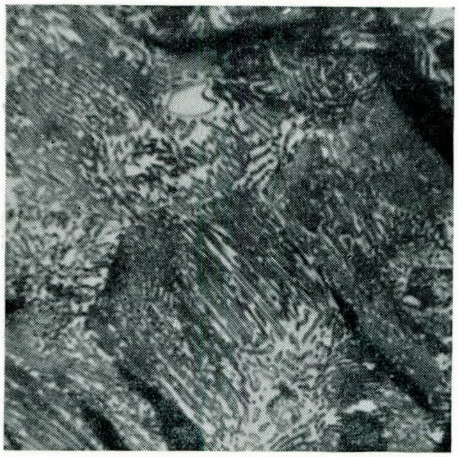


FIG. 14.—Sand-cast 'Loded' iron. All-pearlitic structure (Figs. 6 and 7).
Magnification : × 1,500 diams.

FIG. 15.—Sand-cast 'Loded' iron. All-pearlitic structure (Fig. 7).
Magnification : × 1,500 diams.

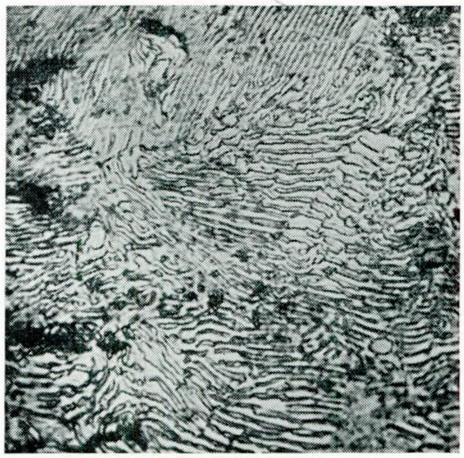


FIG. 16.—Centrifugally-cast 'Loded' iron. All-pearlitic structure (Fig. 6).
Magnification : × 1,500 diams.

silicon, each carrying its respective quota of chromium of the orders of 2 to 2·5 per cent., 2·5 to 3 per cent. and 3 to 3·5 per cent., according to the mass and section of the casting. Molybdenum to the amount of 0·25 to 0·5 per cent. is often incorporated. The jobs are being watched but more time must elapse before offering any results.

Attention is called to the fact that whereas ordinary all-pearlitic irons, for heavy liners, fall between 0·5 per cent. and 1·5 per cent. silicon, in the case of 'Loded' irons there is a possible useful range between, say, 2·5 per cent. and 6·5 per cent. silicon. Lanz Perlit methods would introduce yet another range of 'Loded' irons. The author desires it to be understood that he thinks the 'Loded' iron process opens out a new and wide field of all-pearlitic irons which will necessitate much work to explore the utility and applications of the various types.

In order to illustrate the diagrams by means of actual photomicrographs, there is presented Fig. 9 (kindly lent by Mr. R. T. Rolfe), showing a less-than-all-pearlitic iron, namely, containing ferrite (like Figs. 3, 4 and 5), and Fig. 10, which is all-pearlitic (like Fig. 6). Figs. 12 and 13 indicate the very fine graphite and Figs. 14 and 15 the all-pearlitic structure of a sand-cast 'Loded' iron. It will be noticed that Fig. 15 contains cementite and, therefore, is like Fig. 7, whereas Fig. 14 is in between Figs. 6 and 7. Fig. 16 shows centrifugally-cast 'Loded' iron, all-pearlitic (like Fig. 6).

The Skin or Film on Run-in Bearing Surfaces.

It is early to speak with scientific certainty but it seems probable that the working surface of 'Loded' irons is unusual in its nature, as compared with that of ordinary irons. Results show a slowing-down of the wear rate after the surface-forming period has passed. For example, on an extremely severe commercial vehicle service, liners of about 72 mm. bore showed a wear of ·004 to

·005 mm. during the first 4,400 miles, but the following 4,700 miles showed no further wear of a measurable order.

The author has heard it stated that the working skin of a grey iron cylinder liner is a Beilby layer "of amorphous metal precisely similar in composition to the metal underneath". He suggests that this is unlikely. In his experience, grey irons form a film containing something remarkably like oxide. Indeed, so much has he believed this to be true that he expects 'Loded' irons, by reason of high silicon-content, to present a film such as will have a substantially protective effect and thus reduce the wear rate.

Machinability and Brinell.

The Brinell of 'Loded' irons goes up with the silicon content without rendering the irons unmachinable. For example, large cylinder liners for marine work have been manufactured of 'Loded' irons with Brinells ranging from 300 to over 400.

General Properties of 'Loded' Irons.

The main difficulty in compiling this paper is that little can be known about anything new. The author seeks the leniency of the audience upon this point. It took years to study ordinary all-pearlitic irons and it will take a long time, and many workers, before the metallurgy of 'Loded' irons—their applications, properties and varieties—is written.

'Loded' irons are proving good in unexpected directions. One gets the kind of enquiry where someone has tried everything and found none very good for his particular work and, in consequence, 'Loded' irons have had a chance of being tried. It will be appreciated that they are very heat-resisting and of such composition that their physical properties remain unimpaired by degrees of heat which would break down a normal engineering iron.

As the silicon goes up the irons become shorter and more brittle but a tensile of 17 tons per sq. inch is obtainable on a 'Loded' iron of 5 per cent. silicon-content. Possibly when high-steel mixtures are used, as in the case of practically all high-strength cast irons, the tensile and other properties of 'Loded' irons will further improve, but this has not yet been tried. That 17 tons per sq. inch is got right away on a product in a new range is not discouraging in view of the fact that a few years ago it would have been a splendid result to obtain from ordinary grey iron made in the best conducted foundry.

'Loded' irons have uncommon properties during foundry pouring operations. They lie placid in the ladle, do not splash or spark when poured, and behave more like cream than milk. Requiring no particular superheat they do not affect ordinary foundry sands. It has been noticed over and over again how free are 'Loded' iron castings from defects, such as slag inclusions, blow holes and the like. Their machined surfaces are beautiful and difficult to distinguish from that of steel.

They possess the common failing of high-duty irons of being liable to draw at sudden changes of section. 'Loded' irons made to date offer no amelioration of this foundry trouble, but the extended use of nickel has not been explored and only a few types of 'Loded' iron have been manufactured.

Mass action comes into play in all grey iron calculations as a factor the effect of which can be ascertained only by trial and error. In days gone by the author stressed continuously the hopeless proposition of attempting to get a testpiece to represent a heavy casting unless actually cut out of it. The number of heat units taken by the metal into the mould of a small casting are infinitesimal compared to those taken in in the case of a big casting, and the final result is a great difference in the graphite, the pearlite and the grain. This is exasperating because it means that a foundry must overcome teething troubles before it can manufacture, with certainty of success, any particular design. An advantage, however, is that foundries specialize and obtain a reputation for certain types of castings.

Cylinder Wear.

It is not irrelevant to this paper to point out that the author has disagreed publicly with some of the modern theories concerning cylinder wear from their inception. Such emphasis, he thinks, is placed at times upon deductions drawn from laboratory tests, that opinions have become clothed as facts.

A painful experience of his own in this respect occurred when a year's work in an experimental tank had proved that a particular type of grey iron resisted sea-water attack far better than any other, but one voyage across the Atlantic showed otherwise. The author's fallacy was in drawing practical deductions from facts established under other than practical conditions—in mistaking his little tank for the ocean.

Some years ago the author was told that an accident occurred causing a cylinder top to blow off and it was noticed that the bore of the cylinder became rusted almost instantaneously. His reaction was that, as cylinder tops did not usually blow off, the happening could not apply to normal working conditions and that he had examined hundreds of "normally-opened" bores and had *not* found them rusted. This occurrence was followed by experiments showing that increased wear takes place when cylinder walls are unduly cooled, with the result that, to-day, it is said in no uncertain terms that the *major* cause of normal wear, in the bores of automobile cylinders in particular, is severe corrosion during or before starting up. Up to the moment of writing this paper the author is unable to see that this is more than a theory or that it is confirmed by results under service conditions.

Consideration of the bore of an automobile cylinder at the exact place where maximum wear occurs indicates that that area is lubricated *only* by the top piston ring, *that no other ring ever reaches it.* Visualizing the cylinder bore and the top piston ring laid out flat on a table, there is a small piece of metal running backwards and forwards along the bore in such fashion that when it reaches one end a sudden additional pressure or "kick" is given to it. It is observed also that a little lubricant is supplied at the *other* end of the bore and nowhere else, so that the small moving piece has to wet itself with oil and spread it up the bore as far as its uttermost position, at the end where the "kick" occurs. Further, a hot flame is turned upon that part just at that moment. The author suggests that a reciprocating bearing lubricated in this manner only from one end and heated at the other, is sure to wear at the latter; moreover, with a "kick" also occurring at that vital spot the wear is, so to speak, located as well as assured. Taking it further, if the experiment be allowed to cool down and then started up, some time must elapse before the tiny moving part has succeeded in spreading the cold oil along the cold bore as a perfect film right up to the limit of its travel. If that is a fair description, then the fact that automobile vehicles suffering the maximum number of "cold" stops also suffer the maximum rate of bore wear, is what is to be expected and is due mainly to contact of the top ring with that area of the bore where the oil film is imperfect for some time after starting up from cold.

The author can speak authoritatively as to the fact that exceedingly good results constantly are obtained from irons which are *not* non-corrosive; this would be a miracle if corrosion was the major, or a very important, factor. The author believes that mechanical stresses, oxidation, broken oil film, erosion, flame action, gas penetration and dèbris, are more serious than corrosion in the majority of engines and services. It is an opinion, the corrosion theory being, he thinks, another opinion. To encumber this paper with experiences culled since the days when the conversion of saturated and wet steam engines to superheated and dry steam gave us our first taste of really severe cylinder wear, is unnecessary.

An Initial Review of 'Loded' Irons.

The only way of presenting 'Loded' irons as materials having possibilities of giving improvement without undue cost is to enumerate their properties as they are known in the qualities so far manufactured and to include others anticipated by various authorities, as follows :—

(*a*) Bearing metal qualities common to grey cast irons, namely, they favour the holding of oil-film upon their working surfaces;

(*b*) Some resistance to acidic attack, which becomes the greater as the amounts of silicon and chromium are increased;

(*c*) Ability to form quickly a working skin; to which may be added the expectation that the ultimate superficial film of the skin, formed on high-silicon 'Loded' irons, will prove more adhesive, tough and protective than that of other grey irons;

(*d*) Resistance to effects of gas-penetration, due also to the high silicon content. In this connection it has been shown by a worker of eminence that oxidation and action by certain gases may seriously undermine a ferrous material; in the case of a liner or piston ring, this would mean collapse of the structure supporting the skin of the bore;

(*e*) Stability under heat. It is proved that 'Loded' irons, particularly in the higher series, have a resistance to heat equal to some materials useful by reason of their great heat resistance but useless as engineering irons;

(*f*) 'Loded' irons owing to their high chromium content retain their strength, hardness and all-pearlitic structure unaffected by the thermal conditions suffered by cylinder liners or piston rings;

(*g*) High natural hardness. Ordinary grey irons become unmachinable round about 280 Brinell, whereas 'Loded' irons usually have 300 Brinell, and some of over 400 Brinell have been made which have machined well;

(*h*) The property of resisting dry attrition—this has been proved to be good in 'Loded' irons and they have given satisfaction under severe working conditions, such as those imposed by drawing dies;

(*i*) The proved good-wearing properties peculiar to irons of all-pearlitic structure, which, up to now, have been only low-silicon irons containing either no chromium or a very small quantity. The all-pearlitic structure, rendered possible by this process, qualifies 'Loded' irons, namely irons high in silicon and chromium, as materials suitable for engineering use and construction.

The author strongly reiterates his view of 1921 that the position of our engines in the world's markets will depend upon their selling price and that the attainment of efficiency by non-costly means is imperative. Along these lines of thought the 'Loded' iron process was conceived and is offered as a contribution to the future of grey cast iron, a material unexcelled for its past utility to engineering and, the author believes, yet in its infancy.

The Sheepbridge Stokes Centrifugal Castings Company, under whose auspices the 'Loded' iron process has been developed and the first 'Loded' irons manufactured, are thanked by the author for their permission to present this introductory paper.

Appendix.

Since writing this paper the author has thought it advisable to add the following explanatory diagrams.

Fig. 17 shows Figs. 2 to 8 fitted into the blade of the 11-ton propeller casting mentioned in the text. It demonstrates how the iron becomes more and more pearlitic as it gets further from the thick root of the blade and the thermal influence of the heavy boss, so that, about half way down the blade, it passes through the all-pearlitic condition, after which it becomes progressively more cementitic and hard as the tip of the blade is approached.

Fig. 18 illustrates the author's argument concerning the working conditions of the top piston ring of an automobile engine cylinder. At one extreme end of the stroke, namely *at top dead point,* the bearing is starved of lubricant and exposed to sudden stress and flame. This state of affairs, the author suggests, amply explains why it is that the more frequently an engine of this type is started up from cold the more rapid the bore wear *at that identical position.* In his view, the top piston ring, at such times, has the impossible task of the individual desiring to spread a complete and unbroken film of cold butter upon cold bread using a knife having very little butter on it.

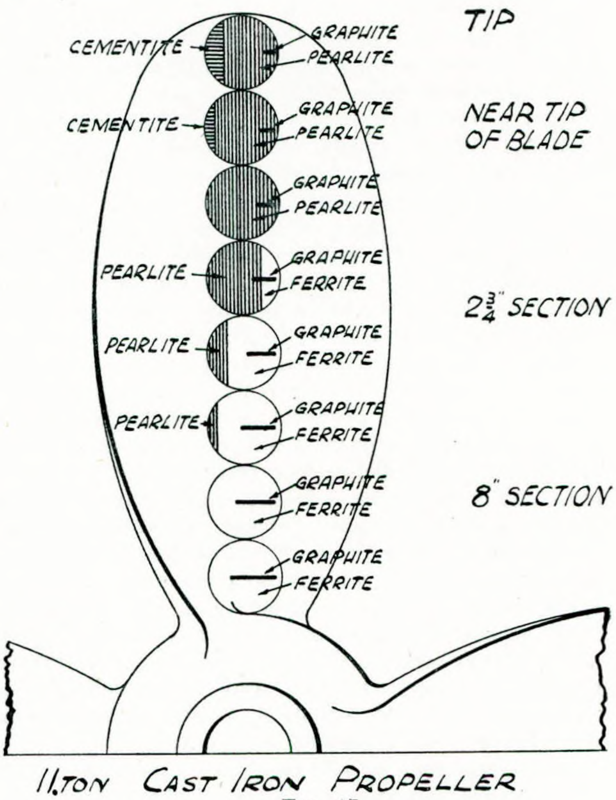


FIG. 17.

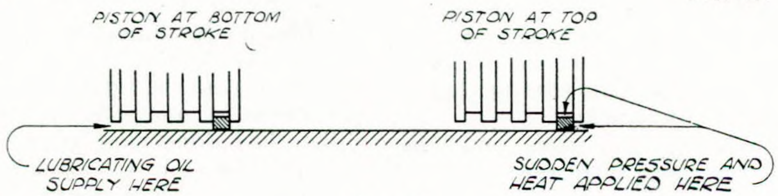


FIG. 18.

Discussion.

Mr. P. H. Smith (Visitor), opening the discussion, said that an interesting experiment had just been concluded. Twenty-one months ago a three cylinder engine, 310 mm. bore, undergoing overhaul had one only of its three pistons metal sprayed with Swedish iron. The engine had now completed a period of 7,000 hours in service without disturbing pistons. The two untreated pistons were just as one would expect after 7,000 hours—dirty and with sticking rings, but withal satisfactory. The treated piston and its liner rejoiced the heart. All rings were irreproachably free and above the top ring the piston surface was a perfect mirror. The liner was the best he had yet seen and it too was a perfect mirror. If the author, who lately had asked for the engineer's co-operation, could explain why a Swedish iron facing to the top of the piston, working in conjunction with a cast-iron liner, could render the combination striation proof, then they would be well on the way to securing added reliability, and could increase the piston diameter which could be operated without recourse to fluid cooling of the piston.

Mr. C. R. van der Ben (Visitor) said that he had a little practical experience of high silicon and chromium irons. In 1936 he had been doing some work on piston ring irons, in the form of pots, and during the course of that work he had prepared some pearlitic irons containing up to 4 per cent. silicon and 2½ per cent. chromium with the object of obtaining increased natural springiness. High silicon irons were generally rather prone to brittleness and chromium did not help them in this respect, and that feature must be borne in mind in considering these materials.

The author claimed that these irons had considerable resistance to heat, *i.e.* the structure was not impaired by degrees of heat which would affect normal irons. In the case of complicated castings (pistons, cylinder heads, etc.), whilst the structure might not be impaired, was there not a tendency to cracking due to brittleness? Also, in the case of liners, toughness appeared to be necessary to resist the dislodgment of minute particles which led to excessive stress being thrown on the surrounding areas, leading to the breaking up of the surface, a view which the author had himself expressed. Skin-forming and maintenance properties, in the speaker's view, were not likely to be better than those of a tougher pearlitic material, although the skin formed might be of a different nature.

In the paper the author referred to the replacing, wholly or partly, of silicon and chromium by other materials—copper, nickel, molybdenum and manganese. Since the author was dealing with the properties of high silicon and chromium irons, the speaker did not quite understand the statement. High silicon and manganese irons containing up to about 4 per cent. silicon and 12 per cent. manganese had been studied and manganese-copper irons had received attention, whilst nickel-molybdenum irons were coming to the fore.

The speaker agreed that structure rather than composition was the important consideration. The bearing metal qualities of cast iron were, as pointed out by the author, all-important in connection with this question of wear. The hard network imparted by phosphorus played an important part in obtaining the bearing metal type of structure.

The deliberate inducing of a hard cementite network—incidentally ensuring that the iron was on the right side of the pearlite point, stressed by the author, was in the speaker's opinion to be preferred to the presence of a similar quantity of phosphide network. This structure of hard cementite in a strong, tough pearlitic matrix gave a remarkable resistance to wear.

He was interested to note that 'Loded' irons were made by the centrifugal as well as by the stationary sand mould process, although the two methods involved structural differences in some respects. Depending in degree upon conditions, some migration of constituents appeared inseparable from the former process. He imagined difficulties must also exist in the centrifugal process in maintaining a pearlitic structure in the bore while keeping the outside of the casting machinable due to the chilling effect of the metal mould.

The author stated that it was fully accepted now that totally pearlitic structure was vital to the performance in service of grey cast iron. That was so, as far as the pearlitic class was concerned, but it must be borne in mind that pearlitic structure was not the only possible one. Austenitic irons, containing no pearlite, were well known for their high heat, corrosion and oxidation resistance, and when such irons contained a hard cementite network in addition, they had given excellent results and a number of liners in this material, though somewhat more costly, were in service in certain engines of the Company with which the speaker was associated.

Speaking of corrosion resistance or acidic attack, he did not think worthwhile differences existed among grey pearlitic irons. There were slight differences, but taken by and large they were not corrosion resisting and resort must be made to the austenitic type when this was required. A further material, developed by the speaker's Company, which also contained no pearlite but differed essentially from the austenitic material he had referred to, had a tensile strength of over 30 tons per sq. inch and a Brinell hardness of about 300 in the cast state, and possessed extraordinary toughness. It was on trial and was proving interesting, though he could not at present give any results. It compared well with other materials on the score of cost.

Mr. J. H. Graves (Associate Member of Council) said that one occasionally came across the term "Meehanite" in connection with iron castings. Could the lecturer give some description of this term and state whether it was what could be called 'Loded' cast iron?

Mr. J. A. Smeeton (Visitor) said that the author was the first British metallurgist to become associated with the Lanz Perlit process when it was introduced by him into this country, and that the author had done most of the spade work in this country relative to the Lanz process.

The author had for the last ten years entirely devoted himself to investigating new qualities of cast iron. Previous speakers had referred to other known qualities of cast irons, but he would call attention to the fact that the purpose of the paper was to discuss 'Loded' irons. It was significant that the author, despite his wide knowledge of irons of all types and for all purposes, had deemed it wise, necessary and useful to make entirely new experiments with something no other metallurgist had yet apparently thought about or investigated.

The minds of engineers and metallurgists tended to run in grooves. No-one apparently, except the author, had realized that by a combination of high silicon and other alloys, especially chromium, and by special heat treatment both in melting and eventually cooling down, exceptionally high percentages of silicon could be used to advantage and still produce a machinable all-pearlitic iron.

He was prepared to accept the author's assurance that these irons were worthy of consideration, but he would like to know to what extent the 'Loded' process would enhance the best features of the Lanz Perlit process. He also desired to know if the author was using hot moulds of varying temperatures with the object of obtaining gradual variable cooling, so that the thinner sections close to the moulds cooled more gradually and thus prevented serious hardness of the thinner sections and minimised the cooling draw or shrinkage which was a natural physical certainty in such circumstances, and could not be prevented by any mixture of metal. Did the author use different temperature of moulds in cooling down to suit variable sections and to prevent draw and subsequent porosity?

Had the author thought of using 'Loded' irons for various classes of cast-iron rolls? Millions of pounds had been spent in this country during the last three years in putting down modern rolling mills, and 'Loded' irons seemed to offer something entirely different which might possibly be used to advantage in the manufacture of mill rolls. Many experiments had recently been made in manufacturing rolls containing various alloys to give toughness, strength and lasting efficiency, and it would be interesting to know if the author had thought of using his irons for that purpose.

The speaker thought too much fuss had been made about cylinder liners and piston rings. Marine engineers using Diesel engines needed them of the highest quality. Manufacturers of high-quality irons had been trying for many years to get the superintendent engineers of shipping companies to specify qualities, and until such special qualities were specified they would not get them from any foundry except such special foundries actually attached to marine engine builders' works. Jobbing foundries were seldom, if ever, inclined to manufacture such patented qualities of irons until forced to do so by trade demands.

He hoped the author would receive the encouragement and patronage he deserved for his 'Loded' irons, which he believed represented a valuable step forward in high-quality irons having all the desired physical and metallurgical properties so valuable to procure the lasting efficiency in marine engines of all types.

Mr. C. Gresty (Visitor) said that the author had described in language containing as few technical terms as possible a new type of cast iron which he had developed and he had also made clear certain very important points about all-pearlitic cast iron in general. The speaker would like to underline one particular sentence, namely, "It does not cause all grey irons to be equal; merely each to be at its best". In the speaker's opinion, non-realization of this had led to a great deal of misunderstanding and misconception amongst engineers. Pearlitic cast irons had been and, in fact, still were spoken of as though they all had similar properties irrespective of their compositions and the processes by which they were manufactured. This, the author rightly pointed out, was not correct.

After drawing attention to the great importance of obtaining a completely pearlitic structure, without any trace of ferrite, the author proceeded to demonstrate that in actual practice it was necessary to work, if anything, slightly on the safe, *i.e.* the cementitic, side. From the speaker's own experience over many years, he could confirm this, and although, as stated in the paper, it might occasionally lead to castings giving a little trouble in machining, this was of minor importance compared with results in service.

In describing in what respects 'Loded' iron differed in composition from other cast irons, various ranges of silicon and chromium contents were mentioned and also the addition of other metals if desired. It would be of interest if the author would give some indication of the relationship between these silicon-chromium ranges and the thickness of the castings for which they were used. The carbon content of the iron was not stated nor whether it was varied according to the silicon and/or chromium contents, and some information on these points would be appreciated.

In the early part of the paper it was stated that 'Loded' iron might be made with normal foundry appliances and the speaker presumed this meant that no furnace other than a cupola was necessary. In this connection he would be interested to know whether the silicon and chromium were both added to the cupola in the form of pig iron or alloys or whether ladle additions were used.

With reference to the properties of 'Loded' irons, the author mentioned the difficulty of giving much detailed information due to the newness of the process. Nevertheless, the speaker would venture to ask him a few questions in the hope that he might have data on some of them at least:—

(1) Did the material "grow" on repeated heating and cooling or did it show a reduction in volume, as had been reported in certain irons containing chromium?

(2) What was its coefficient of expansion?

(3) What was its resistance to repeated impact?

The very interesting suggestion was made in the paper that a combination of the 'Loded' iron process and the Lanz Perlit process might prove very advantageous to both. There was certainly no doubt that the use of the Lanz Perlit principle would extend the range of 'Loded' iron compositions and, further, the castings would be much more free from internal stresses than if cast by ordinary methods. On the other hand, however, whether the converse was true, namely, that Lanz Perlit iron would be improved by the combination, was a matter which would require much investigation. From the point of view of composition the two irons were radically different and some of their properties might also be very different. He had in mind particularly the high resistance to repeated impact and the comparative freedom from brittleness possessed by Lanz Perlit iron, which factors were, in his opinion, amongst the principal reasons for its success in service. He thought that 'Loded' iron, with its greater hardness and liability to brittleness might lead to difficulty in these directions. This was, of course, only an opinion but it was a point on which he would value the author's comments.

Mr. F. A. Hunter (Member) asked if these 'Loded' irons were uniform in structure? One would imagine that if the mixture in its molten state were not uniform, there might be trouble in the machine shop due to hard and soft patches. One could understand the complaint of the works' manager when he came across a hard patch.

He understood that to-day most makers did not grind liners or pistons, but finished them with a boring bar or ordinary turning tool. If there was a hard patch the tool would jump.

Where a structure was not uniform the wear was likely to be in spots. Did that occur in these high silicon irons?

Another point was in regard to graphite. He took it that there was a lot of graphite in the irons. Sometimes there were small pin holes seen in liners after wear, and he would like to know if these were due to the graphite.

The author had not dealt with the corrosion which took place on the water side of the liner just above the rubber rings. It was noticeable more than anywhere else in tugs working in the Thames, particularly in the creeks as compared with the river. Would such liners be better in 'Loded' iron?

On the proposal of **Mr. S. Hogg** (Member of Council), seconded by **Mr. H. Scott** (Member), a hearty vote of thanks was accorded to the author.

Author's Reply to the Discussion.

Mr. P. H. Smith had read recently a valuable paper upon striation phenomena to the discussion of which he (the author) had contributed. The present paper was devoted wholly to a new range of cast irons, a point Mr. Smith overlooked. He asked why a Swedish iron sprayed on a piston rendered the liner striation-proof, but more evidence that it really did so seemed to be needed before the query arose. The author was not an engineer, but nevertheless suggested that some striations might be born during machining processes.

Mr van der Ben seemed doubtful whether these new irons would wear well; but some, at any rate, had already given good results. Mr. van der Ben said that the paper dealt with high-silicon high-chromium irons and that he did not understand the statement that part of the silicon or chromium could be replaced by other materials—nevertheless it was so. He also stated that cementite network was preferable to phosphide network, but the paper mentioned neither; as a matter of fact, some very successful modern liners contained much of the latter.

Mr. Graves sought a description of Meehanite and asked whether it could be called 'Loded' iron. The author's reply to the latter point was that the materials were different and, therefore, the former point was irrelevant to the subject of the paper.

Mr. F. A. Hunter asked whether 'Loded' irons were uniform in structure and the answer was that uniformity and all-pearlitic structure were synonymous terms. Mr. Hunter had seen holes in liners in the position of the wear, but it was impossible for the author to give an opinion without examining the holes Mr. Hunter spoke about. In any case, although the engineering world would reject a liner for the reason of a minute hole being discovered in the bore, and countless thousands of liners had been so rejected, it had not led to any alleviation of cylinder wear, nor was there any sound reason why so much account was taken of small defects to the exclusion of more vital matters. One frequently met specifications for important parts stating, for example, that the combined carbon must be between 0·45 and 0·85 per cent. and that the castings must be utterly free from pinhole defects. This was equivalent to stating that the quality of the iron might be anything from bad to good as long as the castings passed visual inspection.

Mr. Smeeton's contribution was welcome as it was based upon an intimate experience of the Lanz Perlit process and those obstacles to be faced when pioneering in grey cast iron. 'Loded' irons were amenable to ordinary foundry practice whether in refractory or metal moulds, sand-cast or centrifugally-cast. Also they were capable of being cast under Lanz Perlit conditions which would enable other qualities of 'Loded' irons to be used. Mr. Smeeton might rest assured that from the numberless possible grades of 'Loded' irons there would be some useful to many engineering trades. It only required the attention of the workers in this and that industry in order to make advance in these irons. This would take time, but that the field was fertile was metallurgically obvious. In marine engineering the first trials were somewhat naturally in the direction of cylinder liners, if for no other reason than that 'Loded' irons were a definite departure from what we had settled down to consider as normal. The difficulties to be overcome in their manufacture were not too great by reason of their foundry properties being as good as, or better than, those of the low-silicon series used for marine liners and other high-duty parts.

Mr. C. Gresty's remarks were highly valuable. He was one of the metallurgists who learned intimately the metallurgy of all-pearlitic structure and, then, of the Lanz Perlit process. Associated with the author, he saw the gradual growth of understanding of grey iron in connection with jobs of utmost importance. Also he had worked at Lanz Perlit to such effect that that iron stood high up to-day, nearly twenty years after many decried it. The relationship between various compositions of 'Loded' irons and thicknesses of castings was described elsewhere as far as it was possible to do so save in an actual foundry, and when dealing with some particular casting mass. The carbon-content was a matter of opinion. The author believed that the total carbon, up to say 3·45 per cent., should be about as high as the particular composition would carry. He had never seen superior wear figures coming from unnaturally low carbon irons. Also he had observed that founding difficulties arose from low carbon practice. 'Loded' irons could be made using a cupola only, the silicon and chromium being got from pig-irons, although some of the former might be added to the ladle. Generally speaking, the procedure was already known to Mr. Gresty. The properties of the irons would be explored in those (and other) directions queried. That the Lanz Perlit principle would improve 'Loded' irons was very certain and, the author believed, also the converse. The author would not, with his own intimate knowledge of Lanz Perlit, suggest that 'Loded' irons made under that process would supplant the present Lanz Perlit irons; instead, they might supplement them, providing improved ones for certain purposes and opening out an almost unlimited field for progress and aggression against competition. The author wished to record his pleasure that anyone of Mr. Gresty's standing and experience in foundry work and cast-iron metallurgy should have come to contribute to the discussion.

Education Group.

The Training of Marine Engineers and the Results of Their Training from the Point of View of the Superintendent Engineer.

A discussion on the above subject was held on Friday, 18th November, 1938, at a meeting of the Education Group, under the Chairmanship of **Mr. T. W. Longmuir.**

The discussion was opened by **Mr. H. S. Humphreys,** Member of Council and Superintendent Engineer, British Tanker Co., Ltd., who said that the duties and responsibilities of a superintendent engineer could be divided into three parts—the original choice of hull and machinery, the subsequent upkeep of the various units and the economical running of the vessels in the technical sense. The subject matter of that evening's discussion was concerned with merely one aspect of the last division alone, the aspect of the ship's engineers.

Several practical and economic factors had to be considered before attempting to set forth the ideal training. It was obvious that for a superintendent to get the most economical running of his ships he must have well-trained engineers and in the long run he would not get these unless he could offer conditions of employment that on the whole were not less attractive than those for engineers of similar ability ashore. At the present moment, he thought it was correct to say that the average superintendent felt a sense of relief if he could get sufficient mechanics with a reasonable amount of commonsense to take the junior engineers' positions even with no technical training at all. Even then a considerable number made a voyage or two and thereafter left for shore jobs where pay and conditions were, temporarily at any rate, more attractive.

It must be recognised that the shipowner had to face foreign competition based on lower standards of pay and conditions, and however much he might appreciate the importance of highly-trained engineers to obtain the fullest advantage of the constant developments and improvements in marine engineering, the saving in this respect could not always be shown so clearly as the wage bill.

The ideal training for a marine engineer would be of the B.Sc. order coupled with say four years practical apprenticeship during which time the young engineer should gain experience in store-keeping, pattern making, moulding, turning, fitting and erecting.

It was obvious that too few engineers were available who could combine a highly scientific knowledge with a first-class practical craftmanship and one therefore usually had to compromise between the two.

These brief considerations might be taken to imply the necessity for two classes of engineers, one with a highly-developed technical training and the other with a more developed practical workshop training and a standard of theoretical training merely sufficient to meet B.O.T. certificate standards.

A shipowner usually, and rightly so, wished to recruit his shore superintendents from his practical engineers. On the technical qualifications of the superintendent depended a large part of the advantages to be gained in the three matters mentioned earlier as forming the basis of a superintendent's duties, each much wider than the subject they were directly discussing, but each in this way dependent upon it.

It therefore appeared to be essential to provide for a sufficient number of men possessing a high standard of training, in the ranks of the seagoing staff. Regarding the seagoing staff as merely operating engineers, it was quite obvious that apart from their very essential and important qualification of good practical training. resourcefulness and initiative in the emergencies which might arise and of loyalty to their Company's interests, they did not require an elaborate and highly-developed technical training. On the other hand, if they did not possess such training, it was difficult to see how the shipowner could recruit his future superintendents or technical advisers from this field.

The mere statement of this position brought to light difficulties which were not easily dealt with and raised questions which might be pondered over but could not readily be answered.

Was it, for instance, reasonable to expect under present conditions governing the employment of marine engineers that a youth with high technical qualifications and a B.Sc. degree would choose to go to sea with the ambition of eventually becoming a superintendent engineer and a responsible technical adviser to his owners? On the other hand, could the owner expect to obtain the sort of guidance in technical matters which he required without that high standard of training combined with a reasonable amount of sea experience? Another awkward question was how would the good practical engineer feel about the advancement over his head of the B.Sc. type engineer who might be less useful as an operating engineer but vastly more suitable, on account of his training, for the more highly technical work incidental to the superintendent engineer's duties?

While many problems were thereby raised, not all of which could be solved with certainty, it seemed that part at least of the answer lay in making it clear that those engineers who were interested enough to take up a theoretical training would be encouraged and specially regarded, thus leaving the field open to all ranks and avoiding the psychological difficulty. Given that this policy became known, it might then be possible to encourage some more thorough training in the apprenticeship stage, where a basis of theoretical, and particularly mathematical, knowledge would be invaluable later. Thereafter, one other particular factor needed attention. Owing to trade union restrictions the seagoing engineer of to-day was not getting enough of that best of all practical trainings, the opening-out of machinery. Admittedly the practice might have been overdone in the past, but it had certainly gone too far the other way now.

In conclusion, if our shipping and marine engineering industries were to survive keen foreign competition. it could only be done by reasonable co-operaton, unity and goodwill between the practical and theoretical engineers and between the trade unions and employers.

Mr. J. Paley Yorke, Principal of the L.C.C. School of Engineering and Navigation, Poplar, said that Mr. Humphreys was asking for a Utopian state but that was no reason why they should not try to attain it if they could. He had dealt a shrewd blow at their general system of education and had asserted that they were educating for the black-coated class, the traditional grammar school type, but those present who were engaged in educational work had knowledge of another type which had been in existence for a good many years, which unfortunately was not as well known to Industry as it should be, and which was in many ways meeting this demand which Mr. Humphreys had mentioned. He referred to the junior technical schools. The boys who came to them were wanting to be engineers and were prepared to have dirty hands and faces on their jobs! But, he asked, what was the answer of Industry to this question? The technical schools were providing these boys and giving them the best education for industry as Mr. Humphreys had requested, but when they sought openings for their boys in industry they had the greatest difficulty. He had just been opening his annual campaign for placing the boys leaving next Easter. They had 50 boys who had gone through a three years pre-apprenticeship course. Some wanted to be marine engineers, some mechanical mechanics, some electrical. He had just received the batch of answers from the various firms who were marine engineers and so far not one of them could take one of these boys between now and next May. What was the use of training the rest of the boys if they could not place them? He agreed that the matriculation idea had gone too far, and the country was perhaps training more matriculants than it could absorb. But although they might set their faces against it there were marine engineering firms who included in their application form the question "Have you matriculated?" That question should not be there. Mr. Humphreys had put a poser when he asked that psychological question why it was that there were too few of the right type available who had had the desired training. He repeated that they never *would* be available if Industry would not take these boys and use them. Industry and Education had got to unite in an effort to gain the desired ends, and Industry must be prepared to reconsider its needs and be able to state its requirements for recruitment; it must see also that it was providing a sufficiently wide channel for entry of boys who had been "prepared" for industry by an education which was based on the applications of science but which was nevertheless a real education in the highest sense.

Mr. T. A. Bennett, Member of Council, suggested that co-operation was necessary between the shipowners and the shore engineering and shipbuilding firms. At present the latter had no interest in the future efficiency of these young men as seagoing engineers; they were only concerned in the work they did for the firm ashore. From the beginning of their apprenticeship these boys should be under the supervision of the shipowner.

Mr. B. C. Curling, Secretary, suggested as an alternative or in addition to the scheme outlined by Mr. Bennett, that the scope of the Royal Merchant Navy School at Wokingham might be extended by equipping the school to give combined workshop and technical training to those boys who, on finishing their secondary education there, desired to become marine engineers under a long-term system such as Mr. Bennett visualised. In this case arrangements should be made for transferring these boys after, say, three years' apprenticeship (or cadetship) at the R.M.N. School to a shipbuilding or marine engineering firm for one or two years' workshop training under commercial conditions before finally proceeding to sea.

Mr. C. J. M. Flood thought that every marine engineer should be recruited from the junior technical school, because his training in the school workshops was of a responsible type. This training was of a more responsible nature than the mere training in the classroom. He would like to put forward a rather ambitious idea—that the shipping companies should take boys during their holidays and give them sea trips to let them see the life of responsiblity on board a ship. In other branches of transport, such as aviation, somewhat similar facilities were to be available.

Mr. T. A. Bennett further suggested, with regard to the difficulty of placing students as apprentice marine engineers, that the Shipping Federation might keep a register and invite all junior technical schools to send in the names of any of their students who were willing to go to sea, with the object of assisting them to become apprenticed with suitable firms.

Mr. A. C. West, Vice-Chairman of the Education Group Executive Committee, compared the systematic training of the engine-room personnel of ships of the Royal Navy with the present lack of system in the recruitment and training of engineering personnel for the Merchant Navy, and he supported the suggestions put forward by the two previous speakers. He also mentioned the importance of the influence which a chief engineer could exert on junior engineers in encouraging or discouraging them in the continuance of their technical studies while at sea.

Dr. J. G. Docherty, Member of Executive Committee, referred to the grading of Merchant Navy engineers mentioned by Mr. Humphreys, and said that such a system would be virtually the same as that in force in the Royal Navy. He outlined the course of training of engineers in the Royal Navy from their entry into Keyham as cadets until, in the case of selected officers, they finished their studies with a special two years' course at Greenwich. He said that although the ground they covered was nothing like as wide as the B.Sc. syllabus, their studies in the subjects they did cover were much more advanced.

The Chairman said that the difficulty which Mr. Humphreys had mentioned of getting the right type of young man to go to sea was partly due to the fact that the majority of shipowners no longer had their own repair shops in which to train a sufficient number of apprentices to fill the vacancies caused by retirement and wastage. The apprentice entering this type of establishment did so with the definite object of becoming a marine engineer without any thoughts of a shore position.

The Chairman had found that about 50 per cent. of the engineers who obtained the First-Class Board of Trade Certificate were not interested in their calling and endeavoured to obtain a shore appointment; on the other hand, it was most marked that the engineers from certain companies were very contented and expressed a wish to return to *their own ships*—they did feel they were part of the company.

He would include the ship-repairing firms with those suggested by Mr. Bennett. During his training with such firms, in London and other seaport towns, the apprentice had ample opportunity of attending well-organised courses of study, and this, combined with his interesting practical work, produced a good engineer with an orderly mind and tidy habits which, as Mr. Humphreys had said, ensured a tidy engine room.

Mr. H. S. Humphreys, referring to the points which had arisen in the discussion, said that he had somewhat overlooked the junior technical schools; his remarks principally related to the general elementary and secondary schools. He thought that the difficulty of apprenticing boys from the junior technical schools might be due partly to trades union restrictions and partly to the distance that many schools were from principal engineering centres. In the firm where he served his apprenticeship, for every two or three fitters or turners there were some 20 to 25 apprentices. Now the pendulum had swung too far the other way. Any loss of confidence between the trades unions and employers should be speedily restored if they wished to maintain their maritime standard. He thought Mr. Bennett's suggestion with regard to a register of students desirous of becoming seagoing engineers was excellent. As regards facilities being given to boys to make trips during their vacations, while he agreed that the idea was a good one, he thought it might be abused in some cases and these young men might be frightened away from seagoing by unsympathetic chief engineers; fortunately this type of chief engineer was in the minority. He considered Mr. Curling's suggestion regarding the Merchant Navy School was excellent, but he thought it would need careful handling to see that the scheme was not exploited. As regards Mr. Flood's remarks, he thought that there was a demand for men with a somewhat higher general education than was given in the junior technical schools.

Mr. Humphreys emphasized the importance of a closer *esprit de corps* between the deck and engineer officers, and with this in view he had never ceased in his endeavour to advise the shipowners to insist on all officers, deck and engineer, having their meals together either in the saloon or in a joint messroom. Obviously this was to the advantage of both sections and incurred no additional cost whatsoever to the shipowner. After all, the broadening of any man's outlook was a part of his education.

After Mr. Humphreys had dealt with other questions not directly connected with the training of marine engineers, the Chairman, on behalf of the Committee, proposed that the best thanks of the meeting be accorded to Mr. Humphreys for his valuable contribution in opening the discussion. The proposal was seconded and carried with acclamation, and the meeting terminated.

ELECTION OF MEMBERS.

List of those elected at Council Meeting held on Monday, 9th January, 1939.

Members.

Kenneth Bedward, 28, Lostock Road, Davyhulme, Manchester.

Leslie David Bunting, 205, Badminton Road, Downend, Bristol.

William Frank Crichton, c/o Tobacco Manufacturers (India) Ltd., Fraser Town, Bangalore, S. India.

Henry Stanley Edwards, 46, Tair Erw Road, Birchgrove, Cardiff.

Herbert Gibb, United Africa Co., Ltd., Unilever House, E.C.4.

Samuel Jones, 83, Tadworth Road, Cricklewood.

Herbert Murray Liscombe, c/o New Zealand Shipping Co., Ltd., 138, Leadenhall Street, E.C.3.

Victor Savage Mangham, 17, Esplen Avenue, Gt. Crosby, Liverpool, 23.

Edward Francis Ralph Nash, 17, Farnell Street, Harbord, N.S.W.

Thomas Owen, 88, Richard Kelly Drive, Liverpool, 4.

Cuthbert Coulson Pounder, 42, Malone Hill Park, Belfast.

Fred. Warwick, 199, Liverpool Road, Crosby, Liverpool.

Frederick John Howard Sturgess, 1, Chestnut Avenue, East Sheen, S.W.14.

Charles Augustus Suffield, 4, Lloyd's Avenue, E.C.3.

William Robert Wilson, 76, Holders Hill Road, Hendon, N.W.4.

Companion.

Thomas Augustus Wellum, 76, Woodland Road, Chingford, Essex.

Associate Member.

George Keenan, 33, Court Hey Road, Liverpool, 16.

Associates.

Edward James Coleman, Glendale, 45, Pentland Avenue, Shoeburyness.

Horace Eric Doust, Denby, Fairlie Road, Newport, Isle of Wight.

John Arnold Heaton, Fullerton Building, Singapore, S.S.

Cedric Jennings Holyoake, Fairways, Cromer Road, Hornchurch, Essex.

Leonard Talbot Jones, Clevedon, Hillcrest Road, Loughton, Essex.

Charles Lawrie, 101, Ankerdine Crescent, Shooter's Hill, S.E.18.

Thomas Matthews, 17, Ravensworth Terrace, Gateshead-on-Tyne.

Gordon Stanley Nicholson, 41, Clarendon Road, Ealing, W.5.

Charles William Thomson, 199, Pear Tree Avenue, Bitterne, Southampton.

John Brynley Tulip, 245, Victoria Road West, Hebburn.

John Stanley Young, Association of Engineers, Singapore, S.S.

Transfer from Associate Member to Member.

Christianus Lieshout, "Y-View", 5, Badhuisweg, Amsterdam-Noord.

Transfer from Associate to Associate Member.

Joseph Bowman, 5, Stotts Road, Walkerville, Newcastle-on-Tyne.

Transfer from Student to Associate.

Eric Andrew Beavin, Shellbank, 4, Raymere Gardens, Plumstead, S.E.18.

Thomas Arthur Cook, 90, Appletree Gardens, Walkerville, Newcastle-on-Tyne.

John Joseph Morris, 52, Crescent Road, Plumstead, S.E.18.

ADDITIONS TO THE LIBRARY.

Purchased.

Kempe's Engineer's Year-Book, 1939. Morgan Bros. (Publishers), Ltd., 31s. 6d. net.

Official Year-Book of Scientific and Learned Societies, 1938. Charles Griffin & Co., Ltd., 169 pp., 10s. net.

Report of the Fuel Research Board for the Year ended 31st March, 1938. H.M. Stationery Office, 4s. net.

Presented by the Publisher.

Bulletin de L'Association Technique Maritime et Aeronautique, No. 42, 1938.

Aluminium Bronze. Copper Development Association.

The following British Standard Specification and Corrigendum Slip:—

No. 816-1938. Minimum Requirements for Electrical Appliances and Accessories.

No. C.E. (C) 9954. (Corrigendum) Report on the Sampling of Coal with special reference to the Size-Weight-Ratio Theory (B.S. 763-1937).

Munro's Engineer's Annual, 1939. James Munro & Co., Ltd., 16, Carrick Street, Glasgow, C.2, 191 pp., illus., 2s. 6d. net.

In addition to the usual tables for which this publication is so well-known, there is a number of special features included in the present issue. These include an article of special interest on the internal-combustion engine by Mr. J. S. Gander, particulars of the new Board of

Trade examination system, specimen Board of Trade examination papers submitted by two of the colleges which specialise in tuition for these examinations, a diary of memorable events concerning shipping, shipbuilding and engineering, and much other information of value to marine engineers.

D. A. Low's Pocket-Book for Mechanical Engineers. Revised edition edited by B. B. Low, M.A. Longmans, Green & Co., 778 pp., over 1,000 illus., 10s. 6d. net.

The main additions and alterations in the present edition of this familiar work occupy about 240 pages and concern the following:—notes on materials; atomic weights; properties of rolled steel sections; moments of inertia of sections of weldless steel tubes; screw threads; ball and roller bearings; Michell bearings; toothed gearing; measurements of temperature; varieties of fuel; properties of saturated and superheated steam; steam boilers; Board of Trade and Lloyd's Rules for boilers, riveted joints, and shafts; internal-combustion engines; sandblasting; cutting tools and grinding wheels; Brinell hardness testing.

The extracts from the Board of Trade and Lloyd's Rules alone make this work of particular value and interest to the marine engineer, and the huge mass of carefully indexed and arranged additional information to be found within the covers makes the purchase of this work a very attractive investment.

Meter Engineering. By J. L. Ferns, B.Sc. Sir Isaac Pitman & Sons, Ltd., 3rd edn., 347 pp., 194 illus., 12s. 6d. net.

In a previous review of this work we described it as one which could be thoroughly recommended to any meter engineer as a comprehensive, practical and comparatively cheap book dealing with the principles, construction, testing and installation of meters, and the routine of a large meter testing department (see Transactions, Vol. XLVII, August, 1935, p. 177).

The passing of the Electricity Supply (Meters) Act in 1936 has had a profound effect on the equipment and routine work of British meter-testing stations. Since June, 1937, the Electricity Commissioners have issued their various Regulations governing testing procedure and equipment, and, as the effective law is contained in these Regulations, it has become necessary to issue a third edition of the book dealing with these changes.

Since the book is also used in countries other than Great Britain, it was thought advisable, however, to confine the description of the above changes to a special chapter. Other developments which have taken place since 1935 are dealt with in the appropriate chapters so as to make the book fully up to date.

Problems in Engineering Thermodynamics and Heat Engineering. By C. W. Berry, C. L. Svenson, and H. C. Moore. Chapman and Hall, Ltd., 2nd edn., 178 pp., illus., 6s. net.

This is an American publication and contains 1,064 questions. The questions have been arranged under seventeen headings following more or less the sequence adopted by most standard text books on heat engines, but it is noted that more than usual weight has been given to problems on air and vapour mixtures, refrigeration, and heating and ventilation. This feature is not surprising as these types of problems are so closely linked with the daily lives of a large number of American mechanical engineers.

The unique assembly of the volume is worthy of mention; each page is perforated and printed on one side only, so that the problems may be conveniently cut out for attachment to their respective solutions. This novel feature in many circumstances undoubtedly saves time and enhances the value of notes for revision or reference purposes. The range and character of the problems are such as will meet the requirements of all students to degree standard. To the student working these problems the absence of answers to all the problems may prove a handicap as there is no denying the beginner's satisfaction of achievement when he obtains the agreed solution. For the more advanced student and instructor there is the fresh view and phrasing of the American authors on many old problems.

To give the volume a place in the galaxy of similar contemporary literature is indeed difficult. As a complement, however, to lecture notes or to certain text books it may prove to be valuable.

Principles of Electricity and Electromagnetism. By G. P. Harnwell. McGraw-Hill Publishing Co., 619 pp., copiously illus., 30s. net

The book is intended as an introduction to both experimental and theoretical electricity with emphasis on the former It is assumed that the student has already a sound elementary knowledge of the subject and of physics generally. A knowledge of the differential and integral calculus as an essential to an understanding of the text is also assumed of the reader. One of the appendices is a resumé of the types of first- and second-order differential equations that are most frequently met with in the text. Another appendix deals with vector notation which is used in the book.

The scope of the treatment will be gathered from the following general statement of the contents: electrostatics; dielectrics and conductors; d.c. and a.c. circuits; chemical, thermal and photoelectric effects of current; thermionic vacuum tubes; electrical conduction in gases; electromagnetic effects and applications; d.c. and a.c. machines; wave filters and vacuum tube circuits; and radiation. At the end of each chapter is a series of problems and at the end of the book a mathematical appendix.

The book is an advanced treatise on the subject of electricity and its applications. It surveys all the modern developments of the subject and as such should be extremely useful to advanced students and teachers of the subject.

Diesel Engines. By B. J. von Bongart. Chapman & Hall, Ltd., 335 pp., 346 illus., 21s. net.

This book is not a text book in the accepted sense, nor is the term Diesel used to mean compression-ignition I.C. engines where the fuel mixture is supplied at constant pressure; the word Diesel is used loosely to cover all types of I.C. engines not using electrical ignition.

Pages 1 to 80 deal with principles and contain much useful data and numerous interesting curves covering fuel consumption, compression ratios and pressures, efficiencies, fuels and fuel atomization. The remainder of the book describes numerous designs of high-speed engines working on the Diesel cycle. The comprehensive field covered precludes reference to the minor details of all the makes mentioned. A vast amount of information is given, including the description of about fifteen fuel pumps, twenty injection nozzles, numerous precombustion chambers and combustion spaces, twenty automotive engines, a dozen aircraft engines and a dozen medium-speed engines.

Some of the illustrations are good and are covered by explanatory notes, but the book does contain too many reproductions of photographs showing an external view of the particular engine. At the end of four chapters some problems are set, but the reviewer was unable to find either answers or solutions. The book is well printed on good paper, and should be useful to those interested in this particular class of I.C. engines.

Electrical Engineering, Vol. I. By Tolmé Maccall, M.Sc. University Tutorial Press, Ltd., 547 pp., copiously illus., 15s. net.

This book is the first of two volumes intended to cover advanced general electrical engineering work in technical colleges and schools. It is based on a large part of the author's "Continuous Current Electrical Engineering" and a smaller part of the author's "Alternating Current Electrical Engineering", both of which have been familiar to teachers and students for many years, and whose value is well recognised.

The present volume is described as suitable for the first year of the advanced National Certificate Course and for the second year of a degree course. If this was the intention one feels that the book contains at once too much and too little. For example, the advanced student should not need the construction of a Daniell cell explained to him, nor yet the Wheatstone Bridge network with its application in the Post Office Box. The author has explained the introduction of some alternating current matter on the grounds of the continued increase in the use of alternating currents with the consequence that this part of the subject is now introduced much earlier than before in both day and evening courses. But surely, alternating current has always been a material part of the third year of an Ordinary National Certificate Course, and in some areas has for some years been introduced into the second year. One has the impression that the greater part of the a.c. theory dealt with in the present volume would have been covered by the student before he entered on his advanced course. On the other hand, the only a.c. machine dealt with is the transformer. The induction motor, or even the general principle of the rotating field, and the alternator are not mentioned, even in an elementary way. These would surely have been at least begun before the student embarked on the final year of his course. These remarks are offered merely as suggestions with a full realization that it is impossible to lay down any hard and fast line as to what should be done in any one year, and that syllabuses in different schools differ in detail.

The general exposition and treatment is, as one expects from the author, clear and lucid, though after reading the section on armature windings one is confirmed in the opinion that it is high time that some definite nomenclature for the different types of winding was laid down by some recognised authority. At the close of the chapter the author draws attention to the different nomenclature adopted by different writers for the same thing.

The greater part of the very numerous illustrations are good, clear line diagrams, which are much to be preferred to photographic representations, the educational value of which is very problematical. A very valuable feature is the very large number of problems given with each section, the answers to the numerical problems being supplied at the end.

This should be a most useful general text-book for the student of electrical engineering—the reviewer would suggest the third and fourth year students of a National Certificate Course. One awaits the second volume with interested anticipation.

JUNIOR SECTION.

Propellers.

At the South East London Technical Institute on Thursday evening, December 8th, 1938, Mr. F. McAlister (Member) delivered a lecture on the subject of "Propellers" to a large audience composed of members of the Junior Section and students of the College. The Principal, Mr. G. A. Robinson, B.Sc., occupied the Chair.

Illustrated by a film and lantern slides, the lecture was most absorbing, even the difficult section devoted to the various theories associated with propellers and their design proving most interesting. The latter fact was undoubtedly attributable to the lecturer's concise explanations and his happy use of illuminating analogies. A very satisfactory response from the audience in the form of questions followed the lecture, and these Mr. McAlister answered very thoroughly to conclude a highly instructive meeting.

On the Chairman's proposal a vote of thanks to the lecturer was accorded with acclamation, while the Chairman himself was thanked on behalf of the Council for his warm welcome of the visitors by Mr. E. F. Spanner (Member of Council).

The Work of the William Froude Experimental Tank at Teddington.

In view of the success which has attended the joint meetings of the Junior Section with students of technical colleges in the London area, the Council have adopted a proposal to extend this scheme to provincial centres. The first of these provincial meetings was held at the Belfast College of Technology on Tuesday, December 13th, 1938, when Mr. J. L. Kent lectured on "The Work of the William Froude Experimental Tank at Teddington". Mr. W. E. McConnell (Vice-President for Belfast) occupied the Chair.

Illustrated by lantern slides and films, the lecture dealt with the experimental work being carried on at the National Physical Laboratory at Teddington, beginning with the production of wax models of proposed ships. The lecturer explained how tests of these models were carried out for speed, revolutions, steering, wind resistance, etc., how measurements were made of the force required to pull the model through the water, and how, from the data collected, the horse-power required to drive the full-sized ship was calculated and many improvements in design suggested. In addition to ships, experiments had been carried out in connection with seaplanes and submarines. An audience of nearly 300 was present, and by the questions subsequently put by the students, the lecturer was given an opportunity to amplify important points and details of special interest.

On the proposal of Mr. T. C. Tobin, seconded by Mr. R. Lee Annear, B.Sc. (Member), a very cordial vote of thanks was accorded to Mr. Kent, while Mr. D. H. Alexander, M.Sc. (Member), Principal of the College, was thanked by the Chairman for his ready co-operation in arranging the meeting.

ABSTRACTS OF THE TECHNICAL PRESS.

Suitability of Flame-cut Surfaces for Welding.

With the recent growth of welding for fabrication, gas cutting has been used very largely, especially for parts too heavy for shearing. There was never any hesitation in welding bright cut surfaces and even slight rusting did not prevent good bonding, but many engineers have felt doubtful over gas-cut edges. Recently C. W. OBERT, of the Boiler Code Committee of the American Society of Mechanical Engineers, has shown that they may even possess some advantages. In low C steels oxidation is merely superficial, and microstructure shows litle change apart from a slight increase in C in a very thin surface layer and sorbitic structure to a depth of about $\frac{1}{16}$in. Mechanical tests show little deterioration of ductility and strength. Despite an A.S.M.E. prohibition, a gas-cut edge withstands caulking or cold-work better than a machined edge, owing to its sorbitic structure; physical properties of the two are practically identical in low C steels. but it shows greater stiffness in the bending test. In U.S.A. some V or U grooving of the surfaces is usually laid down for plates exceeding $\frac{1}{4}$in. thick and this has become so common that inspectors see a virture in the brightness of the prepared surfaces. It is pointed out that modern gas or electric welding causes sufficient penetration $\frac{1}{16}$ to $\frac{1}{8}$in. to ensure floating away of any foreign matter, and that a slag coating is formed over the metal. The crucial test of the suitability of gas-cut surfaces for welding must obviously lie in testing the weld itself —tensile strength, "nick break", X-ray examination—since visual inspection of the interior is impossible. As a result of experiments, OBERT recommends that in high-speed high-duty welding, gas-cutting should be chosen in preference to machining, the cut should be smooth and uniform and preferably machine-made. The slightly higher carbon content lowers the fusion temperature of the edge, but neither this nor the superficial oxidation appear to exert any effect on the resulting weld metal.—*"Engineering", Vol. 146, 28th October, 1938, p. 521.*

Gear Tooth Deflection and Profile Modification.

In heavily loaded gears, tooth deflection in use is appreciable and there is obviously no point in improving manufacturing tolerances beyond this amount unless a correction for deflection is introduced simultaneously. HYDE TOMLINSON AND ALLEN have demonstrated how the uniformity of angular velocity transmission and life of the gears are affected (*Proceedings of the Institution of Automobile Engineers 1932*). A new apparatus allows the deflection, at any point along the line of action of the gears, to be measured; the effective length of a short lever arm is (l—base circle radius of the gear), d is measured at each setting by a micrometer and h calculated. Ni-Cr steel was used for lever and test gears, treated to give 110 tons tenacity (50 Rockwell C), since its elasticity is more accurately known than that of a case-hardened surface. Normally a gear tooth is subjected to (a) displacement due to (bending + compression + shear), (b) surface compression; (b) is small but not negligible and can be calculated approximaely; the magnitude of the deflection is changing continually. The virtual pitch errors resulting are additive, one gear being increased and the other decreased in pitch. A load/deflection plot for a gear with 23 teeth, 5 D.P. and pressure angle 20°, conforming to B.S.I. specification, was found to be a straight line passing through the origin. When two pairs of teeth are in gear, the sum of deflectors of the first and second pairs must be equal, so that relative load distribution $(\omega_a/\omega_c) = (\delta_{c_1} + \delta_{c_2})/(\delta_{a_1} + \delta_{a_2})$, and $(\omega_a + \omega_c) = W$ the total load transmitted; this enables a diagram to be plotted showing the load variation on a particular tooth. In use the driven gear will lag by an amount equal to the total deflection, and as this varies, changes in angular velocity occur; plots are given of the course of deflection δ up to 0·0012, load (0-100 per cent.), and angular velocity variation, for three different cases. These show that deflection causes considerable deviation from the theoretically uniform motion of the perfect involute, especially at low speeds with detrimental effect in regard to noise and gear life. At high speed, smoothing should occur due to gear inertia causing peak loads several times that normally borne. The virtual errors considerably exceed the 0·0002in. limit of modern gear grinding. and profile modification can be effected on one gear over its entire depth or on both over part of their tooth depth—the latter is better from a manufacturing standpoint, and is carried out by obtaining correct contact at four points; the improvement is obvious on the angular velocity diagram, and the load is applied more uniformly to the tooth. It is estimated that correction reduces the inertia load at high speeds on a tooth to half, with consequent improved carrying capacity. Arbitrary "tip correction" has long been customary with the object of easing contact and reducing noise, but this has never been carried out as far down the profile as the author advocates. Possibly this is due to the fact that fully corrected teeth are non-continuous and sometimes noisy at no-load. but correct functioning at load rather than at no-load is surely to be preferred. The magnitude of tip modification is 0·00013 at 15 tooth, 0·00051 at 50, 0·001 at rack, for a 1in. circular pitch, and appears inadequate at moderate and low tooth numbers; it should be proportional to (load/inch width), *i.e.* to (pitch^2) and not to (pitch). From the angular velocity plot it appears that tip rounding does effect some improvement on the original involute, but not sufficient. With B.S.S. teeth of D.P. 10, 5, 3, 2½ in the same blank, deflections under given tip loads of 10,800, 7,200 and 3,600lb. per in. face, were found to be constant at 0·003, 0·002, and 0·001in. Total compression at two curved surfaces is 1·155 (W/E) since surface deformation can be neglected for practical purposes. Charts are given of l_1 from 0 to 0·8, from rack to 15 teeth in the mating gear; and of l_2 from 2·1 to 2·8 for the gear. In theory the modifications should apply to equal gears but the error is small enough to be neglected even at large reduction ratios. The curve which smooths out the angular velocity diagram is not a perfectly straight line, but obeys the relation $\delta \ = \delta \ (MN/l^2 - l^1)^{1\cdot5}$. In practice the angle $\theta^R = \tan\psi + 2(l_1 + MN)/t\cos\psi$, where t is the number of teeth. For a 20-tooth gear, l_1 and l_2 are found to be 0·423 and 2·3 from the chart for the 40t wheel and 20t pinion. The paper MN, corresponding values of modification and angle can be tabulated. These run from 0 and 23·45° at 0, to 0·00034 and 29·5° at 1·0, and 0·00087 and 34·9° at 1·877 for the pinion; 22·8°, 25·9°, and 28·5° for the wheel. These are plotted as a chart for the 40t wheel nd 20t pinion. The paper is illustrated by 21 diagrams.—*H. Walker, "The Engineer", Vol. 166, 14th and 21st October, 1938, pp. 409-412 and 434-436.*

Gear Tooth Deflection.

In correspondence regarding Walker's paper on the above [*see* preceding abstract] W. Sellar points out the uselessness of improving manufacturing accuracy beyond 0·0002in. when theoretical errors much greater than this remain and draws attention to his I.Mar.E. paper read on 18th December, 1923, *"A Basis for the Explanation of Marine Gearing Troubles"* [*see Transactions, Vol. 35, 1923, pp. 525-570*]. It was shown that the increase in the length/diameter ratio caused phenomena very different from those with short face widths and the effect of the number of teeth in mesh suggested a breakdown of the (uniform load intensity per inch) rule.

E. McEwen emphasizes that the articles apply only to spur gears, and seem particularly applicable to aircraft gears where the costs of a special cutter for each material can be faced; further, the discussion is limited to cases where both gears have the same modulus, in brief to highly loaded and important spur gears of the same material. Further, he suggests that the formula should be amended to:

$$\tan\theta = (IN/10) = \tan\psi + 2(l_1 + MN)/t\ \cos\psi.$$

θ at the tip of the tooth is the pressure angle and is therefore given by

$$\cos\theta = (\text{base radius})/(\text{radius of point considered}) = r_p \cos\psi)/r.$$

For 20 and 40 tooth examples therefore

$$\cos\theta_{20} = 0{\cdot}854266 \text{ so that } \theta = 31^\circ\ 19'$$
$$\text{cost } \theta_{40} = 0{\cdot}894945 \text{ so that } \theta = 26^\circ\ 30'.$$

—*"The Engineer, Vol. 166, 4th November, 1938, p. 500.*

Current Rating and Impedance of Cables in Buildings and Ships.

Conclusions to be embodied in the Regulations for Electrical Equipment of Ships are reported (Ref. F/T 115). The work deals with the effect of a.c. instead of d.c., new types of installation (heavy cables in cleats, grouped cables in conduits, ducts, chases and surface systems), bare Cu rods, long vertical runs under cover, and the effect of steel or reinforced concrete in the neighbourhood of a.c. systems. Ninth edition figures are substantially confirmed; some new circumstances are investigated in detail. Work may be classified into three types: (1) current carrying capacity of large cables in free air, (2) effects of running cables through holes in a steel plate, through a steel-rod structure simulating reinforced concrete, and parallel to a steel plate; with single phase and three-phase distribution, (3) properties of small rubber insulated cables up to 0·5in.^{2} installed in a variety of ways. Reduction in current carrying capacity due to skin effect and sheath loss is serious only above 0·5in.^{2} section. The increase due to better cooling from increased spacing, may be partly or wholly counterbalanced in lead-covered cables by increase in sheath losses. The voltage drop due to the increased impedance of a.c. cables running near a steel plate may necessitate a reduction of the rating to below that based on the permissible temperature rise; in a reinforced concrete, expansion of the steelwork from the heating effect of heavy currents in large cables may be serious. The following conclusions are reached: (1) Former I.E.E. current ratings based on the work of Melsom and Booth (*"Journal of the Institution of Electrical Engineers", Vol. 47, 1911, p. 711*) have been confirmed for covered and surface ("bunched and open") systems and in other cases divergence from the average is relatively small. (2) Where more than two cables are so run, reduction factors must be applied approximately as follow: for 4, 6, and 10 cables (or equivalent), 0·8, 0·7, and 0·6 respectively; these factors do not vary greatly for different systems. The six-cable factor also applies to the current rating of one three-core or four-core cable from two single-core cables of the same size. (3) Up to 0·5in.^{2} for 2 or 4 cables, 0·25in.^{2} for 6 cables, 0·15in.^{2} for 10 cables; d.c. and balanced a.c. ratings may be taken as identical. In steel conduit, lack of balance in a.c. systems may reduce carrying capacity materially. (4) Carrying capacity based on temperature rise, is in agreement with calculation, but too much attention must not be paid to the results owing to variation in conditions. Impedance or voltage drop agrees with theory but in the presence of ferrous material certain assumptions must be made. (5) Bare Cu rods can be run at higher temperature than insulated cables and have higher ratings. If rubber-insulated cables are connected thereto, excessive heating occurs only within a short distance of the joint. (6) The loss of the margin of safety allowed by I.E.E. regulations, when vertical chases are used, cannot generally be recommended, and hence a reduction in rating may become necessary. Intermediate stoppings are not necessarily a cure. (7) Rating of cables in conduits, chases and ducts, and on walls is given by $kA^{0\cdot59}$, where the factor k depends on the type of installation and the number and nature of the cables. (8) For different core temperature rises, corresponding ratings can be obtained by the relation $(i/i_0)=(\theta/\theta_0)^n$, for cables of less than 0·1in.^{2} section $n=\frac{1}{2}$, for larger cable $n=0\cdot54$ for (θ/θ_0) between 0·56 and 1·8. The paper includes 31 graphs, 8 tables, and appendices on "Impedance of Single-conductor Cables" and "Theoretical Determination of Current-carrying Capacity"; the results are presented in such a way as to be clear to the non-electrical reader.—*H. C. Booth, E. E. Hutchings, and S. Whitehead, "Journal of the Institution of Electrical Engineers", Vol. 83, October, 1938, pp. 497-516; discussion pp. 557-565.*

Internal-Combustion Motors and Steam Turbines.

Apart from pure electrotechnical deliberations, Committees Nos. 5 and 19 of the I.E.C. 1938 Conference held at Torquay and London, were concerned with turbines and internal-combustion engines respectively. The author draws attention to the value of the technical conclusions regarding specification, description and performance of motors which have now been definitely laid down after many years in tentative form. These rules apply to capacity being measured directly by dynamometer or equivalent equipment without in an way limiting their adaptation to special kinds of motors, *e.g.* for transport or aircraft. The following equivalents have been adopted.

1 kW.≡102 kg.m./sec.≡737·8 ft. lb./sec.

1 PS (metric horse power)≡75 kg.m./sec.≡525·5ft. lb./sec.

Normal atmosphere for motor testing≡76 cm.Hg. 20° C., 70% humidity.

1 m.^{3} at 0° C.≡38·13ft.^{3} at 68° F. (20° C.).

Agreement was reached regarding the form of data, and the nature of auxiliary equipment to be regarded as normal to the motor, between buyer and seller.

The 1931 I.E.C. rules for turbines, Pt. I and II, are restricted to condensing units with or without reheating and steam extraction for condensate preheating, and their extension to other types is now under consideration; the author points out how great apparently minor discrepancies actually are. Finally the American proposal for an "efficiency" as the ratio of work done to the product (quantity of steam × drop in heat), was unanimously adopted. German industry would still favour a compromise, perhaps on the basis of the *"Thermal Turbine Efficiency"* of G. Darrieus (*Rev. de l'Electricité, Vol. 27, 1930, p. 963*), in view of the importance of "packing steam" in its turbines. A proposal for standardizing the rules for measurement of the quantity of steam extracted, in different countries, is to be worked out.—*G. Ruppel, "Zeitschrift V.D.I.", Vol. 82, 22nd October, 1938, p. 1240.*

Roots Type Supercharger for Oil-engines.

Owing to its simplicity, efficiency, and long life, the Roots blower is attractive for scavenging two-stroke and for obtaining increases in the output of two-stroke and four-stroke Diesel engines, and has been widely adopted for oil-locomotives in U.S.A. In the type described, rotors of solid-drawn steel tubes, accurately ground to involute form are welded to hollow high-tensile steel shafts. Minimum backlash and accurate centring are obtained with spur-gears, and the shafts are mounted in ball bearings at one end and roller bearings at the other, light-alloy or cast-iron casings are used; for silent operation at high speeds double-helical gears may be fitted. Since oil is prevented from contact with the rotors by a seal, the engine lubrication system can be used. By use of by-passes, delivery pressure can be made to vary with engine torque, so that pressure charging of the constant speed engine is quite straightforward. Its efficiency is about 90 per cent. so that the power absorbed is very small at low pressures, at which the volumetric efficiency is high, but falls off with high delivery pressure and decreasing speed. Clearances must be kept as small as possible, and the larger the apparatus therefore, the greater the volumetric efficiency at low speed.—*"The Oil Engine", Vol. 6, October, 1938, p. 192.*

Sea-going Sludge Vessels.

To carry sludge 10 miles out to sea New York has ordered three self-propelled craft at a cost of £100,000 each; it is estimated [in U.S.A.] that these will dispose of it at a cost of less than 7½d./ton. Their particulars are:—

Length overall	260ft.
Length at loaded water line	250ft.
Beam moulded	43ft. 6in.
Depth moulded amidships	16ft.
Designed mean loaded draft	11ft.
Mean freeboard at 11ft. draught	5ft.
Deadweight carrying capacity	16,000 U.S.A. tons
Volume of sludge compartments ...	55,000 cu. ft.
Designed speed	10¾ knots
Speed on trials	11¾ knots

All-steel construction has been used, with two decks, straight stem and round overhanging stern; the hull is divided into seven watertight compartments by six bulkheads extending up to the main deck. An airspace extends forward and aft below the sludge holds, and tanks for ballast, fuel, water, etc., are suitably disposed. A watertight centre line bulkhead minimizes free surface effects in the sludge, which contains 95 per cent. water. Gravity loading is by a 10in. flexible metal hose into the 14in. wrought-iron ship's main; discharge is by twelve 18in. sluice valves on the sludge deck, connected to wrought-iron 18in. tail pipes at the bottom of the hull. Float gauges and 6in. overflow pipes are fitted. It is claimed that emptying is possible in 5 min., but normally a longer time is taken. When loaded the vessel draws 11ft., giving a 5ft. head; as the sludge pours away this is gradually reduced to 9in. To avoid backing, the pumps draw cooling water from a closed circuit within the ship. Propulsion is by twin 715 b.h.p., direct-reversible, six-cylinder, four-cycle, oil engines at 270 r.p.m., with air starting; 70 tons of bunkers give a cruising radius of 2,500 miles.—*"The Engineer", Vol. 166, 25th November, 1938, pp. 286-287.*

New Yokes for Squeeze Riveters.

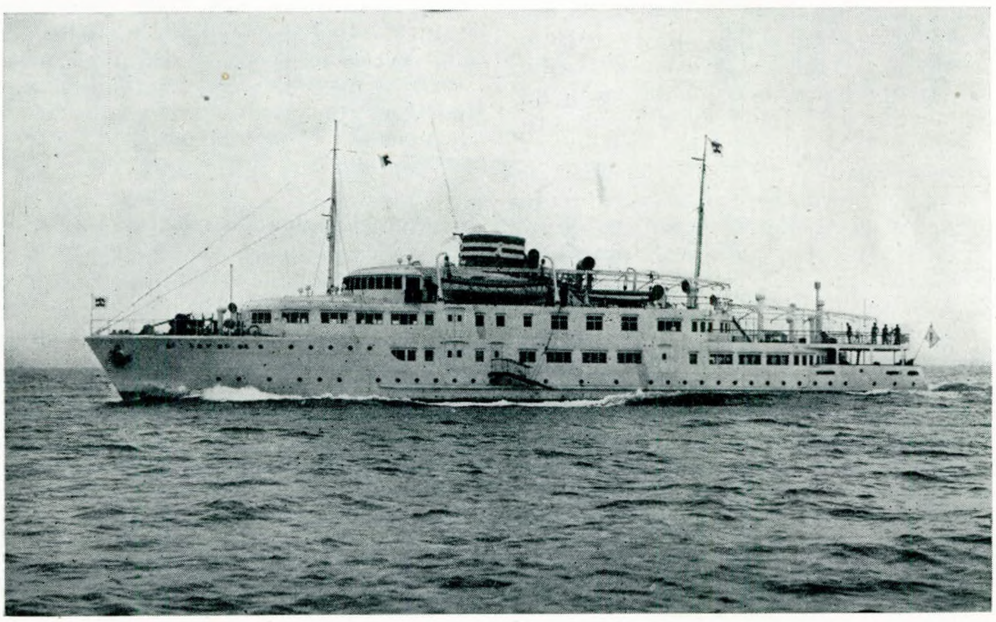
The new tools are designed particulary for aircraft section riveting but are also suitable for other applications. By use of a small wheel-mounted hydraulic intensifier the air pressure is increased 36 times giving a high pressure at the snaps, which are capable of passing over a total thickness of 1½in. at any angle in relation to the cylinder or handle. Interchangeable yokes can be fitted and the new tool has the advantage of lightnes and compactness besides being able to work in locations which ordinary pneumatic riveters cannot approach. —*"The Engineer", Vol. 166, 25th November, 1938, p. 596.*

P. & O. Liner "Naldera".

This old vessel of 16,000 tons proceeded in November to the shipbreakers in the Forth. After her last voyage she lay for a short time in the Thames having been chartered for transport of the British Legion Police Force to be employed during the Bohemian plebiscite which never occurred. This unusual close was not unfitting for a ship which was a long standing joke as having been "everything except a submarine". Her keel was laid in Greenock in 1914, but work was totally interrupted for three years, when the Government ordered her completion since cargo tonnage was in serious demand. Conversion was barely finished when orders were given for reconversion as a troop-carrier; no sooner was this completed than she was gutted for reconstruction as an aircraft carrier. In 1920, after the ship had been handed back for civilian use, she underwent final reconstruction as a liner and was well known to many old friends who will regret her passing. Not until six years after her keel laying did she finally leave the Clyde. —*"The Engineer", Vol. 166, 25th November, 1938, p. 579.*

Streamlined Japanese M.s. "Sirogane Maru".

The passenger motor ship "Sirogane Maru" was built and engined by Mitsubishi Heavy Industries, Ltd., to the order of the Setuyo Syosen K.K. for that company's service between Osaka and the islands in the Inland Sea. The vessel is of unusual



The passenger vessel "Sirogane Maru" on trials.

design in that her hull and superstructures are completely streamlined and she has unusual equipment for the comfort of the passengers. The ship has a length b.p. of 185ft. 6in., a moulded breadth of 31ft. and a moulded depth of 14ft. 3in., the mean draught being 9ft. 4in., and the gross tonnage 929. The main engine is of 1,000 b.h.p. and gives the ship a service speed of 14 knots.

The vessel carries 42 second class and 1,265 third-class passengers and there are four decks, the boat deck covering most of the length amidships, the promenade deck extending nearly the whole length, the upper deck extending from stem to stern and the second deck being continuous except for the machinery space. The vessel has no sheer, all deck lines at the sides being straight and the decks, except the forecastle and boat decks, have no camber. The hull is sub-divided into six watertight compartments and cellular double bottoms extend over about one half the length amidships and are arranged to carry ballast, fresh water and fuel oil. There are no derricks or winches, the loading and discharging of cargo being effected through side cargo ports.

The passenger accommodation includes six second-class staterooms, the remaining rooms being intended for third-class passengers, each room being comfortably equipped and fitted with rectangular windows. The wireless receiver may be used for broadcasting to the public rooms and is also connected to a gramophone. Electric fans assist natural ventilation and all the living rooms are electrically heated.

The main propelling machinery consists of a single Mitsubishi, four-stroke cycle, airless injection, trunk-piston engine, having eight cylinders of 420 mm. bore, with a piston stroke of 620 mm. The 1,000 b.h.p. normally developed drives the propeller at 240 r.p.m. Fuel injection is by the common-rail pressure injection system. The cylinder jackets are cooled by sea-water supplied by a plunger-type pump driven by the main engine, as are also the plunger-type forced lubrication pumps. Starting air is supplied by a three-stage compressor driven by one of the auxiliary generator engines and there is also an auxiliary two-stage air compressor which is belt-driven by the main shaft, in addition to an emergency air compressor driven by a 4 h.p. engine. Two air reservoirs are arranged in the engine room.

There are two 35 kW. generators, each driven by a four-stroke airless injection engine with two cylinders of 220 mm. bore and 350 mm. stroke, developing 66 b.h.p. at 420 r.p.m. The electrically driven auxiliaries include a general service, a freshwater and a fuel-transfer and stand-by lubricating-oil pumps, a bilge and ballast pump and a De Laval lubricating oil purifier. The electric windlass on the forecastle deck is driven by a 20 h.p. motor and can haul the anchors and cables at a speed of 30 ft./min., the stern capstan being driven by an 18 h.p. electric motor. The steering gear of Mitsubishi all-electric design, controlled on the Ward-Leonard system, has a 25 h.p. steering motor and 5 h.p. generator motor.—*"The Motor Ship", Vol. XIX, No. 227, December, 1938, pp. 338-340.*

Mechanical Properties of Medium Alloy Steels.

Attention is drawn to the possibility of obtaining good mechanical characteristics in a steel in which the expensive [and in Japan non-indigenous] Ni is replaced or eliminated. After consideration of a large quantity of tensile, impact and creep data the author concludes that not only is this possible, but that where Ni is replaced by (Cr + Mo) many common troubles are absent, *viz.* white spots, sand marks, ghosts, quenching cracks. A tendency in this direction is also obvious in Germany [see *Stahl u. Eisen, 6th May, 1937, p. 484*]. In the plot of impact value against tempering temperature, the "temper brittleness' trough is visible in alloy steels but not in straight steels. Addition of 0·5 per cent. Mo to Ni steels with over 4 per cent. Ni or Cr-steels with over 2 per cent. Cr, raises the maximum and minimum impact value obtained on tempering and in such cases the effect of C is not marked. In Ni-Cr steels with $Cr<1$ per cent. this is not possible, and the author therefore suggests it is safe to increase Cr to 2 per cent. and decrease Ni to the same figure; a similar effect is observed in Ni-Cr-Mo steels. With Cr content at 2 - 3 per cent. the mechanical properties are so improved, with or without Mo, that it is no longer necessary to depend on Ni additions; further, white spots and segregation rarely occur. In general, with steels higher in Cr, the tempering range is widened, scaling resistance is enhanced, and the temper-brittleness trough occurs at higher temperature. More than 1 per cent. Mo need not be added, and even at 0·5 per cent. air-hardening properties begin to be evident. The effect of Ni on creep is deleterious.—*K. Kurokawa, Scientific Papers, Institute for Physical and Chemical Research, Tokyo, Vol. 34, No. 844, October, 1938, pp. 1322-1355.*

Engineers and the Peace of the World.

The war that never began is over and we have resumed our peaceful vocations, let us rejoice that the evil tapping at the window has been exorcised, and seek peace not by continual suspicion and dread of our neighbours but by winning their esteem and confidence and extending to them an equal measure of sympathy. Marshal Saxe said that the best of all campaigns were those won without a battle, Germany has achieved her aims without bloodshed. For these she would have fought and the Allies would have won, but it would have led not to Peace but to Armistice, though only after the destruction of great cities and invaluable art treasures, retardation of the world's progress and the sacrifice of millions of young lives. Mr. Chamberlain has shown that the better way is possible, but he could not have succeeded had not all the peoples of Europe been opposed to war; every nation is terrified at the means of destruction which scientists and engineers have evolved. In particular the airplane with its load of gas and incendiary bombs has brought terror to the densely concentrated populations of Britain and Germany, and neither nation would readily enter into conflict with the other. Indeed war has become so horrible that the prospect will not bear considering; for this, paradoxically, these same engineers and scientists are responsible. The rise, progress, and development of all nations is to-day in the hands of engineers and they meet together in friendly intercourse. Cannot their great unity be used for perpetuation of peace; their influence even in the military dictatorships is incalculable, yet little use is made of this power? In the end, whether a nation be democratic, autocratic or republican it is the people that must suffer and prosecute the war and from their mutual toleration peace must ultimately spring. The editorial closes with the firm belief that in the encouragement of better international understanding, the engineer, with a mind trained to reason, can and will play a splendid part. —*Editorial, "The Engineer", Vol. 166, 7th October, 1938, p. 381.*

Interesting Shaft Fractures.

A 7in. shaft driven at one end by a 350 b.h.p. at 250 r.p.m. through a flexible coupling, and driving a combination ball mill at 30 r.p.m., failed within the coupling. In the sulphur print the ends of a number of segregate threads are visible but there is no obvious relation between these points and the spiral crack. On hammering, the outer rim of the shaft which had lain under the coupling was knocked away bodily. It appears probable that the crack started at a corner of the keyway, travelled spirally towards the centre at the dead end; at the other extremity it worked outwards at the periphery, approximately in line with the inner end of the keyway. Under microscopic examination there was a fair number of non-metallic inclusions yet not enough to classify the steel as "dirty", it was rather coarse-grained but not abnormal. C was estimated at 0·25 per cent. Notched bar tests on transverse specimens (simulating the spiral direction of the crack) gave 10·2 and 10·3 ft. lb., and a static notched bar test 13·7 ft. lb., which must be considered good. It is obvious that the coupling can never have been a good fit, since hammering had occurred between key and way, and pounding between the bore of the coupling and the surface of shaft.

A very similar failure is shown in the end of a Ni-steel extension shaft of a steam turbine, transmitting the load through a single-reduction double-helical gear. Failure occurred underneath one side of a claw type flexible coupling; here the fracture was more circular but the inner broken end was more markedly conical. A longitudinal crack developed as before from the corner of a keyway, and finished transversely at the circumference almost in line with one end of it; there was however an independent diagonal crack, developing into the interior. No crack occurred at a second keyway. The steel was clean and sound, but heavy hammering marks showed that the coupling had been a bad fit.—*British Engine, Boiler and Electrical Insurance Co., Ltd., Technical Report for 1937,* reproduced in *"The Engineer", Vol. 166, 25th November, 1938, p. 590.*

A Simple Method of Calculating the Bending Moment on Propeller Blades.

The usual method of estimating the bending moment due to thrust and torque (or the "hydrodynamic") bending moment as distinct from the bending moment due to centrifugal forces, is to resolve the forces acting on the blade into thrust and torque components, calculate the bending action due to each separately, and then re-combine the component bending moments. An alternative method is based on the statement that the resultant of the bending moments at the roots of all the blades is simply the torque applied to be propeller. In practice, a "typical" blade section is that at 0·7 of the screw radius from the axis and (referring to the diagram), the value of the angle $(\phi+y)$ at this section is found by detailed analysis to be very nearly the same as for the blade as a whole.

The details of the method are as follows. The torque is expressed in terms of actual horse-power P at the screw (allowing for shaft losses) and revolutions per minute N, as

$$Q=33{,}000\ P\div 2\div N$$
$$=5{,}250\ P/N \text{ (ft. lb.)}$$
$$\text{or } 63{,}000\ P/N \text{ (in. lb.)}$$

The "axis bending moment",

$$Mo-Q\div n,\ \sin(\phi+y)$$

where n=number of blades. This follows from a simple resolution of the torque into its components.

The blade root bending moment

$$M=f.M_o$$

where the value of the factor f is found to be as below, for various boss diameters:

Root radius ÷ seven radius	0·15	0·20	0·25	0·30
Factor f	0·79	0·715	0·645	0·57

As regards the value of the angle $(\phi+y)$ where a hydrodynamic analysis of the propeller has been carried out, the separate values of ϕ, the "angle of advance", and of v, the "gliding angle" of the section, will be known and can be substituted, but where only the overall screw efficiency is known, the value of the angle can be readily obtained by equating the efficiency to the standard expression

$$\eta=J\div x.\ \tan(\phi+y)$$
$$=J\div 2{\cdot}2\ \tan(\phi+y)$$

if x be taken as equal to 0·7, the fractional radius at the typical section. Here J. is the usual "advance constant", given by

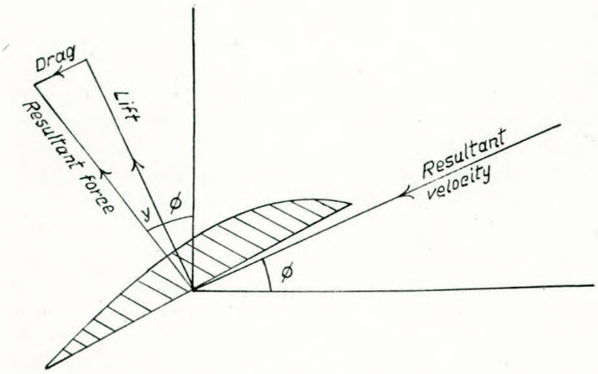
$$J = 101{\cdot}3\ V \div N\ D$$

V being the speed of advance (ship speed less wake speed) in knots and D the screw diameter in feet. Hence

$$\tan(\phi + y) = J \div 2{\cdot}2\ \eta$$

and the value of $(\phi + y)$ and $\sin(\phi + y)$ can be read from the trigonometrical tables.

As a numerical example, consider a four bladed



propeller absorbing 1,000 horse-power at 100 r.p.m., the speed of advance being 10 knots and the screw efficiency 0·70. The diameter of such a propeller would be about 13ft. and the pitch ratio about unity.

$$Q = 63{,}000 \times 1{,}000 \div 100$$
$$= 630{,}000 \text{ in. lb.}$$
$$J = 101{\cdot}3 \times 10 \div (100 \times 13)$$
$$= 0{\cdot}78$$
$$\tan(\phi + y) = 0{\cdot}78 \div (2{\cdot}2 \times 0{\cdot}70)$$
$$= 0{\cdot}506$$
$$(\phi + y) = 26{\cdot}85^\circ$$
$$\sin(\phi + y) = 0{\cdot}452$$
$$M_o = 630{,}000 \div (4 \times 0{\cdot}452)$$
$$= 348{,}000 \text{ in. lb.}$$

Assuming a boss diameter ratio of 0·2

$$M = 0{\cdot}715 \times 348{,}000$$
$$= 248{,}000 \text{ in. lb.}$$

The simplicity of the method can be seen from the above numerical example. In addition to the hydrodynamic bending moment, for the usual type of blade which is raked aft, there is the centrifugal bending moment to be considered and this will be dealt with in a subsequent article, but it may be stated that for propellers having a similar circumferential tip speed (*i.e.* N × D constant), and angle of rake, stresses due to the hydrodynamic forces alone give a fair indication of the relative blade strengths.—*Taylor, "The Shipbuilder", No. 350, Vol. XLV, pp. 647-648, December, 1938.*

The Motorship "Wilhelm Gustloff".

The propelling machinery consists of four Diesel engines of the M.A.N. single-acting, two-stroke cycle, airless- injection, trunk piston type, built by Messrs. Blohm & Voss. These engines are arranged in pairs to drive two propellers through single-reduction gearing. Each engine has eight cylinders of 520 mm. bore by 700 mm. stroke, the rated output per engine being 2,375 b.h.p. at 220 r.p.m. A centrally-situated fuel-injection valve is fitted in each cylinder cover and each cylinder is provided with an individual fuel pump, having one suction valve, two delivery valves and one by-pass valve. The suction valves can be controlled when the engine is running and any fuel pump can be isolated if necessary, the pumps being actuated from the crankshaft by means of push-rods. The manœuvring shafts are operated by compressed air applied to an oil-filled servo-cylinder on each engine. Two Roots-type reversible scavenge-air blowers are mounted at the rear of each engine and are gear-driven from the crankshaft. The cylinders and covers are cooled by fresh water, oil being used for piston-cooling.

The four main engines are arranged abreast and the port and starboard pairs drive the port and starboard propellers respectively, the single-reduction gearing giving a shaft speed of 105 r.p.m. when the engine speed is 220. The high quality mild steel shafting for each propeller is about 80 m. (260ft.) in total length.

The pumps for the principal main-engine auxiliary circuits are electrically driven and five similar Diesel-generator sets are provided—two in the main engine-room and three in the auxiliary engine-room. They are of the single-acting four-stroke cycle, airless-injection type, each engine having six cylinders and developing 570 b.h.p. at 330 r.p.m. and being constructed by Messrs. Blohm & Voss. The five standard d.c. generators are of Siemen-Schuckert manufacture, directly coupled and each rated at 380 kW., 220 volts, 330 r.p.m. An emergency generator set of 50 kW., coupled to a three-cylinder single-acting, four-stroke cycle engine of 80 b.h.p. at 650 r.p.m. is also provided, located in a separate compartment on the sun deck. Should the main supply of electricity fail, the emergency dynamo automatically starts up and comes on to load. The emergency air-compressor also is driven through a clutch from the Diesel engine of this generator set. A hand-operated compressor set is fitted to charge a small receiver should no other compressed air be available.

The main compressor sets are two in number, supplied by Maschinenbau Balcke Gesellschaft of Bochum. They are of the three-stage single-cylinder type and have each a capacity of 194 cu. ft. of free air per minute when discharging at 1,000lb. per sq. in. pressure into the starting-air receivers of the main engines through reducing valves. Sea-water cooling is used and oil filtering is arranged. Each compressor is driven by a direct-coupled d.c. motor of 110 h.p.

Steam is employed in the "Wilhelm Gustloff" chiefly for hotel purposes and for warming the water in the swimming-pool, being generated in two water-tube boilers. Each of these boilers has a total heating surface of about 3,770 sq. ft., of which 1,720 sq. ft. is oil-fired and 2,050 sq. ft. is heated by the main-engine exhaust gases. As all the steam raised is led to a common receiver, either one or both means of firing can be used. The working pressure is 175 lb. per sq. in. gauge.

The electrical installation is claimed to represent the most modern conception in regard to arrangements on board ship and there are two main switchboards in separate compartments. There are no fewer than 254 electric motors of all kinds, with a total consumption of 2,125 kW. The electrical supply is of 220 volts d.c. and the lighting is arranged on the unipolar system. some 16 tons of cable being required. This, incidentally, is insulated with home-manufactured fabric instead of the usual lead sheathing. Electricity is used in connection with the fire-detection equipment, the watertight door system and signal lamps.

The wireless installation of the ship is very complete and comprises one 150-Watt S.W., one 70-Watt S.W., one 200-Watt M.W., and one 10-Watt S.W. wireless transmitters, in addition to one emergency low-power M.W. transmitter and seven wireless and telephony receivers.

The "Wilhelm Gustloff" has now been in regular service for about nine months and has proved very satisfactory in every respect.—*"The Shipbuilder", No. 350, Vol. XLV, pp. 649-652, December, 1938.*

New Japanese Motorships for the Transportation of Lumber in the North Pacific.

The two latest vessels built and engined at the Yokohama Dockyard of Mitsubishi Heavy Industries, Ltd., for the carriage of lumber in the North Pacific for the Toyo Kisen Kabushiki Kaisha are of special interest in that the whole of the auxiliaries and equipment are of Japanese manufacture. As the two vessels—named "Zenyo Maru" and "Keiyo Maru"—are sister ships, it will suffice to refer to the first-named. The vessel is of the two-deck type, with poop, bridge and forecastle, with a length b.p. of 436ft., and moulded breadth of 58ft. 3in., a depth moulded to upper deck of 32ft. 0in., and a gross tonnage of 6,442. The hull is divided into eight watertight compartments, six of the bulkheads extending to the upper deck, while that between Nos. 3 and 4 holds is not carried above the second deck, to allow for the carriage of lumber in the 'tween-deck space. For the same reason, No. 2 hold is made unusually long. There are two cargo holds forward of the engine-room and three aft. No. 3 hold is longitudinally sub-divided to give two deep tanks suitable for general cargo or cargo oil, which last may also be carried in the fore peak and in No. 1 double bottom Nos. 2. 3, 5, 6 and 7 being used for oil fuel, No. 4 for fresh water and No. 8 for fresh water or water ballast. Fresh water is also carried in the after peak and there are deep tanks at the sides of the engine-room for oil fuel or water ballast, which will be used for adjusting heel and stability as required. Provision has been made for the carriage of timber in the wells, in addition to that in the 'tween decks of No. 2 hold. The officers and crew are berthed amidships. The deck auxiliaries are electrically driven and include a windlass and 12 powerful cargo winches.

The propelling machinery consists of a single Mitsubishi-M.A.N. two-stroke cycle, airless-injection engine of six double-acting cylinders, developing 4,700 b.h.p. at 133 r.p.m., and designed to give the ship a speed of 16 knots.

The auxiliary machinery includes three main generating sets, each consisting of a Mitsubishi-M.A.N. single-acting, four-stroke cycle, trunk-piston, airless-injection engine coupled direct to a d.c. generator of 100 kW. at 255 volts, and there are two air compressors of the vertical single-cylinder two-stage type, directly coupled to the outer ends of two of the Diesel generators. The cooling-water and oil pumps are electrically driven, as are the fire, general-service, ballast, bilge and fresh water pumps which are fitted in the engine-room, as is also a vertical oil-fired donkey boiler working at a pressure of 114lb. per sq. in. for the supply of steam for heating, cooking, etc. The ship carries a wireless transmitter with a 500 Watt output for long and medium wave lengths and a 50 Watt auxiliary set, in addition to all the other standard navigational equipment of the usual type. —*"The Shipbuilder", No. 350, Vol. XLV, pp. 653-657, December, 1938.*

The Twin-screw Turbine Steamship "Amra".

The t.t.s. "Amra" built for the British India Steam Navigation Co., Ltd., by Messrs. Swan, Hunter & Wigham Richardson, Ltd., at Newcastle-on-Tyne, has been designed for passenger and cargo service between Calcutta and Rangoon. With a length b.p. of 440ft., a moulded breadth of 61ft. and depth moulded to shelter deck of 36ft. 3in., the ship is of 8,314 gross tons and her propelling machinery of two sets of single reduction geared turbines, built by the Parsons Marine Turbine Co., Ltd., of Wallsend, is designed to give a service speed of 16½ knots. Steam is provided by three Babcock & Wilcox coal-fired water-tube boilers, constructed under licence by the shipbuilders. The machinery is designed to develop 8,800 s.h.p. at about 130 r.p.m., and the boiler plant represents the latest development in modern coal-fired marine steam practice.

The three boilers, arranged in one boiler-room, operate at a pressure of 450lb. with a final steam temperature of 750° F. Each boiler has a generating surface of 5,965 sq. ft., with 1,115 sq. ft. of superheater surface and 4,800 sq. ft. of air heater surface. The air-heaters are of the usual Babcock tubular type and after the air-heater, each boiler is fitted with a Howden-Vortex (dry type) grit arrester. The forced and induced-draught fans have been supplied by Messrs. James Howden & Co., Ltd., of Glasgow, and the fan motors are all grouped in one compartment which is quite separate from the stokehold, all air for the fans being drawn from boat-deck level through this compartment. thereby ensuring a large volume of reasonably cold air over and around the motors.

The normal fuel used will be Calcutta coal and the boilers are fitted with the latest type of Babcock-Erith retort-type stokers, each stoker having nine retorts and the stoker mechanism (comprising retort-pushers, moving grates and slicing bars) being electrically driven through totally-enclosed gearing. The final section of each grate consists of dump-bars operated by wheel and quadrant, by means of which ash is dropped into a dump-pit formed in the rear casing of each boiler, where it is quenched before extraction through the rear doors of the pits. The grate tuyères and rear sections are of special heat-resisting metal. Two 3-ton per hour coal-crushers are fitted in the boiler-room, one forward and one aft, and two clinker-crushers are arranged between the two forward boilers and the after boiler for dealing with any clinker too large for passage through the ash-ejectors, one of which is fitted in each wing of the boiler-room. The stoker hoppers are fed by hand, either direct from the cross-bunker or *via* the crushers, according to the sizing of the coal. The boilers are fitted with Babcock-Clyde soot blowers for the combustion chambers and Calorized Diamond blowers in the boiler passes and air heaters.

Apart from the mechanical-firing equipment the most outstanding feature of the boilers is that the drums are of the fusion-welded type—the first to be supplied for the British Merchant Service since Board of Trade sanction had been obtained. The boiler drums were fabricated at the Renfrew Works of Messrs. Babcock & Wilcox, Ltd., the process including stress relieving after welding. The testing included a full X-ray examination of the welds.

The three turbo feed pumps have been supplied by Messrs. G. & J. Weir, Ltd., of Cathcart, Glasgow, and the Weir patent closed-feed system has been fitted.

The auxiliary machinery is electrically driven, current being provided by three turbo-generators, which have an output of 275 kW. at 220 volts, and have been manufactured by Messrs. W. H. Allen, Sons & Co., Ltd., of Bedford. There is also an emergency dynamo set on the boat deck, with a Crossley vertical two-cylinder Diesel engine and a Sunderland Forge dynamo of 20 kW. at 220 volts.

As the ship is to trade in tropical climates, special attention has been paid to the insulation and ventilation of the machinery spaces, a novel feature of the ventilation being the provision of Thermotank punkah louvres in the engine-room ventilating trunking for controlling the air supply to the various confined spaces.

The "Amra" recently completed successful trials on the Tyne, when a speed of 18½ knots was attained.—*"The Shipbuilder", No. 360, Vol. XLV, pp. 662-669, December, 1938.*

Aluminium for Marine Applications.

The use of aluminium for cabin bulkheads, lifeboats and deckhouses is referred to, the low weight compensating for the increased cost. Birmabright (aluminium-magnesium) resists corrosion, can be worked cold and machined readily, and can also be cast and welded. Its resistance to sea water is particularly good. Lifeboats of this material are stated to be only about two-thirds the weight of those they replace, the actual saving being about 40lb. per person carried. Wooden boats deteriorate in the open and are combustible, while steel boats are liable to rust. A 2½ years corrosion test on a boat moored at Southampton was very successful and a number of vessels have since been equipped. Many deck and internal fittings can also be made in light alloy. Precautions must be taken against electrolytic action, rivets and bolts being made of light alloy or stainless steel, and zinc plates fitted at the propeller. Anodising of the surface is unnecessary for Birmabright, except as a decorative finish.—*"The Shipping World", 16th November, 1938.*

The Kort Nozzle for Motor Coasters.

The Kort nozzle, hitherto applied principally to tugs and trawlers working at high propeller slip, is stated to be advantageous for seagoing ships under similar conditions. A gain has been shown in Hamburg tank tests on a large motor tanker, and the nozzle has been fitted to a small coaster resulting in an increase in speed of 10 per cent. on trial in fine weather. The particulars of this ship, the "Joma", are: length 131ft., beam 24·6ft., depth 9·8ft., deadweight 360 tons. The engine develops 240 s.h.p. at 320 r.p.m., and the propeller has a diameter of 4·9ft. and a pitch of 3·75ft. It is stated that a still greater improvement would have been obtained had the propeller been redesigned to suit the nozzle, and in a new ship the stern frame would be dispensed with, the rudder being carried by the nozzle. Manœuvring was also improved after the conversion.—*R. J. Bates, "The Shipping World", 16th November, 1938.*

Air Conditioning in Ships.

Air conditioning is defined as the control of temperature, humidity, movement and purity of the air. This is partcularly important in ships exposed to rapid changes of climate. Temperature and humidity require automatic control, but the object of this is not to secure absolute constancy of conditions, as this would involve too great a contrast between indoor and outdoor atmosphere, depending on the weather. Thus for an external range of from zero to 100° F., the internal temperature might be allowed to vary from 68° to 85° F., and similarly the humidity could be allowed to range from 40 to 60 per cent. inside as against 30 to 100 per cent. in the external atmosphere. It is the relative rather than the absolute humidity which is important, *i.e.* the percentage saturation and not the moisture content by weight. Thus in winter with a low outside temperature and high humidity, warming the air may result in the humidity becoming too low for comfort, unless water is added, and conversely in summer. In the tropics dehumidification rather than cooling is required. Dehumidification is effected by refrigeration and consequent precipitation of excess moisture, and the ship's stand-by refrigeration plant is sometimes available for this purpose.—*G. IL. Sainty, "The Shipping World", 16th November, 1938.*

Improvements in Ships' Auxiliary Machinery.

The advantages accruing from the use of electrical auxiliaries in place of steam auxiliaries are discussed, and mention is made of the wide scope for electrical power in marine work. Particular comparisons are made between steam-driven and electrically-driven deck auxiliaries, and it is stated that although the electrical deck equipment costs 2½ to 3 times as much as the steam equipment, the extra initial cost is more than offset by the economies effected. For instance, a standard steam winch lifts 3 tons at 60ft. per minute and runs up a light hook at 240ft. per minute, whereas the comparative figures for a standard electric winch are 100 and 450ft. per minute. Additionally, steam equipment shows heavy power losses, some continuous whether the auxiliaries are working or not, but with electrical equipment the transmission efficiency on a 220-volt circuit is almost 98 per cent. Electrical machinery also has the advantages of not being affected by climatic conditions, of being always available for use, and of calling for current according to the load. Experience has shown direct current to be most suitable for marine purposes, and it is almost always used at a voltage of 110 for lighting only, or 220 for lighting and power. Steam consumption for steam-driven generators is less than the steam consumption for steam-driven auxiliaries. The steam should be used expansively and in one large unit, rather than in several small units. It is stated that the cost of repairs and upkeep is much lower with electrical machinery, and it is suggested that a simpler and cheaper type of electric winch should be developed for cargo vessels.—*"The Shipping World", 16th November, 1938.*

Dual Firing of Merchant Ships.

The main methods for dual-firing Scotch boilers are described. These are: (1) For vessels with closed ashpit system of forced draught the furnace fronts are constructed to burn coal or oil without any change, other than that the oil burner is slid further into the furnace when oil is being used; (2) An arrangement of the furnace front which allows the oil burner to be fitted through the fire door opening. In each case there is a description of (*a*) the practice when the firebars are left in position when burning oil fuel, and (*b*) the practice with the firebars removed; (3) Furnace fronts are supplied for oil or coal only, in which case the front must be completely changed when reverting from coal to oil; (4) The method when mechanical stokers are used is similar to (1), but at a changeover from coal to oil, the stoker coal-throwing mechanism and the detachable hopper would be removed. There is little data for dual-firing on water-tube boilers, but there are one or two ships which burn oil, coal, or wood. In these ships hand-firing is employed, but if advantage is to be taken of modern boiler practice, mechanical stoking must be employed, because it enables constant temperature and combustion conditions to be maintained, and the experience gained with Scotch boilers should permit of a design which would obviate any danger of damaging the stoker when burning oil.—*G. T. Marriner, "The Shipping World", 16th November, 1938.*

Distinctive Tankers.

The oil tankers completed in the U.S.A. during the past year are reviewed, and a table is given of the principal characteristics of 57 tankers included in the 1936-1938 programme. Nineteen deep-sea, two Great Lakes, and three coastwise tankers are reviewed, and indications are given of the extent to which standardization has been carried in current construction. Most of the 19 deep-sea tankers have the Arcform construction and the Isherwood bracketless system of hull construction, but some have the Bethlehem-Frear system, which is described. Seventeen have the twin arrangement of longitudinal bulkheads, which is now preferred to the centre-line bulkhead and summer tanks. Electric welding has been introduced into the hull construction to varying degrees. In 15 cases propulsion is by geared turbines, in two turbo-electric, and in two by direct-drive Diesel. The working pressures for the geared-turbine boilers vary from 400 to 450lb. per sq. in., with a total heat of steam of 725 to 750 degrees. Particulars are given of trial-trip data, and of certain minor but distinctive features. The Great Lake tankers are conventional in design, but it is claimed that the coastwise tanker "Dolomite IV" is perhaps the most outstanding vessel of the year. It has been designed to carry liquid and dry cargoes in bulk alternatively, and has already carried kerosene to China and grain on the return voyage; it has a special hull construction based upon channels fitted girth-wise; gunwhales are rounded to a 3ft. radius; the cargo spaces are lined with sheet nickel, welded in, to provide smooth surfaces and prevent corrosion when carrying chemicals; and the cargo pumps and piping are also nickel lined.—*Robert Morrell, "Marine Engineering and Shipping Review", November, 1938.*

Combustion Efficiencies of Gas and Oil Engines.

The author points out that with the very many types and sizes of engines met with in all stages of repair and disrepair, the usual statement of cu. ft. per i.h.p. (based on cylinder dimensions and number of impulses per unit time) gives no useful comparison of performance. It was found, however, that when the m.i.p. was taken as a fundamental unit representing power output and the rate of fuel consumption computed from the gas meter readings was expressed in terms of B.Th.U. per cu. ft. of total cylinder volume (piston displacement plus clearance volume) the factor obtained by dividing m.i.p. by B.Th.U. per cu. ft. (which bears the author's name) gave a direct indication of thermal efficiency. He states that during 23 years the general utility of this method has been well proved, and indicates several points of interest which analysis on this basis of the performance of every type of internal combustion engine has brought to light. Thus, in a large number of single-cylinder horizontal gas engines of various sizes, all throttle governed and with low tension magneto ignition, the thermal efficiency of engine performance in terms of m.i.p. (*viz.* m.i.p. ÷ B.Th.U. per cu. ft.) decreased with increasing mixture-strength B.Th.U. per cu. ft. of total cylinder volume. Again, in high-speed compression-ignition engines it is interesting to determine to what extent combustion efficiency is affected by increasing rotational speeds. Here the analysis of tests made on a 4-cylinder Paxman-Ricardo engine indicated that speeds of 700 and 800 r.p.m. give practically equal combustion efficiencies, and a similar merging was to be detected at speeds of 1,200 and 1,500 r.p.m., when the m.i.p. was above 100lb. per sq. in. and the B.Th.U. per cu. ft. was above 40. Tests on engines of the same type brought out a drop in combustion efficiency which occurred when a liquid fuel injection timing favouring 1,000 r.p.m. was left unaltered for a speed increase to 1,500 r.p.m.—*Tookey, "Gas and Oil Power", Annual Technical Number, 1938, p. 16.*

Forced Circulation Boilers and their Application for Marine Purposes.

The author briefly compares the design of a natural circulation with a forced circulation water tube boiler and gives a detailed description of a marine type "La Mont" boiler built in this country. Contrasting the two types he points out that in the design of a natural circulation boiler the primary object is to set out the heating surface so as to obtain good circulation, combustion conditions being adopted to suit. In a forced circulation boiler the best combustion condition can be chosen and the heating surface arranged to give the highest heat transfer. Longer tubes of small diameter placed in any position that circumstances demand can be used, and these can be arranged to form a complete water wall round the combustion chamber. A considerable weight of insulating material can thus be dispensed with, and as no radiant heat can penetrate the water wall, no high temperature refractories are required. Similar advantages can be realised in the arrangement of the connection heating surfaces. Gas velocities and rates of heat transfer can be calculated with some degree of accuracy; hence it is possible not only to forecast the heat absorption and evaporation of each tube, but also to give each tube a quantity of water proportioned to the duty which it has to perform. The "La Mont" forced circulation system was introduced in 1930 and the first mercantile marine installation was ordered in 1933, since when 36 boilers of this type have been fitted in 17 vessels, while 31 Diesel driven vessels have been fitted with "La Mont" waste heat extraction installations. The boiler described by the author is oil fired and designed to give a continuous supply of superheated steam at the rate of 110,000lb. per hour or 125,000lb. at overload, no economiser or air heater being fitted. It occupies a space of about 13ft. 6in. wide by 12ft. 6in. fore-and-aft and 13ft. 6in. high. The maximum working pressure and temperature are respectively 300lb. per sq. in. and 640° F. The heating surfaces are 456 sq. ft. projected in combustion chamber, 4,560 sq. ft. convection evaporator, and 1,070 sq. ft. superheater; the feed water inlet temperature is 200° F., and the heat release in the combustion chamber is about 230,000 B.Th.U. per cu. ft. at the normal full load. Comparing Scotch and "La Mont" boiler installations occupying the same space in a vessel, the author gives the example of a set of three Scotch boilers supplying a total of 43,000lb. of steam per hour at 225lb. pressure and 610° F. temperature. This set would weigh 225 tons, and the author states that the same boiler room would accommodate a set of two "La Mont" boilers supplying a total of 64,000lb. of steam at 300lb. pressure and 650° F. temperature on a weight of 80 tons, i.e. about 50 per cent. more steam at slightly higher pressure and temperature with a saving in weight of 175 tons.—*Trevithick, "Trans. N.E. C. Instn. of Engrs. and Shipbdrs., 2nd December, 1938.*

High Speed Diesel Engines.

The author observes that in the Diesel engine it is a matter of considerable difficulty to design a combustion chamber arrangement which will give smooth and efficient combustion over a wide range of both loads and speeds, and gives particulars of the Perkins Aeroflow ignition system which has been applied to commercial Diesel driven road and rail vehicles. This system represents a combination of the two main methods of fuel introduction which are in use at present, viz.: (1) the direct method, in which the fuel is sprayed directly into the working cylinder and combustion is controlled by the type of spray and the timing of the injection; (2) the indirect method, in which the fuel is injected into a special combustion chamber separated from the working cylinder by one or more passages. In the first system there is relatively little air movement inside the combustion space, the fuel particles seeking their own air for combustion in traversing the cylinder; in the second system a high degree of air turbulence is set up in the special chamber so that the fuel oil is sought out by the rapidly moving air. The author, who describes these two systems in detail, considers that under a fixed set of conditions the first of these systems offers the ideal, giving maximum efficiency and cold starting, but fails when a wide speed range is called for, while the second caters well for a wide speed range but fails when cold starting is required. In the Perkins engine a special combustion chamber is joined to the working cylinder by a relatively long tangential throat of Venturi shape and the atomiser is located in the upper wall at the narrowest part of this neck or throat close to where it joins the chamber. The atomiser is arranged to give two sprays, one tangentially into the chamber in the same direction as the air flowing into it, the other down the throat direct into the cylinder. The fuel sprayed into the chamber in the same direction as the air does not tend to destroy this movement, so that by suitably proportioning the chamber and the throat optimum mixing of the fuel and air can be obtained irrespective of engine speed. The downward spray into the cylinder attacks the heated air before there is any tendency for it to be cooled in passing through the throat, thereby giving cold starting under adverse condition as in the direct injection type. The author states that as regards specific output and weight per b.h.p., the Perkins Aeroflow engine compares favourably with many of the best modern petrol engines, the weight of the latest engine of this type being 6lb. per b.h.p. on a car rating or 7½lb. per b.h.p. on a commercial vehicle rating, as against 6½ to 8lb. per b.h.p. for modern six cylinder petrol car engines.—*Chapman, "Gas and Oil Power", Annual Technical Number, 1938, p. 4.*

An Informal Discussion on Bearing Metals.

Discussing modern bearing metals at a meeting of the Diesel Users Association, Dr. O'Neill observed that difficulties in high duty bearings have arisen principally from the development in the lining of the crazy paving type of cracking, which has become more serious in big ends than overheating and seizing. As it is suspected that fatigue failure is a cause of such cracking the use of harder alloys is indicated, but scoring of the journal may then result, and copper-lead and similar alloys generally require hardened (e.g. nitrided) journals. In addition to high fatigue strength excellent adhesion of the lining to the shell is necessary, and it is believed that low internal casting stress will lengthen the working life. Mr. P. T. Holligan referred to the suggestion which is sometimes made, that with an unbroken oil film between the metal surfaces in a bearing the actual composition of the bearing metal should not matter, but he pointed out that according to the statements made by the oil companies and other organisations there is a definite chemical interaction between the lubricating oil and the metal surfaces. They had found that definite polar compounds are formed in which the molecules tend to stand up on end like chains, so that you could imagine them appearing like a field of wheat, the extent of the bond of these compounds with the metal depending not only on the oil but also on the metal. Mr. A. K. Bruce thought that trouble often arose with forced lubrication through pumping abrasive debris through the bearing and owing to the reduced Brinell hardness at the temperature corresponding to actual bearing operation an ample quantity of clean lubricating oil should be provided. It should be remembered that the supply of oil which would suffice to maintain the oil film would be quite inadequate as a means for keeping the bearing cool. Speaking as a representative of a firm of bearing makers, Mr. B. F. Baker pointed out that cadmium has a thermal contraction three times that of steel, so that cadmium bearing metal used to line any bearing larger than 3in. simply pulled itself off. In general, they had not found these alloys to be better than tin bearing alloys, nor on an average were copper-leads superior. Mr. C. Green stated that in his experience of slow speed journals the composition of the metal had made appreciable difference to the length of life of the journal or bearing if properly lubricated, and Mr. J. B. Liebert wondered whether adhesion was quite such an important matter as some people had suggested in view of the Ford practice of babbitting direct on to the cast-iron block without steel or bronze liners, the only adhesion allowed being the provision of dowel holes.—*"Gas and Oil Power", Annual Technical Number, 1938, p. 21.*

Operating Experience with Gas Fuel Diesel Engines.

The author gives particulars of the operation of a two-cycle Diesel engine alternatively using natural gas which has been in service at the municipal electric plant at Lubbock, Texas, since August, 1936. Although this engine will ignite the gas on compression, a small quantity of fuel oil is injected with it as a stabilising medium, ignition on the straight gas, which contains about 75 per cent. of methane, being somewhat erratic. The gas is compressed to about 1,100lb. per sq. in. in the injection compressor and this pressure is automatically maintained. The amount of pilot oil is a constant quantity for all conditions, accounting for about 5 per cent. of the total B.Th.U. of the fuel consumed at full load. Performance records show that using 0·39lb. fuel oil per b.h.p. hour with a heat value of 19,200 B.Th.U. per lb., the B.Th.U. per b.h.p. hour on straight oil fuel would be 7,488, which compares with 8,160 B.Th.U. per b.h.p. hour on gas fuel, or 11,978 B.Th.U. assuming generating efficiency at about 91 per cent. During a nine months' period this engine was in service on gas for 6,462 hours, i.e. 98·6 per cent. of the total possible time, on an average load of 757 kW. or 75 per cent. of the rated capacity, showing as a result a saving over all-oil operation of about 33 per cent. at the present price of fuel oil. Exhaust temperatures at full load on gas do not exceed 500° F., and these temperatures do not go up until 10 to 15 per cent. overload is attempted when it is necessary to reduce the load. Referring to the risk of explosion, the author points out that when the engine is running as a gas engine natural gas only is being compressed, there being no oxygen present to support ignition; some explosions had, however, occurred in the exhaust manifold. In the power cylinders wear was found to be 50 per cent. less than in the oil Diesels of the same make running at the author's plant, and the cylinder walls retained a better oil film when using the same lubricating oil. Speaking generally, the engine takes less time and trouble to maintain and it picks up and drops changing loads more easily than the oil Diesels.—*Graham, "Gas and Oil Power", Annual Technical Number, 1938, p. 20.*

High Temperature Lubrication and Colloidal Graphite.

In the colloidal form in which it is extensively used for lubrication, graphite is essentially a high temperature lubricant being largely unaffected at temperatures, viz., 1,000° F., at which normal lubricating oil would not only be vaporised but would ignite spontaneously. Colloidal graphite can therefore give valuable support to the oil film in the hotter zones of the cylinder of an internal combustion engine and will offset boundary conditions. Friction measurements indicate that the coefficient of friction for a one-inch journal bearing at 230lb. per sq. in. fully lubricated and with a journal speed of 500 r.p.m. would be around 0·001 for 100° C. and over. Under boundary conditions this would be 100 times as great, while with colloidal graphite present in the oil film the coefficient of friction under such conditions would be of the order of 0·005 to 0·01 which compares favourably with fluid film lubrication. When fluid or full film lubrication is maintained in a bearing face colloidal graphite does not sensibly lower the friction, but it does so as soon as boundary conditions are set up by bearing pressures and temperatures. A graphoid surface can be formed on iron, steel, and other metals and among its properties are an ability to encourage the orientation of polar oil molecules, an important factor in oil adherence. Lubrication can thus be improved by the use of oily additions to the lubricant and by surfacing the metal with colloidal graphite, the two being complementary and equally important approaches to the reduction of cylinder wear.—*"Gas and Oil Power", Annual Technical Review", 1938, pp. 28-29.*

Welded Tanker's Performance.

The all-welded tanker "Imperial", built at the Collingwood Shipyard, Ontario, recently ran her trials. The tanker is of the single-deck type, with five cargo tanks sub-divided by an oil-tight centre-line bulkhead. The machinery consists of two sets of two-stroke, single-acting Diesel engines, coupled by single-reduction gearing to a single screw shaft. The trials took place in heavy weather and the satisfactory results obtained demonstrate the suitability of this form of construction for oil-carrying ships. The flat panels of stiffened plating which form the major portion of the structure are well adapted for being welded "on the ground", thus enabling the process to be carried out under the best conditions and the freedom from trouble which has attended earlier all-welded tankers in service, is a recommendation for this system of construction. Much of the internal damage sustained by oil tankers during heavy weather consists of small leaks in bulkheads and this type of defect can be largely avoided by the use of welding instead of riveting.—*"Fairplay", Vol. CXLIX, No. 2900, 8th December, 1938, pp. 369-370.*

Castor Oil as an Anti-priming Agent.

Recent experiences with castor oil for such a purpose includes the case of two Lancashire boilers in a colliery, working at 120lb./sq. in. pressure, which had to be forced hard to cope with the steam demand. It was found that priming could be stopped by the addition of 15 p.p.m. of castor oil —added as such—at a saline concentration of anywhere between 1,200 and 2·850 grains per gallon of boiling water. Priming usually occurred at over 2,100 grains per gallon and the dose of castor oil seemed effective for allowing a further increase of about 200 grains per gallon on the salinity. If the saline concentration was maintained at the 2,100 grains per gallon, or at whatever strength the castor oil had first been used, a single dose was usually effective for several hours.

Castor oil proved astonishingly effective in the case of a multiple-effect evaporator with forced circulation and ample vapour space, which primed very badly at times, whilst lost vacuum and water-logged traps gave endless trouble, though the evaporator was normally worked at a steady saline concentration. At irregular times something was getting into the liquor to cause the priming, which was usually particularly bad when working with the highest liquor level and lowest vacuum (15-16in.). Tests were made with castor oil and it was found that the addition of 10 p.p.m.—added as straight oil—invariably prevented priming for days, even with a saline concentration of 15,000 grain per gallon. Sometimes a smaller dose (as little as 3 p.p.m.) was sufficient at the same high saline concentration, but more than 10 p.p.m. was never required. If the attendants were quick enough to observe the start of foaming, a dose of the oil stopped it and brought the set back to normal working in a minute or so. Less oil was also needed at such times.

These experiences bear out the present-day explanations of foaming and priming, *viz.* that dissolved solids and suspended matter both play a part, the former producing a foam and the latter stabilising it. In the first case referred to, the source of the suspended solids was found, while with the evaporator, it seems more likely that some other stabilising agent was getting in occasionally.—*"Boiler House Review", Vol. 52, No. 6, December, 1938, p. 388.*

New Uses for Rubber in Shipbuilding.

Apart from the use of rubber in the seating of engine-room auxiliaries to reduce vibration at high speeds, rubber is now being used for coating propeller blades to protect them against erosion. At the present time it is possible to fasten rubber to metal so that the connection is equal to the strength of the rubber itself and this property is being utilised with increasing frequency. In the new Cunarders "Queen Elizabeth" and "Mauretania" the end laps of the underwater plating are being made flush with wedges of rubber composition, not only to lessen the resistance of the ships, but also to reduce erosion at these places. Rubber is also well adapted as a covering for tail shafts in conjunction with a bronze bearing of reduced length and it is stated that the saving in cost when a rubber casing is substituted for a bronze liner, is about 25 per cent. of the total cost of the shaft, with a considerable reduction in weight. In view of the fact that rubber has been used for many years to line pipes in chemical industry plants, it is suggested that rubber should be eminently suitable for lining pipes in the salt-water systems of ships, which are subjected to a much less severe test. Although the first cost is higher than that of an unlined pipe, the installation should provide trouble-free service throughout the life of the ship. Ordinary rubber perishes when in contact with oil, but there are now available synthetic rubbers which can be used successfully as jointing in hatches of oil tankers or oil fuel bunkers.—*"Fairplay", Vol. CXLIX, No. 2901, 15th December, 1938, pp. 413-416.*

New Engines for Italian Liners.

It has been decided to re-engine the 33,000-ton motor liner "Augustus", built in Italy in 1927, by replacing her present four two-stroke, double-acting M.A.N. engines of 7,000 b.h.p. each, with new Fiat engines of 40,000 b.h.p. The smaller liners "Esquilino", "Viminale", "Romolo" and "Remo" are to be provided with new Sulzer engines capable of giving them a speed of 17 knots, by the Cantieri Riuniti dell'Adriatico/Sulzer.—*"Journal de la Marine Marchande", Vol. 20, No. 1,028, 15th December, 1938, p. 1865.*

The Benson Boiler in German Ships.

The first marine plant incorporating a Benson boiler was that of the German steamer "Uckermark", in which a Scotch boiler was replaced by a Benson boiler in 1930, and others were installed in the new German steamers "Windhuk" and "Pretoria", built in 1936 by Messrs. Blohm and Voss for the Hamburg-South African trade. These vessels are 576ft. in length overall, the beam being 72ft. and the gross tonnage about 16,500. The propelling machinery consists of two sets of single-reduction geared turbines developing 14,200 s.h.p. and giving the ships a service speed of 18 knots. Steam is supplied by two Benson boilers at a pressure of 1,170lb. and a temperature of 900° F. These boilers are worked on the forced circulation principle, the water injected by the feed pump emerging as steam at the superheater outlet, there being no steam or water drums. Each boiler has a heating surface of 6,900 sq. ft. and a normal evaporative capacity of 28·5 tons, which can be increased to 40 tons of steam per hour. The Benson boilers are placed in the wings of the boiler room and a water-tube boiler supplying steam at 400lb. for the auxiliaries is arranged between them. The ships can be run at 60 per cent. of full power on one boiler only, a speed of 15 knots being obtained, and only 30 per cent. of the total machinery space is occupied by the boiler room. To produce the same power, five water-tube boilers or ten cylindrical boilers would be required, occupying 60 per cent. of the total machinery space.

The results obtained during ten voyages of the "Pretoria" and eight voyages of the "Windhuk", equivalent to 280,000 sea miles, show a high efficiency of engines and boilers, the average oil fuel consumption for all purposes being about 0·57lb. per s.h.p./hr. and the boiler installation gave satisfactory service during the period under consideration. This figure, while exceedingly satisfactory, does not differ greatly from the consumption of the typical high-pressure water-tube boiler installation favoured in modern British passenger liners.—*"Fairplay", Vol. CXLIX, No. 2900, 8th December, 1938, pp. 368-369.*

Unusual Diesel Repair.

An unusual Diesel engine repair which must have saved the owners a considerable sum, was recently carried out by Weldangrind, Ltd., of Notting Hill, W.11, to the bottom of the sump of a 450 b.h.p. stationary-type, four-stroke, airless-injection, Diesel engine. It was found that some time after the installation of the engine, oil in the sump was percolating down into the concrete bed through five porous core runners at the bottom of the sump. All oil was removed from the latter and its interior was washed down with a degreasing fluid. The affected areas were then sand-blasted by placing a rectangular container over the area to be blasted, the container having a sand-blasting nozzle in the top and a flexible exhaust pipe at one side. After sand-blasting in the usual way, the sand supply was cut off and only air allowed to pass from one to two minutes in order to drive the residue sand out of the container into a receptacle on the exhaust pipe. This eliminated all danger of any abrasives finding their way into the bearings. The area so treated was then sprayed with pure zinc to fill in the pores, the thickness of the deposit varying according to the depth of the cavities exposed. A coating of high carbon steel was finally applied over the zinc to protect it from any chemical action that might take place. The total weight of metal deposited was 4lb. of zinc and 1lb. of steel and the entire job only necessitated the engine being out of commission for three days.—*"Gas and Oil Power", Vol. XXXIII, No. 398, November, 1938, pp. 283-284.*

Diesel Propelling Machinery in German Warships.

The "pocket battleships" "Deutschland", "Admiral Scheer", and "Admiral Graf Spee" were the first large warships to be driven by Diesel engines, the machinery of these 10,000 ships consisting, in each case, of four two-stroke cycle, double-acting M.A.N. type engines with nine cylinders, arranged in pairs to drive two shafts through reduction gears to which they are coupled by Vulcan hydraulic couplings. These are necessary to damp out vibrations and provide a useful means of cutting the engines in or out without shocks, but involve considerable additional weight. The engines run at 450 r.p.m. while the speed of the shafts is 250 r.p.m. and the entire group of four engines is controlled from a control station from which the engines can be started, stopped or reversed, together or separately. The scavenging air is supplied by four engines of similar type, but having only five cylinders and these engines also drive the oil and water pumps. The total power of the main engines is 56,800 h.p. The auxiliaries are electric-driven and there are eight Diesel-driven dynamos of 250 kW. each, driven by engines of 375 h.p. The total weight of the entire engineering installation is 485lb. per s.h.p. and the minimum fuel consumption for the main engines and scavenging engines is 0·385lb. per s.h.p./hr., while that of the dynamo engines is 0·394. The cruising radius of the ships is reported to be over 10,000 miles and from all available information, their machinery has proved satisfactory in service and gives them a speed of 26 knots.

Earlier experience was gained with the all-Diesel drive of the gunnery training ship "Bremse" of 1,250 tons displacement, whose engines of 26,000 s.h.p. give her a speed of 27 knots. The propelling machinery is similar in design and arrangement to that of the "pocket battleships", but appreciably smaller, since the power is less than half. The height of the main engines from the centre line of the crankshaft to the top of the engine, is about 8½ft. It is reported that the "Bremse" is extremely noisy under way.

The cruiser "Karlsruhe" is turbine-driven, and has an 800 h.p. Diesel engine geared to each of the two shafts through Vulcan clutches, giving her a speed of up to 9 knots, but above this speed the steam plant must be used and the Diesels are useless. An improvement in this respect was effected in the light crupiser "Leipzig", which has three shafts, the two wing shafts being driven by geared turbines of 30,000 s.h.p. on each shaft, while the centre shaft is driven by four Diesel engines connected through Vulcan clutches to a reduction gear as in the "Deutschland" class. The Diesels furnish 12,000 s.h.p. on the centre shaft, which gives the ship a speed of up to 18 knots; above this, the wing shafts must be used. To reduce drag losses, the wing shafts are driven by motors when not in use and although this requires 500 h.p., it is estimated that 3,000 h.p. in drag losses are saved thereby. The problem of getting full Diesel power both at cruising speed, when the propellers run at 100 r.p.m. and the 400 r.p.m. corresponding to full speed, was solved by using a variable pitch propeller.

Of the more recent German ships, the light cruiser "Nürnberg" (1934) has a machinery installation very similar to that of the "Leipzig", while the two 26,000 ton battleships "Scharnhorst" and "Gneisenau" are also equipped with Diesels for cruising, although no particulars are available. The two 10,000 ton cruisers now under construction—the "Blücher" and "Admiral Hipper"—will have geared turbines, as will, according to reports, the new 25,000 ton battleships.—*"The Marine Engineer", Vol. 16, No. 736, December, 1938, pp. 357-358.*

Electrically-propelled U.S. Minelayer.

The first electrically-propelled minelayer was delivered to the U.S. Quartermasters' Corps some months ago, electric drive being adopted because of the need for extremely accurate manœuvring when laying mines. The ship is propelled by twin screws, each driven by a 560 h.p. single armature motor running at 230 r.p.m. and the prime movers consist of three 600 h.p. Diesel engines, two of them driving single armature 300 kW. main generators and 100 kW. auxiliary generators, at 400 r.p.m. The three generating sets are arranged abreast of each other and the middle engine drives a double-unit main generator, each unit of which has a capacity of 150 kW. and also a 100 kW. auxiliary generator. This enables the load of the two propellers to be divided between the three main engines and gives the great flexibility of power both for propulsion and auxiliaries.

The control equipment, which is on the variable voltage system to secure the necessary refinement, is of special design, the main control board, of the latest dead-front type, providing for armature and field connections for various combinations of main generators, propelling motors, cable-reel motors and auxiliary generators. Control of the propelling motors is provided in an elaborate control station in the pilot house with extensions on the flying bridge, and at the engine-room control board.—*"The Marine Engineer", Vol. 61, No. 736, December, 1938, p. 362.*

Pressure Alarms.

The importance of providing automatic warning to indicate failure in the cooling water circulation and forced lubrication systems of vessels is demonstrated by the number of new ships recently fitted with whistle or electric monitor alarms. Three new motorships built by Messrs. Wm. Doxford & Sons, Ltd., are fitted with alarms mounted on a backplate, complete with pressure gauges, air-filter, shut-off cocks, connecting pipes and unions for protecting the jacket cooling and lubricating oil systems of the main engines. The whistle alarm gear will operate on the full air receiver pressure of 600lb./sq. in. In the case of a motor tanker recently built by Messrs. Swan, Hunter & Wigham Richardson, Ltd., each alarm is also fitted with red plunger indicators to enable the engineers to see at a glance which system is faulty. The alarm pressure is adjustable between zero and 30lb./sq. in.

The electric type of monitor pressure alarm fitted in a number of new motorships operates by means of indication lamps and a Klaxon horn direct from the engine-room lighting circuit and has also been used for fuel overflow tanks to give warning if the oil becomes too high.—*"The Marine Engineer", Vol. 61, No. 736, December, 1938, p. 367.*

Twenty Knot Dutch Cargo Vessels.

The United Netherlands Navigation Company have just taken delivery of a fast motorship named the "Arendskerk", of 7,890 tons gross. The ship has a length b.p. of 383ft., a beam of 64ft. 3in. and a moulded depth of 42ft. 9in. to the shelter deck, being of the open shelter deck type, with five cargo holds. The propelling machinery consists of twin screws driven by two Sulzer two-stroke cycle, single-acting engines of ten cylinders with a bore of 650mm. and a stroke of 1,200mm., each developing 10,000 b.h.p. and designed for a service speed of 17 knots. During trials the speed of just over 20 knots was obtained. A sister ship, named the "Abbekerk" is in process of completion.—*"Journal de la Marine Marchande", Vol. 20, No. 1028, December, 1938, p. 1865.*

Motorships for Coastal Service of Italian Colonies.

The Societa Anonima Navigazione Eritrea has recently ordered a number of small vessels for the passenger and cargo services of the company on the coast of the Italian colonies of North-East Africa, from the Societa Anonima Franco Tosi of Legnano. These ships are of the single-deck type with a continuous cellular double bottom arranged to carry fuel and lubricating oil and fresh water. The hulls are welded throughout, except for the longitudinal seams of the outer plating, which are riveted. The ships have a length of about 113ft., a beam of about 22ft., and a moulded depth of about 14ft. 6in., the maximum draught fully loaded being 9ft., and the displacement 1,100 tons. The coasters have the relatively high speed of 13½ knots and their propelling machinery consists of a pair of four-stroke cycle, single-acting, six-cylinder Tosi engines with Büchi superchargers, driving twin screws. Each engine is designed to give 720 h.p. at 210 r.p.m. under normal conditions, but this may be raised to 800 h.p. and 225 r.p.m. with two hours' supercharging. The sea water circulating and forced lubrication pumps are driven off the main engines. Electric current at 220 volts for motors and 110 volts for lighting purposes, is furnished by two 30 kW. generators driven by two-cylinder Tosi engines of 45 h.p. at 500 r.p.m. The auxiliary machinery includes an electrically-driven air compressor and refrigerating machine with air-conditioning equipment. The cargo handling equipment includes six electric winches and the steering gear is of the all-electric type.

The hull is subdivided into four main watertight compartments and the ship's officers are berthed in a central deckhouse which is air-conditioned and can be maintained at a temperature of 18° F. below that of the atmosphere. The native crew are berthed aft and a hospital is provided under the forecastle.—*"Journal de la Marine Marchande", Vol. 20, No. 1027, 8th December, 1938, p. 1829.*

Belt Drives.

A method which, it is claimed, prevents the slipping of belts, has been developed in this country and after a series of trials extending over two years, it has now been placed on the market. The method involves the application of a plastic material to the belt face of the pulley whereby its character is changed, but the material has to be applied only to a depth of one-sixteenth to one-eighth of an inch to give the desired result. The pulley must be perfectly clean and quite free from oil and grease before the material is applied, and then the adhesion is complete, the substance setting in a period of about 24 hours to a stone-like consistency. It is claimed that the new surface does not wear the belt or cause injury by clogging the leather or fabric and the material is unaffected by grease, oil or dust. It enables a flat surface pulley to be converted into a crown pulley and is particularly suitable for high-speed drives.—*"Shipbuilding and Shipping Record", Vol. LII, No. 23, 8th December, 1938, p. 703.*

Diesel-electric Ferry for the Clyde.

"Clyde Vehicular Ferryboat No. 4", plying between Govan and Partrick, was built for the Clyde Navigation Trust by Ferguson Bros. (Port-

Glasgow) Ltd., and possesses a number of unusual features. The vessel is 82ft. long, 44ft. wide and has a depth of 12ft. to the main deck. She takes two minutes for her passage across the river, which is 550ft. wide at this point. The ferry is double-ended, with two propellers at each end on two through shafts driven through gearing by the two main propulsion motors. Normally, all four propellers are used, the two forward ones acting as tractors. No rudders are fitted, steering being effected by varying the speed and direction of rotation of the propellers, which enables the ferry to be manœuvred conveniently in all circumstances and to be turned completely round on her own axis in a very short space of time. In order to bring the vessel's carrying deck level with the quay at all stages of the tide, it is arranged for raising and lowering by means of six vertical screws operated through gearing by an electric motor. The prime movers consist of two 250 b.h.p. six-cylinder Diesel engines, of the 4-stroke, solid injection type, the cylinders having a bore of 9½in. and a 12in. stroke. These engines are direct-coupled to two 160 kW., 440 volt D.C. generators running at 500 r.p.m. In normal circumstances they run in parallel and give a constant current at all voltages up to 440. The auxiliary sets consist of two six-cylinder, 4-stroke, solid-injection Diesel engines developing 33 b.h.p. at 550 r.p.m., each directly coupled to a 25 kW. 220 volt generator, either set being capable of supplying all the power required for lighting and auxiliaries. Batteries are provided for use in the mornings before the auxiliary sets are started. The two propulsion motors are of the forced ventilation protected type, each rated at 220 b.h.p. at 600 r.p.m., and each driving two propellers, one at each end of a through shaft at 150 r.p.m. through a 4:1 reduction gearing. There are four thrust blocks with oil glands and forced lubrication. The vehicle carrying platform is raised and lowered by a 100 h.p. 220 volt motor running at 500 r.p.m. coupled to a worm reduction gear which transmits the drive to a fore-and-aft shaft at each side of the vessel, through bevel gearing. The fore-and-aft shafts operate the six main vertical lifting screws—three at each side—by means of worm gears, the total travel being 17ft. Both propulsion motors and the platform motor are operated on the constant current control system and as the platform motor is not in use at the same time as the propulsion motors, a simple changeover switch is provided. Four cam-operated contactor type controllers are fitted for use with the propulsion motors, two being on the bridge and two in the engine-room, providing alternative control positions. Bridge control is normally used.—*"G.E.C. Journal", Vol. IX, No. 4, November, 1938, pp. 293-298.*

Modern Ship Performance.

In order to prove the remarkable claim made by naval architects and marine engineers that the coal consumption of a cargo vessel of given size and speed has been reduced by nearly 50 per cent. since 1925, a well-known marine engineering firm has analysed data from half-a-dozen vessels built some 15 years ago. The ships were all of the general cargo class of 8,000 to 9,000 tons d.w. with voyage speeds of 9 to 10 knots and the machinery in all cases was of the triple expansion saturated steam type, coal-burning. The vessels were of good average class at the time they were designed, but as was customary at that time, they were ordered entirely from the point of view of minimum cost per ton of deadweight.

In order to standardise the effects of weather conditions, state of bottom and quality of hull during voyages in all parts of the world, the results of half-a-dozen ships were taken over a period of about a year's service. The average performance is shown in the table under the column marked S.S. 1924.

Then two steamers delivered in 1936-37 were considered. They were also general cargo vessels of 9,000 tons d.w. capacity with voyage speeds of 9½ to 10 knots, but their hulls and machinery were of a modern type and were not designed exclusively from an aspect of lowest cost per ton d.w. Extra expenditure to secure increased efficiency was authorised and various devices, such as re-heated steam reciprocating machinery, were used for this purpose. As before, a record of about a year's service was taken in all parts of the world and is given in the column S.S. 1937.

The voyage performances are compared in the following statement:—

	S.S. 1924.	S.S. 1937.
Displacement, tons ...	11,320	12,290
Speed, knots	9·02	9·47
I.h.p.	1,703	1,440
Coal, per day, tons ...	29·83	17·97
Coal per i.h.p./hr., lbs. ...	1·65	1·165
Admiralty coefficient ...	227	315
Coal coefficient	12,650	25,195

It will be noted that S.S. 1937 carries 1,000 tons more at about ½-knot higher speed on 12 tons less coal per day, so that if S.S. 1937 were reduced to the same speed and displacement as S.S. 1924, her coal consumption would be almost exactly half (50·3 per cent.) of the older ship.

It can also be deduced from the Admiralty coefficient that improvements to hull, propeller and rudder have reduced the h.p. required for S.S. 1937 by some 28 per cent. From the specific fuel rates it can be shown that for a given h.p. S.S. 1937 will burn 29 or 30 per cent. less fuel.—*"The Shipping World", Vol. XCIX, No. 2373, 7th December, 1938, p. 622.*

Relations Between Propeller Revolutions and Horse Power.

The main variables are shaft horse-power, speed of ship and propeller revolutions, the effect of ship speed for ordinary merchant ships being of secondary importance and disc area ratio is in practice a fairly constant factor, so that a constant thrust loading may be taken as a basis of comparison. It has been found that for propellers of varying pitch ratio at "optimum" efficiency the "lift coefficient" of corresponding sections remains nearly the same, which taken in conjunction with constant thrust loading denotes approximately constant top speed (revolutions × diameter). A good approximation to optimum diameter is: diameter varies as v ($\sqrt{P/V \div N}$) P being shaft horse-power, V the speed and N the revolutions. Hence top speed varies as v ($\sqrt{P/V} \times N$) and for constant tip speed N varies as $\sqrt{V/P}$.

This relation is of exactly the same form as the condition for constant piston speed and mean effective pressure for a fixed number of cylinders and it may be concluded that when the power is increased by increasing the number of cylinders in an internal-combustion engine, piston speed and revolutions should be lowered from the aspect of propeller design and efficiency. Thus, for example, a 50 per cent. increase in power should be associated with a decrease of rather less than 20 per cent. for constant tip speed and thrust loading.

While this relation applies generally to propellers of moderately high thrust loading such as are usual in motorships and to screws not subject to severe restriction of diameter, it should not be applied over too wide a range, as at the high speed end the thrust loading and disc area ratio tend to increase, thereby vitiating the assumptions made since the tip speed also increases, while at low speeds the tip speed tends to decrease, largely because the pitch ratio would otherwise be too low for efficiency. The effect of this in decreasing the thrust loading is partly offset by the diameter restriction commonly applied to low-speed propellers, rendering it impossible to adopt optimum pitch in such cases, but in general, the ratio between revolutions N and the quantity $\sqrt{V/P}$ gives a reasonable criterion of the suitability of the revolutions for the speed and power as regards propeller design, when comparing different ships in the same class.—*J. Lockwood Taylor, D.Sc., "The Marine Engineer", Vol. 61, No. 736, December, 1938, p. 361.*

Measurement of High Temperatures.

For measuring high temperatures the instrument used is not in contact with the hot body, as such pyrometers depend on the radiant energy emitted by the hot body and obey certain laws which apply to a perfect *"black body"*. A "black body" is one absorbing all radiations falling on it, without loss by reflection or transmission. The radiation from the interior of a chamber at uniform temperature approaches closely to the ideal conditions. On the other hand, only a fraction of the theoretical energy is received from a body in the *open* and this fraction (always less than unity) is called the *emissivity* and depends on (*a*) wave length, (*b*) temperature of surface, and (*c*) character of surface. A few typical values are given below:

Emissivity of surfaces for red light (wave length = 0·65 μ).

Silver	0·07	Iron	0·37
Copper, solid ...	0·11	Iron oxide, 800° C.	0·98
„ liquid ...	0·15	„ „ 1,200° C.	0·92
Cuprous oxide ...	0·70		

For bodies in the open corrections have to be made. The *radiation pyrometers* used under "black body" conditions are subject to the *Stefan-Boltzmann* Law, which may be stated as "an increase of 1 per cent. in the absolute temperature of the radiating body increases the energy emitted by 4 per cent.". Stated mathematically, the law is:

$$E = K\ (T^4 - T^4_0)$$

where $K = 1{\cdot}34 \times 10^{-12}$ calories per sq. cm./sec. E is the total energy radiated by body at absolute temperature T to surroundings at absolute temperature T_0. Since T_0 is small compared with T we can write:

$$E = KT^4$$

For bodies in the *open*, we can use the formula to find true temperature T:

$$E - K\ e\ T^4 = KS^4 \text{ or } T = \frac{S}{\sqrt[4]{e}}$$

where e is total emissivity and S is apparent temperature indicated by pyrometer. For example, the instrument reads 900° C when sighted on iron; in the open the true absolute temperature is:

$$T - \frac{900 + 273}{\sqrt[4]{0{\cdot}37}} = 1{,}504° \text{ absolute or } 1{,}231°\ C.$$

Most of the radiation pyrometers use either a lens or a mirror to concentrate the heat rays emitted by the hot body on to a small thermocouple and the E.M.F. developed is measured by a calibrated millivoltmeter. Ranges are usually 550° to 2,000° C, but there is really no upper limit.

In the *Fery* pyrometer inclined mirrors in front of the thermocouple indicate when correct focus has been obtained—*viz* the image of the hot body appears broken in halves when out of focus. Such radiation pyrometers require about 15 seconds to take a reading, but can be made recording in the same way as a thermoelectric pyrometer. It is essential that the image of the hot body should be sufficiently large to cover the sensitive thermo-element, but the distance from the hot object is immaterial.

The K & S pyrometer, however, uses a bimetal spiral with a pointer and compensating spiral, the heat rays being concentrated by a lens on to the bimetal spiral.

In optical pyrometers the *intensity* of the *light* from the hot body is compared with that from some standard source, and both are matched in the instrument to *one* specific wave-length, usually red light ($\mu - 0{\cdot}65$). Even a colour-blind person can do this. The optical devices used to make this comparison of the two intensities of light differ in various makes of instrument. In the *Wanner* pyrometer a polarising device compares the red ray from the hot body with the ray of the same wave-length from an electric lamp, the intensity of which is calibrated by an amyl acetate lamp, while in the disappearing filament pyrometer the intensity of a standard filament lamp is varied until it disappears against light from the hot body. The lamp is placed inside a telescope, the focusing of which forms an image of the hot body in the plane of the filament. The filament and image are viewed through the eyepiece of a telescope, adjusted to suit the operator's eye and an electric current is passed through the filament until it is just hot enough to disappear against the image of the hot body. This current can be measured by an ammeter and if previously calibrated, can be used to indicate the temperature of a hot body. The reading obtained from an object in the open will depend upon its reflecting power and surroundings. An oxide free metal may reflect considerable sunlight into the instrument and give a false reading.

The photo-electric cell can also be adapted to read the temperatures of moving articles when these are visibly hot.—*E. C. Rollason, M.Sc., "Metallurgia", Vol. 19, No. 109, November, 1938, pp. 15-16.*

Auxiliary Diagrams for Calculating Propellers Working in Nozzles.

Diagrams are given (*Figs. 4 and 5) to assist in obtaining the principal characteristics of a propeller working in a nozzle, also to determine the corresponding coefficient of propulsion.

The curves represent a summarv of a series of trials on a number of propellers with nozzles, working in open water.

They are calculated in accordance with the methods previously proposed by the author.

It is necessary to note that there are at least two variations from the rule for using similar diagrams relating to ordinary propellers, i.e., for determining:

(1) The coefficient of suction t;

(2) The pitch ratio $\frac{H}{D}$.

Denoting (as is usual in propeller calculation)

$t = \frac{P - Pe}{P}$ = coefficient of suction at the slip value S,

t_0 = coefficient of suction with a slip value $S, -1$ (at mooring trials) we have in the case of a propeller without nozzle :—

$$t = \frac{t_0}{S_1}$$

In the case of a propeller with a nozzle, it is necessary to consider the coefficient of suction as constant for all slip values and numerically equal to :—

$$t = t_0 = \text{constant}$$

If the value of t_0 is determined by the usual method, then in the first approximation :—

$$t = 0{\cdot}4 \text{ W} \qquad (3)$$

where $W = v - v$ = coefficient of flow in a forward direction (wake factor).

As regards the pitch ratio, it should be noted that contrary to the usual diagrams the pitch ratio for the zero lifting force H_0/D, is taken as the parameter instead of the zero thrust H_1/D, as in view of the presence of the resistance of the nozzle the effective pitch, i.e., the value n, at which the total thrust of the propeller (with a nozzle) becomes zero, will be less than H_1/D of the propeller.

A good example of the influence of the resistance on the efficiency of the combination is shown by the graph Fig. 1, in which the results of the calculations for the curve of the effect of the combined propeller and nozzle $H_0/D - 1{\cdot}2$ is given. In the graph, K=the coefficient of the total thrust of the propeller (with nozzle), excluding the resistance of the nozzle, R, includes this resistance.

Fig. 1 shows the curves of efficiency of propeller : No. 1 (with straight tips) and Fig. 2 shows the efficiency of propeller No. 2 (elliptical form).

The pronounced divergence of the curves K_1 and K, with a corresponding large drop in the efficiency at small values of slip (high N), are typical of a propeller nozzle installation.

Fig. 2 shows the relation between the total thrust and the thrust of the propeller alone. This figure also shows the results of calculations for the curves of efficiency of a propeller with the same pitch ratio $H_0/D - 1{\cdot}2$ but with an elliptical contour of the blades (as against the truncated form in Fig. 1).

As may be seen commencing with the values of $\lambda \equiv 0{\cdot}7$, i.e., for a slip value of $S_1 < 0{\cdot}35$ the resistance of the nozzle exceeds the value of the additional thrust which it exerts and the total thrust of the combination becomes less than the thrust of the propeller alone.

In a previous paper by the same author, it was shown why it was possible to expect that this negative effect of a nozzle fitted abaft the hull at small powers, will be compensated by a positive reaction of the nozzle on the structure of the wake.

In the calculations, this is taken into account by taking the value t from formula (2) and not from formula (1).

As regards the resistance of the nozzle, as indicated in the two given instances and from the graphs which are taken as a basis for constructing the auxiliary diagrams, the resistance is calculated in accordance with the formula :

$$K_r = 0{\cdot}045 \left\{ \frac{H_0/D + 3}{4} \right\}^2 \sqrt{\frac{H_0/D}{H_0/D + N}} \qquad (4)$$

* None of the illustrations, except Fig. 3, is reproduced.

where the factor 0·045 wth a length of nozzle equal to $\frac{3}{4}$ the diameter of the propeller, corresponds approximately with the coefficiency of the profile resistance of the nozzle $C_1 \cong 0{\cdot}006$.

The difference between the pitch of the edges H and the pitch of the aero lifting power H_0 depends on the suction of the blades. The value of H_0/D as shown in the diagram (Fig. 3) refers to the characteristics at 0·7 of the radius of the propeller with approximately a constant pitch H.

We may therefore with sufficient accuracy, based on Fig. 3, assume that:

$$\frac{H_0 - H}{H} a_0 (\tan v + \text{cotan } v) = a_0(\tan v_0 + \text{cotan } v_0) \quad (5$$

where, for a section from a circular segment $\hat{a} = 1{\cdot}748_0$, and for an aviation section $\hat{a}_0{}^\circ = 1{\cdot}578_0{}^1$
$_0$ – the maximum ordinate of the curve of the centre line of the blade section in that part of the breadth b at 0·7 R.

With a correct curvature of the blade section, the ratio 8_0 together with $\frac{H_0}{H}$ should increase with an increase in the load.

In propellers for tugs the ratio $\frac{H_0}{H}$ is on an average 1·1 to 1·15.

It should be noted that in the proposed auxiliary diagrams that each spot in the efficiency values corresponds to its optimum contour of the blades also to the optimum form of the nozzle.

The determination of these forms must constitute a special study of the final detailed design of the propeller and nozzle, which is outside the scope of this article.

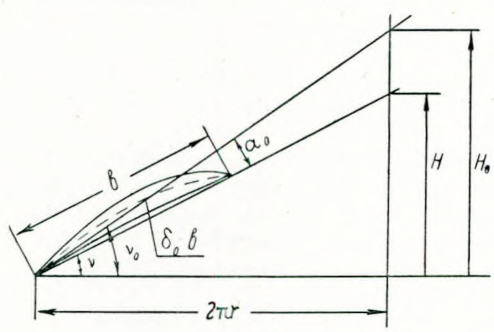


FIG. 3.

The calculations for the auxiliary diagrams are made on the assumption that the nozzle opening is not increased in width abaft the propeller; also that the blades of the propeller are polished, in cases where the blades are not finished off, the efficiency values would in the best case be about 5 per cent. less than shown in the diagram i.e.$<0{\cdot}95$ n.

Utilizing the diagrams in Figs. 4 and 5, two examples are worked out with the following particulars:

Wake factor	$w = 0{\cdot}25$
Suction coefficient ...	$t = t_0 = 0{\cdot}4w = 0{\cdot}125$
Towing speed	$v = 2{\cdot}2$m./sec.
Hull resistance	R=320kg.
Maximum diameter of propeller	D=1·5m.

Example I. What horse power is required for a pull on the towing hook z=3000kg. and what would be the most advantageous number of revolutions?

Example 2. What would be the pull on the towing hook where the horse power of the engines W P S=198 i.h.p. by $n_m = 200$ r.p.m.^{r}.—*"Soudostroienie", No. 4, 1938.*

Stern Tube and Lubrication System.

The Guthans system of automatic stern gland and pressure lubrication is designed for tugs and other vessels working in waters containing silt and sand. The stern tube is of steel, with a stern bearing consisting of a bronze liner in way of bearing only, with a bronze-backed, white-metalled split bush. The inboard bearing has a steel liner and a bronze-backed, white-metalled split bush. The whole stern tube is supplied with grease under pressure through the stern bearing, with a gauge at the inboard bearing to indicate the pressure at all times. The stern gland is automatic in operation, a constant pressure being maintained on the packing by six stainless steel springs. When the shaft is running, a Hill-McKenna oil pump driven by an eccentric on the tailshaft, forces greases into the stern bearing through a 1¼in. pipe. This pump or grease-feeding ram is filled by a separate grease-charging ram worked by steam or compressed air. A grease filter is fitted in the charging pipe. A working pressure of from 5 to 10lb./in.^{2} is maintained on the grease in the stern tube, which together with the automatic stern gland, suffices to prevent any water or dirt from entering the stern tube, thereby precluding the risk of corrosion. There is no more wear than is experienced with the ordinary line shaft and main bearing.—*"Motorship and Diesel Boating", Vol. XXIII, No. 12, December, 1938, pp. 585-586.*

Refrigerated Cargo Liner for South Africa.

The m.v. "Richmond Castle", launched in November at Belfast, is the first of two sister ships built by Messrs. Harland and Wolff for the South African services of the Union Castle Line. Her sister ship "Rowallan Castle" is to be launched in December. The "Richmond Castle" is 450ft. long B.P., with a moulded breadth of 63ft., and a moulded depth (to upper deck) of 37ft. The gross tonnage is about 7,850 and the ship is fully insulated with a total capacity of approximately 414,000 cu. ft. arranged for the rapid conveyance of deciduous and citrus fruits from South Africa in their season. The vessel has two complete decks, besides lower and orlop decks forward and aft of the machinery space and bridge and forecastle decks. There are seven watertight bulkheads extending to the upper deck and the double bottom extends from the fore peak to the after end of No. 4 hold, being arranged to carry oil fuel and water ballast. Deep oil fuel tanks are arranged on either side, at the after end of the machinery space. All the cargo holds and 'tween decks, also the bridge 'tween decks, are insulated for the carriage of fruit, whilst the 'tween decks in No. 4 hold and the three compartments in the bridge 'tween dacks are also arranged to carry chilled produce when required. The propelling machinery consists of a single Harland-B. & W. two-stroke cycle, double-acting engine with eccentric drive for the exhaust pistons, uniflow scavenge by rotary blowers and tuned exhaust pipe system. Cylinder covers and rackets are cooled with fresh water and the pistons are cooled with oil from the forced lubrication system. The thrust block is incorporated in the engine bedplate. There are three 300 kW. generators driven by 6-cylinder Harland-B. & W. 4-cycle trunk type engines, each set being mounted on a common built-up bedplate, with salt-water cooling for cylinder jackets and covers. There are two electrically-driven air compressors for main engine starting and manœuvring air and all engine room auxiliaries, including about 25 pumps and other machinery, are electrically driven. The refrigerating machinery by Messrs. J. & E. Hall is electric, the temperature of the cargo spaces being regulated by cold air circulation, the chilled produce spaces also being fitted with a system of brine grids. The windlass and 10 cargo winches are all electrically driven and the double plate streamlined rudder is operated by electric steering gear of the builders' make. The ship is equipped with Thermotank ventilation and the living accommodaton is electrically heated by over 40 heaters of the builders' own manufacture. There are also electrically operated hot presses and water boilers in the galley.—*"Shipping", Vol. XXVII, No. 317, December, 1938, pp. 18-19.*

Novel Design of Bilge Keel.

The new 22,000 ton liner "Oranje". recently launched for the Netherlands Steamship Co., Ltd., will be equipped with bilge keels of a new type, designed by Mons. Rosingh of the Wilton-Fijenoord Engineering and Shipbuilding Company and protected by a patent. Experiments with bilge keels of this type have proved successful in the case of two torpedo boats ("G15" and "G16") built by the firm for the Dutch Navy. The Wilton-Fijenoord bilge keel consists of a series of fixed wings, streamlined in section (similar to an aeroplane wing), attached to the hull at right angles to the plating, the distance between the wings being such as to enable each wing to be fully effective. The inner edges of the wings are welded to a plate riveted to the hull plating and their outer edges are welded to a continuous steel tie-bar of circular section. The wings are shaped from rectangular steel sections, being 8in. wide, 36in. long and $1\frac{9}{16}$in. thick at their maximum cross-section, while the tie-bar to which their extemities are secured has a cross-section of about 4 sq. in. and the wings are separated by a distance of 26in. Considering each element as analogous to an aeroplane wing exposed to a flux under a certain angle of incidence, the "lifting force" perpendicular to the flux is calculated by means of the formula

$$S=\tfrac{1}{2}\,p\,V^2\,FC.$$

The density p, velocity V and the area F of the wing being constants, it follows that the lifting force is proportional to the coefficient C. The well-known formula of *Prandtl,* verified by experience, allows the coefficient C to be determined according to the ratio S/c of the length of the wing to its width. For example, with an angle of incidence $S/c=0{\cdot}5$, owing to the decrease of the actual angle times as great (free wing) when $S/c=8$, that when of 10°, the lifting force coefficient C is about four of incidence at the tip of the wing due to the formation of eddies. In the case of the bilge keel, the ship's hull prevents the setting up of eddies at the inner ends, each wing behaving as a free wing with the ratio S/c twice as great. Thus wings with a ratio $S/c=4$ behave as if the ratio were 8, anything above this having little effect in increasing the value of S and the efficiency of the arrangement. Experiments have proved that the resistance to passage through the water is no greater with the novel form of bilge keel than with the standard design. Comparative tests were carried out by the Dutch naval authorities with torpedo craft to determine the anti-rolling properties of the new bilge keels at speeds of from 16 to 21 knots. It was found that with ordinary bilge keels the alteration of weight due to fifteen men crossing from one side of the ship to the other, caused her to roll 10°, whereas fifty men only produced a rolling angle of 6° in the case of the new bilge keels, in addition to which the ship righted herself 2·2 times as fast in the second case as in the first. In practical tests at sea in heavy weather and steaming at 21 knots, it was found that the ship rolled about 30 per cent. less with the new bilge keels and that she recovered herself three times as quickly. The speed of the ship was not affected under any conditions by the new bilge keels. To obviate damage to the bilge keel tie-bars, these are placed 6in. inside the maximum beam of the vessel and above the level of the keel. The satisfactory results of the tests carried out with the two torpedo boats decided the Netherlands Steamship Company to fit the new bilge keels to their new liner "Oranje" and another large Dutch liner is to have her present bilge keels removed and replaced by winged bilge keels.—*"Bulletin Technique du Bureau Veritas", Vol. 20, No. 10, December, 1938, pp. 201-202.*

Electrical Accidents and Their Causes.

A report under this heading from H.M. Electrical Inspectors of Factories has just been published by H.M. Stationery Office (Price 9*d.* net). The report deals with 583 accidents due to electrical causes involving 106 fatalities. Of these 583 accidents, 152 occurred on switchgear. 120 of these being on equipment operated at below 650 volts.

A large number of accidents were due to the use of metal tools on live apparatus, and gave rise to fatal burns. Another 90 occurred on cables or flexibles, and 69 were due to electric welding. Only seven took place on transformers and six on portable heaters and irons. There was an increase of 48 per cent. in the number of accidents due to electric testing, many of these being due either to connecting a low-voltage lamp across a higher voltage system in error, or to putting the base end of a test lead to earth. Such mishaps usually cause the test lamp to burst and it is therefore recommended that it should be enclosed in an insulating box. Earthing can be prevented by making the length of exposed conductor as short as possible and by the use of a properly constructed test spike. The report calls special attention to failures of switchgear with explosive violence, most of which did not involve loss of life, but frequently caused much structural damage. The early replacement of obsolete designs of switchgear is recommended. Attention is also drawn to the failure of the limit switches fitted on cranes to prevent overwinding, a number of which disclosed defects in design and maintenance, when examined. In one case, tests resulted in four failures out of six attempts to operate the switches by overwinding. A somewhat similar problem is to be met with on steel-furnace charging machines, where the braking of the travel and slewing motions is normally effected by reversing the controllers. Should the supply fail, however, on account of the main switch opening, the operator loses control and accidents have occurred in consequence. The general construction of this class of machine makes the application of straight mechanical braking almost impracticable, but electric brakes either of the solenoid or rheostatic-resistance patterns could be used.

The report is well worthy of study, more especially because it shows what care is being taken to ensure safety in the use of electrical power.—*"Engineering", Vol. CXLVI, No. 3085, 16th December, 1938, p. 708.*

Electric Arc Welding in Cylindrical Boiler Repairs.

An article illustrated by 21 diagrams by *M. R. Lenglet,* Engineer of the Bureau Veritas and expert consultant in Strassburg, discusses the use of electric arc welding for the execution of repairs to wrapper plates, end plates, manholes, furnaces, combustion chambers, combustion chamber tube plates and tubes of marine cylindrical boilers. The precautions to be adopted and methods of stopping leaks through defective rivets are described in detail.—*"Bulletin Technique du Bureau Veritas", Vol. 20, No. 10, December, 1938, pp. 196-201.*

An Automatic Arc Welding Machine.

The Metropolitan-Vickers Electrical Company have built a new automatic welding machine for welding large boiler drums in Russia. It can be used for longitudinal and circular welds on plates up to 3in. thickness and will accommodate cylinders up to 50ft. long and 10ft. 6in. in diameter at this thickness, the maximum size being 78ft. by 3ft. 3½in., and the minimum 3ft. by 1ft. 6in. The machine consists of five parts—the work bed, two travelling columns which carry the welding heads and machine controls, control gear housed in a short steel cubicle at the back of the machine, two sets of transformers and reactors for supplying current to the welding heads and a d.c. motor generator set operating the control gear and driving motors. The work bed, about 50ft. long, is made up of two independent sections each equipped with eight sets of rubber tyred rollers for taking the drums. These rollers are mounted on cross slides which enable them to accommodate drums of from 1ft. 6in. to 11ft. in diameter, and project about 2ft. 6in. above the floor level, leaving the two ends of the work bed clear to facilitate loading and unloading and to permit overhang of long drums. For longitudinal welding the rollers are stationary, merely supporting the job, while for circular welding they are revolved by a gear-driven shaft and 4 h.p. motor. The two driving motors are electrically interlocked to ensure a balance speed range and uniform rotation of both sets of rollers when the work spans both sections of the work bed. A single rail track along the rear side of the work bed is provided for the two 20ft. travelling columns, which consist of frame structures guided by rollers bearing on both sides of a guide rail at the top. The floor track is long enough to allow the columns to run clear of any job on the work bed at either end. They are driven by independent motors or by a hand drive for quick positioning. The operator works on a platform mounted on the travelling columns and projecting over the work bed. This platform carries the welding head, electrode reel and instrument control panel and its height can be adjusted by an electric hoist to suit the diameter of the cylinder on the work bed. The columns can weld in either direction along the track and all controls on the panel are duplicated by push-buttons on the operator's arm rest. The machine is fully automatic and pre-selector push-buttons are provided on the control panel. When these are set and one of the main "start" push-buttons is pressed, the electrode is fed down and the arc struck, the welding travel motion being automatically maintained until the arc ceases or the main "stop" push-button is pressed. The two standard Metrovick welding heads for covered electrodes can use Nos. 8, 6, 4 or 3 gauge electrodes. A special feature of the welding-heads is the fume extractor consisting of a sheet metal shroud attached to the collector body just above the arc, through which the fumes are drawn up a flexible rubber hose by a small extractor fan and exhausted through a grill above the machine. The welding heads can be vertically and horizontally adjusted for accurately positioning the electrode on the joint. Welding current is supplied by two 45-

kVA transformers with a secondary current range of 230/530 amperes, obtained by a series tapped reactor. The drive motors and control gear are operated from a 60-volt d.c. supply from a 15-kW. motor generator set housed with the welding supply transformers in a bay at the rear of the machine, behind the travelling columns. For longitudinal welding of thick plate sections or wherever multiple passes have to be applied to a joint, the two columns and welding heads follow each other along the seam and weld simultaneously, thus making two passes at the same time. At the end of the run in one direction the travel motors on each column are reversed and the welding heads return along the seam. Scale or slag on the weld is easily removed between passes by a motor-driven wire brush. The design of the machine allows the two parts of the work bed and the welding heads to be used for one long cylinder spanning both parts, or the two sections may be used independently on different jobs.

The physical properties of the average all-weld test specimens are: Yield point, 25 tons/in.^{2}; ultimate tensile strength, 30 tons/in.^{2}; percentage elongation, 35 per cent. on 4in. area; reduction of area, 60 per cent. For convenience of handling the electrodes are made in coils of about $\frac{1}{2}$ cwt. in weight and 320ft. long, which on continuous welding will last for about four hours with an average rate of deposit of 11lb. per hour.—*"The Engineer", Vol. CLXVI, No. 4327, 16th December, 1938, pp. 670-671.*

Combination Ice Breaker and Submarine Depot Ship.

A new vessel under construction for the Finnish Government is provided with three propellers, one forward and two aft, for ice breaking, and is also equipped to serve as a depôt ship for submarines. The ship is steel-built, with a length of 211ft., divided into nine watertight compartments, and very heavily constructed to withstand pounding on ice. Living accommodation for 100 men is provided, to enable submarine crews to sleep on board. The Diesel-electric propelling machinery comprises 3 Atlas-Polar Diesel engines of 1,600 h.p. each, driving three generators at 320 r.p.m. Each of the three propellers is driven by 1,335 h.p. electric motor, the forward screw turning at 160 r.p.m., while the two after ones run at 140 r.p.m. The motor controls are on the bridge. There are three Diesel generator sets for auxiliary service current.—*"Motorship and Diesel Boating", Vol. XXIII, No. 12, December, 1938, p. 593.*

Increasing the Economy of Old Oil Engines.

Most of the stationary oil engines built more than 10 years ago, are of the air-injection design, although this system of injection is very rarely employed in the case of new engines. It is curious, however, that so few of the older oil engines are being converted to airless injection, thereby reducing the fuel consumption by between 7 per cent. and 10 per cent. A similar situation exists in marine work, since some 80 or 90 per cent. of the ships built before 1928 were propelled by air-injection oil engines. Within the past two years over 100 of these vessels have had their machinery converted to the airless-injection design and almost without exception the above saving of fuel has been attained, according to the owners of the ships concerned. In one case a fleet of 20 ships under single ownership is having such a modification carried out.

No British manufacturers seem to be specialising on the provision of the necessary equipment for converting engines from air to airless injection, although there are at least four or five big concerns which make a special feature of this work on the Continent. It is suggested, therefore, that one or other of the leading British Diesel engine builders should standardize a system of converting engines and that owners of air-injection engines should investigate the possibilities of effecting such a change, based upon an economy of not less than 7 per cent. in the annual cost of the fuel.—*"The Oil Engine", Vol. VI, No. 68, Mid-December, 1938, p. 231.*

Casting of Propellers with Reduced Allowance for Finishing.

(Concluded from "Soudostroienie", No. 3, Engineering Abstract No. 10, November.)

In concluding this article a detailed description is given of the best methods for casting bronze propellers with a minimum allowance for finishing, and for avoiding as far as practicable the formation of blow holes and other defects by running the metal in from the bottom of the mould.

A composition of the metal for bronze propellers is suggested, with the mechanical properties corresponding to same. The composition of the moulding loam is also given.

Tables are furnished indicating the dimensions of the pouring system in terms of the diameter of the propeller, the amount of the allowance for finishing for the inner and outer surfaces of the boss for propellers of various diameters, and a suggested allowance for the blade sections.

The following views and sketches are shown (28 in all) with detailed description in connection with each. The arrangement for drying the mould, showing the positions of the drying stoves; the method of forming the boss with striking board fitted to the vertical spindle by two arms; a scheme for forming the contour of the blade sections; arrangement for fixing the allowance for finishing the edges of the blades; adjusting the blade sections on the mould; the mould with the blade sections placed in position; views of the mould in different stages of construction; the top cast iron plate being fixed in position; view of the mould after drying operations; device for verifying the pitch by means of set square, also with the use of a pitchometer; patterns for checking the round of the fillets and thickness of blades; arrangement of the reinforcement of the mould showing the holding down bolts; a view of the mould with the vent channel open and a view with the vent covered in; the core box, framework of centre core and the core mould complete; sketch showing the formation of local shrinkage holes at the junction of the blades with the boss and method for avoiding such formation; general view of a foundry with a completed mould for a propeller in the foreground; sketch of shields for keeping the slag on the inner surface of the boss and preventing it from flowing towards the blades; view of a propeller after being removed from the mould.—*"Soudostroienie", No. 4, 1938.*

Electricity and the Ship.

The biggest auxiliary power plant to be completed in the coming year will be that of the "Queen Elizabeth", comprising four 2,200 kW. 220 volt d.c. geared turbo-generators and two 75 kW. d.c. emergency Diesel generator sets. In the "Queen Mary" there are seven generators in groups of four and three, with outputs of 5,200 and 3,900 kW. respectively. The "Mauretania" will have four 800 kW. 220 volt d.c. geared turbo-generators, while the new Dutch transatlantic liner "Niew Amsterdam", of similar size, has three 1,000 kW. 220 volt d.c. generators running at 750 r.p.m., besides two Diesel generators of 425 kW. running at 300 r.p.m., for harbour use. The normal auxiliary load in the British ship is therefore 200 kW. more than in the Dutch vessel, the steam pressure being the same.

The Swedish motorship "Stockholm" under construction at Monfalcone (Italy) and recently severely damaged by fire, is somewhat smaller than the "Niew Amsterdam" (about 28,000 tons gross against 36,287), but her auxiliary requirements are 1,350 kW. greater than those of the Dutch ship and even if the latter's auxiliary Diesel sets for harbour use are included, the "Stockholm's" requirements are 500 kW. greater. The latter ship is equipped with five 7-cylinder Atlas Polar Diesels, each direct coupled to a 870 kW. generator set running at 300 r.p.m. and rated at 1,280 b.h.p. The electrical output of the m.v. "Stockholm" is actually greater than that required for the whole of the street lighting of the city of Gothenburg, which comprises only 11,000 lamps. The three main engines of the "Niew Amsterdam" (rated at a total of about 19,700 s.h.p. at 115.118 r.p.m.) have their scavenge air supplied by three rotary blowers driven by electric motors at 2,300 r.p.m. A similar system has been adopted for the Harland B. & W. engines of the Union Castle liner "Athlone Castle" and her sister ships. In these vessels the electric current is supplied by five 6-cylinder Harland B. &. W. single-acting, two-stroke engines running at 260 r.p.m. and having a total output of 3,500 kW. The Belgian cross-Channel motorship "Prince Bandouin" has the scavenge air for her two 12-cylinder Cockerill-Sulzer Diesels supplied by three Brown Boveri rotary blowers, the total electrical output of the ship's four Sulzer four-stroke Diesel generators being 1,920 kW. at 550 r.p.m. Her sister ship "Prins Albert", completed some three years later, has her auxiliary load reduced to 600 kW. at 550 r.p.m., supplied by three Sulzer Diesel generators. This was possible because the two main engines were designed to drive their own scavenge pumps from the side of the engines. In the new Danish motorship "Selandia" (8,482 tons gross), two three-cylinder two-stroke Diesel generators supply the current used by the 150 d.c. electric motors and 1,100 lamps. Even relatively small vessels, like coasters, have a high auxiliary load to-day and frequently have Diesel-electric propulsion. This applies especially to ships with powerful cargo handling equipment, or to salvage tugs with powerful towing winches. Small coasting vessels for tropical service are sometimes fitted with air conditioning plant and in one such ship with main engines of just over 1,400 h.p., there is a total of 60 kW. for auxiliary load, direct current being supplied at 110 volts.—*"Lloyds' List & Shipping Gazette", No. 38,373, 21st December, 1938, p. 19.*

New American One-man Boiler Tube Cleaner Air Valve.

A simple air valve just placed on the market by The Roto Company, of Newark, N.J., makes it possible for one man to operate a tube cleaner by himself. The new valve can be attached to any make of tube cleaner for straight or curved tubes of 2in. or more, and is placed immediately behind the motor, so that the operator himself can turn on and shut off the air. The valve has only a single moving part and passes through the tube easily, being smaller in diameter than the cleaner, with an air passage diameter equal to the bore of the hose. A quarter of a turn of the handle either way instantly shuts off the air and the valve cannot close while the cleaner is inside the tube. Before the introduction of this new valve, one man had to control the air at a point remote from the tube cleaner, the operator working the cleaner having to signal him to turn the air on and off every time it was removed from one tube and inserted into the next.—*"Marine Engineering and Shipping Review", Vol. XLIII, No. 12, December, 1938, pp. 578-579.*

EXTRACTS.

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

Engine Operation with Heavy Oil.

By J. J. Broeze and J. O. Hinze* (of the Royal Dutch-Shell Research Laboratory, Delft).

"The Motor Ship", December, 1938.

The problem of the extent to which Diesel engines can utilize heavy fuel is one of great interest. In most oil-producing countries and in places where freight and handling charges are not of the greatest importance, there are substantial price differences between the light distillate and the heavy undistilled petroleum products. In some cases the capacity of Diesel engines for utilizing fuel other than the light (and most expensive) distillate is a determining factor in the sale.

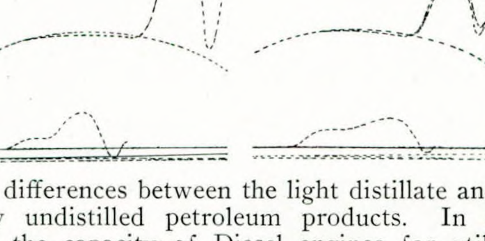


Fig. 1.—(Below) A. (Left) B.

For the satisfactory combustion of fuel in oil engines, three main properties are of importance—ignition quality, viscosity and volatility. The ignition properties mainly depend upon the nature of the crude oils from which the fuel is derived, and of these oils there are scarcely two which are similar, except superficially. It often appears that the various boiling fractions of the same crude oil form a homologous series of hydrocarbons. In such cases, it may be expected that the reaction capacity increases with the molecular weight, and the ignition characteristics are more favourable the higher in the boiling curve the fraction is chosen.

This is, however, by no means invariably the case, and, apart from exceptional instances, the general rule may be laid down that, with a given crude oil, the ignition qualities (for example, the Cetane number based on ignition delay period), with fractions of high boiling points of, say, 250° C. to 300° C. or upwards, diminishes.

The ignition delay period is twofold, being divided into a physical and chemical part. If the boiling limit be raised, the ignition delay period is increased. In diagrams which show the pressure during the ignition period, it is to be seen that, with easily vaporized fuel (B), the pressure fall, consequent upon the withdrawal of heat, is sharper and deeper than with heavy oil (A, Fig. 1).

This fact is of practical importance in that, with a deliberate increase of the boiling limit, difficulties may arise, and experience shows that these difficulties occur first with a cold engine. Heavy oil may often give satisfactory running under load, but difficulties can occur on light load or when starting. This is undoubtedly due to the high air temperature when the engine is on load, but may also be attributed to the fact that, when starting, the penetration of the fuel is excessive.

The viscosity increases in general with a rise in the boiling limit. This is of great practical importance in connection with the settling and purification of the fuel and the resistance of the suction piping. In these respects, however, a simple and satisfactory solution may be reached, although the viscosity figure may be many times that of the ordinary Diesel

*Translation of excerpts of paper read before the Verein Deutscher Ingenieure at Augsburg.

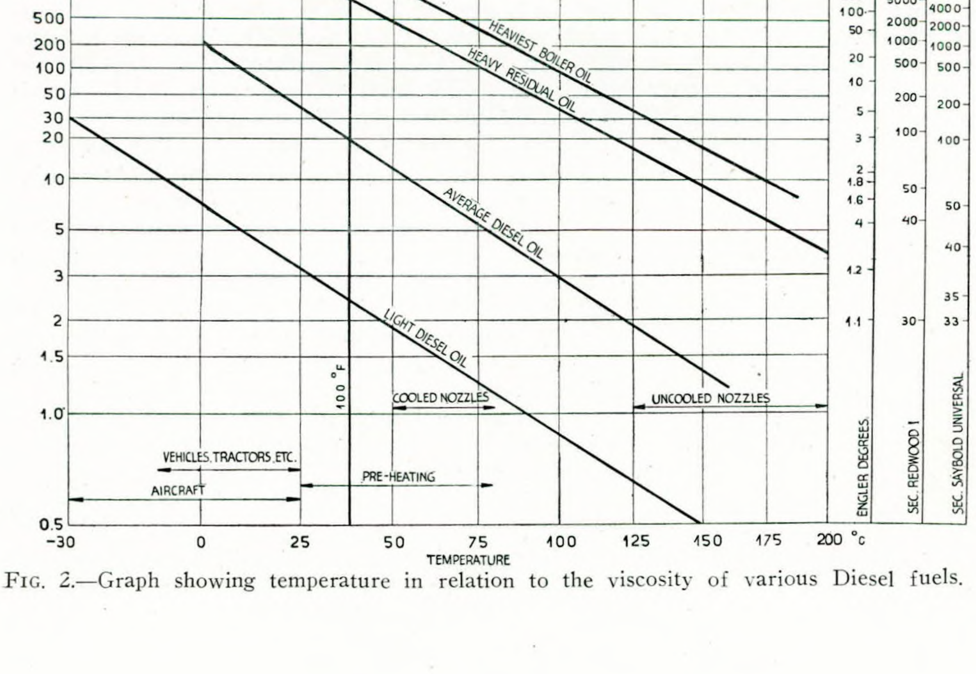


Fig. 2.—Graph showing temperature in relation to the viscosity of various Diesel fuels.

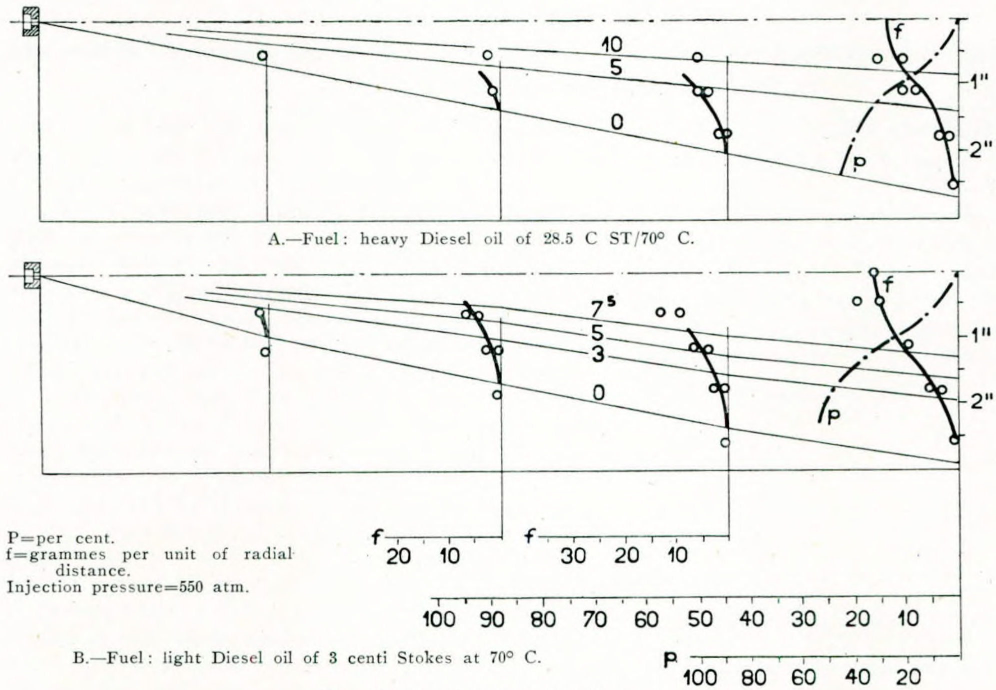


FIG. 3.—Spatial fuel distribution.

fuel. Fig. 2 shows the viscosity temperature flow for various fuels of high boiling point in relation to the viscosity of a gas oil. It is clear how far, with preheating, satisfactory results can be achieved. If the injection pressure is high enough, so that turbulence is satisfactory and external friction is overcome, the viscosity plays little role in performance.

Fig. 3 shows the space distribution of two fuels of widely varying viscosities, the injection pressure being 550 atmospheres. Such differences may be minimized by the choice of satisfactory sizes for the nozzles and the number of holes in the nozzles. More important effects of small (two to five times) increases in viscosity on the engine performance have shown themselves in quite other directions, and, in particular, in the operation of the fuel pumps, and troubles with valves and pumps,

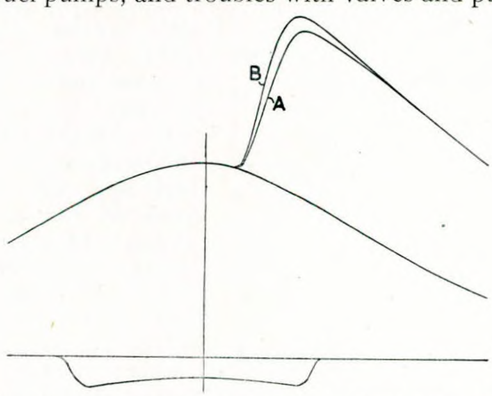


FIG. 4.—Slower combustion in spite of higher volatility of fuel A.

rather than in pulverization.

It is possible, although only under favourable conditions, to attain satisfactory combustion with a fuel which has a viscosity a thousand times greater than that of lighter fuel. Even with commonly used fuels, the viscosity figure under running conditions varies between quite wide limits (from 0·5 to 50 centi-Stokes, figures often met with in practice), without any permanent influence. These facts lead to the conclusion that with suitable control of the running conditions (as preheating of the fuel and higher injection pressure), there are no essential difficulties in the employment of heavier fuels so far as viscosity is concerned. So far as sensitiveness to modification in spray form is concerned, the classical construction with a central nozzle would appear to be less insensitive than that with a valve at the circumference of the combustion chamber.

Of far greater importance than viscosity, according to the experiments which have been carried out in our laboratory, is the volatility of the fuel, although, at the same time, it must, unfortunately, be stated that a definite measure for the volatility can be determined only with difficulty, in particular with high boiling point fuels which cannot be distilled without decomposition.

Fig. 4 gives curves obtained under the same conditions with two fuels of varying boiling point and with similar ignition characteristics. It is to be noted that, contrary to all expectation, the more volatile of the two gives the slowest combustion. This is, however, most notable at full load. At light load the more volatile fuel shows to advantage.

There are two methods of approach for the employment of high-boiling-point fuel for use in oil engines :—

1. The usual method. The undistilled residues, mixed with distillates according to their properties, are used as fuels.

2. Distillation is carried farther than has hitherto been common.

When the first method is adopted the fuel contains a certain percentage of all, up to the heaviest

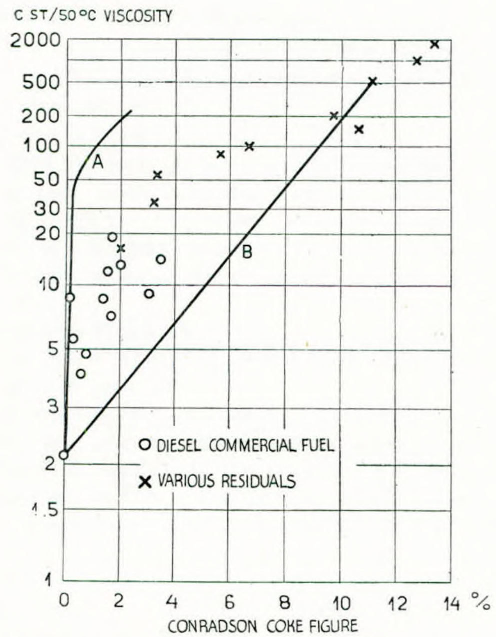


FIG. 5.—Relation between kinematic viscosity and the Conradson coke figure.*

and high-molecular fractions—in greater or smaller proportions respectively, according to the derivation of the crude and the percentage of the mixture of the residues. The properties of the residues from the various crudes differ considerably, so that in order to make comparable mixtures from the individual grades varying proportions must be used. Many of our experiments have, therefore, been carried out with a view to determining a standard by means of which comparisons might be made between these products.

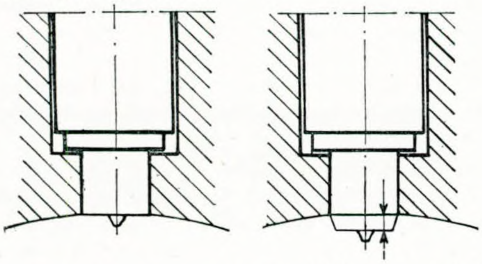


FIG. 6.—Illustrating the manner in which an uncooled (left) and cooled (right) nozzle should be fitted.

We believe we have found this standard in the Conradson figure, at any rate so far as present-day means allow. The Conradson figure of various residues (assuming, as usual, that the distillation is carried to between 350° C. to 400° C.) lies between a few per cent. and 15 per cent., whilst the distilled portions show a negligible coke content. Quite independent, but equally notable, variations exist in the viscosity value. Fig. 5 illustrates the position of a number of particular products, each one defined by a point in the graph. Our experience is that, with a comparatively low coke figure (about 0·5 per cent.), oil engines must have cooled nozzles, since otherwise the disposition to coking makes itself felt. When the nozzle surface is small, combustion must be delayed in order that coke formation should be prevented. This disposition to coke formation on the nozzle can be noted very conveniently on a sensitive exhaust thermometer, which indicates the growth of the coke trumpet and the more or less regular manner in which it falls off. This coke formation has a distinct influence on fuel consumption. Our work has comprised experiments on nozzle cooling, and among the most interesting experiments were investigations on the possibility of a fuel-cooled nozzle of small circumference. It was shown how important it was that the front surface of the nozzle should be polished. There should be no gaps or ridges on the frontal

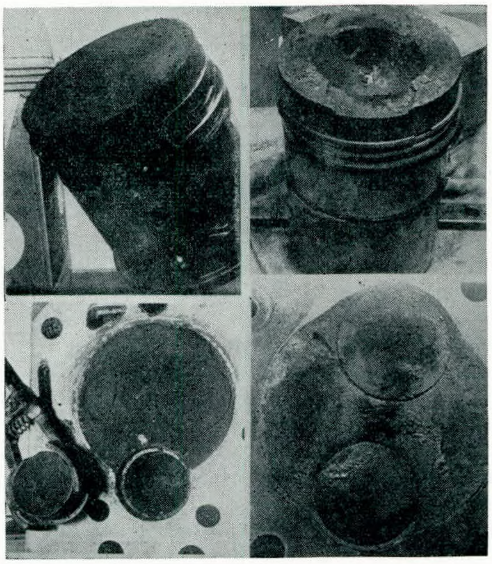


FIG. 7.—Illustrating the effect of running a high-speed engine on fuels with 3·5 (left) and 1·2 (right) Conradson figure.

surface, and the nozzle should project a few millimetres through the wall (Fig. 6) contrary to the arrangement of an uncooled nozzle.

If the nozzle can successfully be maintained clean, then, at any rate, a steady combustion may be attained and the fight can be waged against the wetting of the combustion-chamber wall by fuel drops. For this, the highest possible wall temperatures, in particular at partial load, and cooling with distilled water are desirable. In this respect big engines start with an initial advantage, as they have thick cylinder walls, and it is an advantage which is increased by the employment of low revolution speed. Actually, with a well-designed air swirl, if the temperatures are sufficiently high it is possible, even with small engines, to burn any liquid fuel that may be deposited on the walls.

*Kinematic viscosity is the absolute viscosity divided by the specific gravity.

In general, the temperatures in the combustion space, if the engine is on fair load, are so high that, although after-burning is indicated both on the pressure diagram and by the fuel consumption, no coke formation, apart from locally, results, even when fuels are used with Conradson figures of 10 or more per cent. At lower loads the tendency towards after-burning increases.

Fig. 7 shows how far it is possible to go in this direction "in the laboratory". The left portion of the illustration shows the cylinder cover and pistons of a high-speed swirl-chamber motor of only 1·6 litre stroke volume, after 16 hours' running at 1 atmosphere (14lb./sq. in.) brake mean pressure, the most difficult condition with a fuel having a coke figure of 3·5 per cent. On the right the cover and piston of an engine of equal size with direct injection are shown, working in the same conditions but with only 1·2 per cent. coke residue (Conradson), which reduction was attained by a different mixture of the same fuel constituents. The influence of the much lower temperatures in the last-named engine is clearly indicated.

We stated in the previous paragraph "in the laboratory", since in practice the difficulties with such fuels for small engines are too great. The wear on the cylinder liner is also too high.

(2) An extension of the output of Diesel fuel is possible in the second manner mentioned, namely, through a further development of the limits of distillation. Production costs, however, are thereby increased, since only vacuum distillation comes into question. A second difficulty is that, by an increase of the boiling limit, a substantial rise in viscosity follows. This certainly does not introduce technical difficulties, but has the disadvantage that in the normal fuel specification the upper-viscosity limits, based on the commonly used products, are too low to enable an economical employment to be possible.

In Fig. 5 it may be seen that an increase in the distillation limits gives a line which, with a low coke figure, shows a higher viscosity in contrast to the line which is given with a mixture of gas oil and heavy-residue oil.

In general, the difficulties in the employment of heavy distillates from the technical standpoint can be more readily overcome than by a mixture, as discussed in (1), with equal viscosity.

The experiments with high-boiling-point fuel have shown that, by suitable construction of the engine, even the heaviest residue, which has hitherto been used for boiler heating, may be employed. In order to keep the wear within normal limits, the use of some resistant material is necessary.

It has been shown that, even without constructional alterations, the viscosity of fuel need not be maintained at so low a figure as is now common. An increase in present limits would render possible a greater production of distillate.

Modern Methods and Modern Steels in Welded Ship Construction.*

By Dr. P. Schoenmaker and Ir. G. de Rooy.

"Shipbuilding and Shipping Record", 24th November, 1938.

When we compare the application of the welding process in submarine construction in 1933 with that of to-day, it becomes very clear that in this period important developments in welding of high tensile steels have taken place and this is demonstrated in greater diving depth to more than 100 m. and in heavier armaments.

In many submarines the double hull-system at the ends of the boat passes to single hull-construction, as otherwise the two hulls would come too close to each other. At the ends, therefore, we get a pressure-body, of which the section is no longer cylindrical, but more closely resembles the ordinary ship shape. The consequences are that the fore and aft frames are heavily stressed on bending and therefore must be strongly constructed.

In the double bottom and in the horizontal keelplate the butt joints are entirely welded. These seams have been welded partly in the workshop and partly on board. All oil and watertight floor-timbers (see illustration p. 105E), in the double bottom are also entirely electrically welded; this welding is all done in the workshop. In the left-hand illustration page 103E, a double bottom section is reproduced which shows the lower edge of the double bottom plating. These sections are transported to the slipway and attached to the horizontal keelplate (see lower illustration on p. 105E).

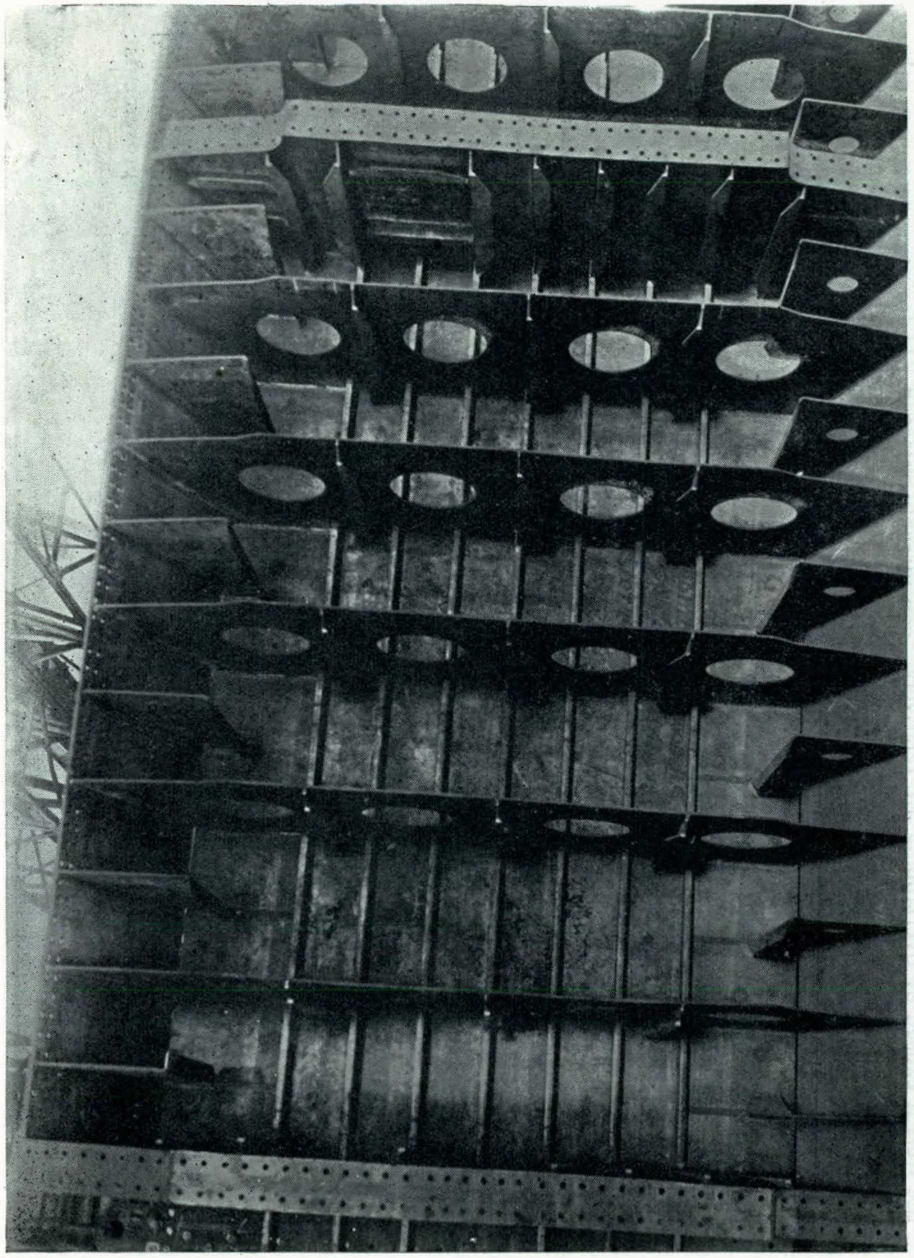
In the submarine minelayers now building the connection of the horizontal keeplate to the first sheer-strake is entirely welded.

The seams and butt joints in the compression cylinder were partly welded in the shop and partly on board. For this connection a V-joint with rewelding strip was used; the strip is only then added when the root of the V-weld is chipped away and rewelded.

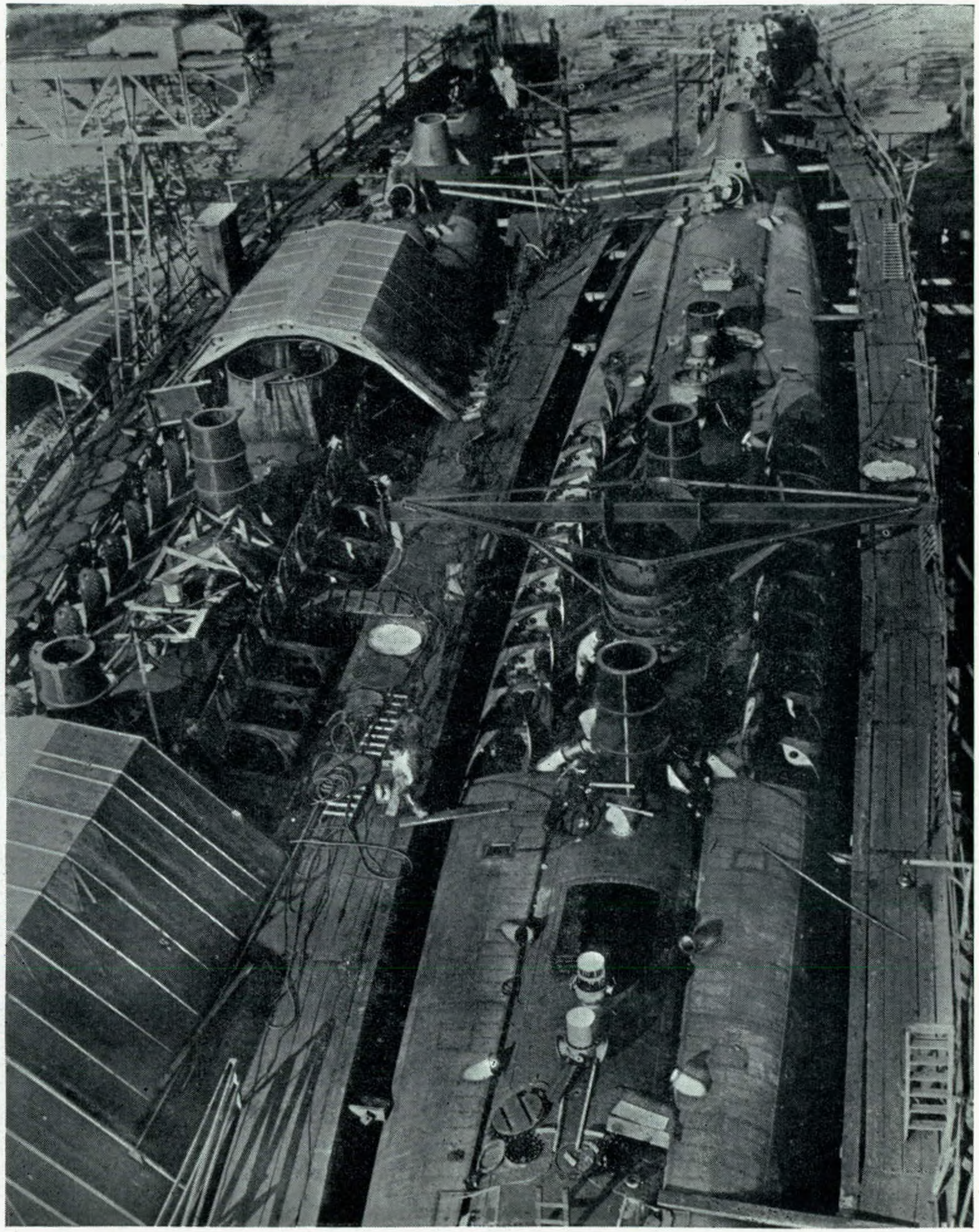
Difficult construction.

A very difficult and therefore most interesting form of welding construction, which has only been used lately, is that of the frames in the forecastle and after body of the ship. Consequent on the oval shape of the frames considerable bending moments occur. According as the required moment of resistance increases, the height of the frame becomes

*The authors of this paper, Dr. P. Schoenmaker, Chief Metallurgist and Construction Engineer, Smith-Transformer Works, Nijmegen, Holland, and Ir. G. de Rooy, chief of the Construction Department of Submarines of the Royal Dutch Navy, received the first main award, $3,765, in watercraft classification of the $200,000 programme sponsored by the James F. Lincoln Arc Welding Foundation, Cleveland, Ohio, in which savings of $1,600,000,000 were shown available to industry by wider application of arc welding. The original paper, of which this is an abstract, contains approximately 27,000 words and 178 illustrations.



Double bottom section built up in workshop and afterwards transported to slipway.



Bird's-eye view of two Netherlands submarine minelayers largely constructed by electric welding.

greater and of the inner bunt-lines heavier. Each of these frames is carefully calculated so that each section could be exactly determined.

Through welding a very considerable weight economy was obtained as it thus became possible to bring the frame section in accordance with the occurring stresses with a consequent better division of material. When welding the frames, an additional complication arises because the outer flanges do not stand perpendicular on the body plate. The flange plate must follow entirely the bevel of the hull. Because of this, it is necessary to let the body plate form an ever-changing angle of deviation of 90° on different points and frames.

Many other important parts, like engine beds, gun foundations, watertight bulkheads between inner and outer hull, the shaft-bossings and machine gun bores, the small ballast partitions on the horizontal keel-plate and the torpedo loading head, were all electrically welded. All these parts are made of high tensile steel.

The right-hand illustration on page 103E gives a bird's-eye view of the two submarine minelayers in February, 1938.

The principal advantages of welding are the elimination of angle steels and overlapping, namely, a saving in material which in the first place gives a considerable saving in weight next to a cost economy.

Weight saving.

In smaller vessels where the flange percentage and the weight caused by overlapping are relatively high, this saving in weight will be greater than for ocean steamers. For an all-welded small tanker about 130ft. long, the total saving in weight comes to about 30 per cent.; for a welded cargo boat of 250ft., to about 12·5 per cent.

Next to that it should be remembered that the indirect costs, which often form an important item, can be considerably decreased.

In order to get an idea of the advantages offered by the use of high tensile steel, a check has been made of what economies are obtained in the case of a ship where the welding process has already been extensively made use of if the various parts are made of welded high tensile steel.

For a passenger steamer of 40,000-ton displacement 1,500 tons of high-tensile steel material can be used. In connection with the higher yield point a reduction of the scantlings of 20 per cent. is fully justified, so that the replacing of mild steel by high-tensile steel gives a weight saving of 300 tons, which can still be increased to 370 tons if the welding process is used. This means an extra increase of the deadweight capacity by ± 2 per cent.; an advantage that repeats itself every trip and represents over the whole life of a ship of from 15 to 20 years a considerable amount. Even if the price of high-tensile steel is higher and the cost of welding, because of stricter examination with X-rays for instance, somewhat greater than by riveting, the use of a welded high-tensile steel construction will show a financial advantage, as the greater deadweight capacity, if perhaps not directly, certainly after one or two years, will yield favourable financial results.

Economy.

It is also possible to let the ship keep her same deadweight capacity, so that the displacement can become ± 1 per cent. smaller. This means for the service speed a saving in power of at least 300 h.p., which will show a yearly saving in fuel of £2,000.

To this must be added the savings in operation consequent on the lower harbour and piloting fees because of the smaller displacement and therefore smaller tonnage.

In warships, cruisers, destroyers, and submarines, where the question of cost plays a minor role than in the mercantile marine, it is the weight and space-saving which is the most important factor. If therefore the use of the welded high-tensile steel construction in commercial shipbuilding is still limited, in naval building this process is being applied more and more, and was extensively used in the building of the submarines in 1938.

The weight economies obtained through welding of the hull, the double bottom, the watertight bulkheads. the foundations and numerous other parts, and through the use of high-tensile steel, means for a submarine of about 1,000 tons surface displacement a weight decrease of certainly 65 tons, whereby the fuel capacity and armaments can be considerably enlarged. If for some reason or other this is not possible or required, the saving in weight can be used to increase the ballast whereby for a ship of the above-mentioned dimensions the metacentric height could be increased by no less than 4in.

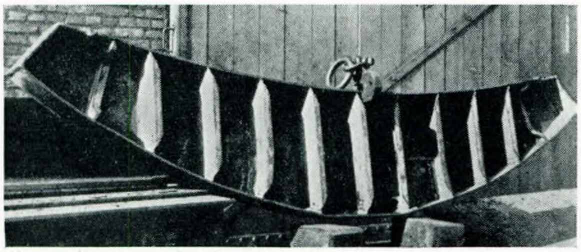
The great advantage of the use of high-tensile steel becomes still more striking, when we see that by not increasing the dimensions in regard to those of mild steel, but by keeping them equal, the diving depth for a boat of 1,000 tons surface displacement can increase by certainly not less than from 30 to 40 per cent.

ECONOMY OF WELDING AND THE USE OF HIGH-TENSILE STEEL.

Constructional part.	Welding against riveting. Saving in weight per cent.	Welding against riveting. Saving in cost per cent.	Welded high tensile steel compared with riveted mild steel. Saving in weight per cent.	Welded high tensile steel compared with riveted mild steel. Saving in cost per cent.
Shell and deckplating...	9	8	20·8	8·3
Double bottom	23·5	20·2	33·3	7·0
Flat bulkheads	18·0	12·3	34·5	9·5
Concave bulkheads ...	8·6	3·6	32·8	11·7
Engine foundation ...	15·9	12·7	32·7	2·5

When these economies are divided over divers factors, the result would be that the ship mentioned could benefit by the following improvements:

(1) 50ft. greater diving depth (15 tons); (2) 2in. greater metacentric height (20 tons); (3) more ammunition and torpedoes (5 tons); (4) heavier anti-aircraft guns (4 tons); (5) larger Diesel engines, therefore greater surface speed (8 tons); (6) a larger storage battery, therefore greater submerged speed (9 tons); (7) more fuel and lubricating oil, therefore greater operating radius (4 tons). These savings in weight can naturally be varied.

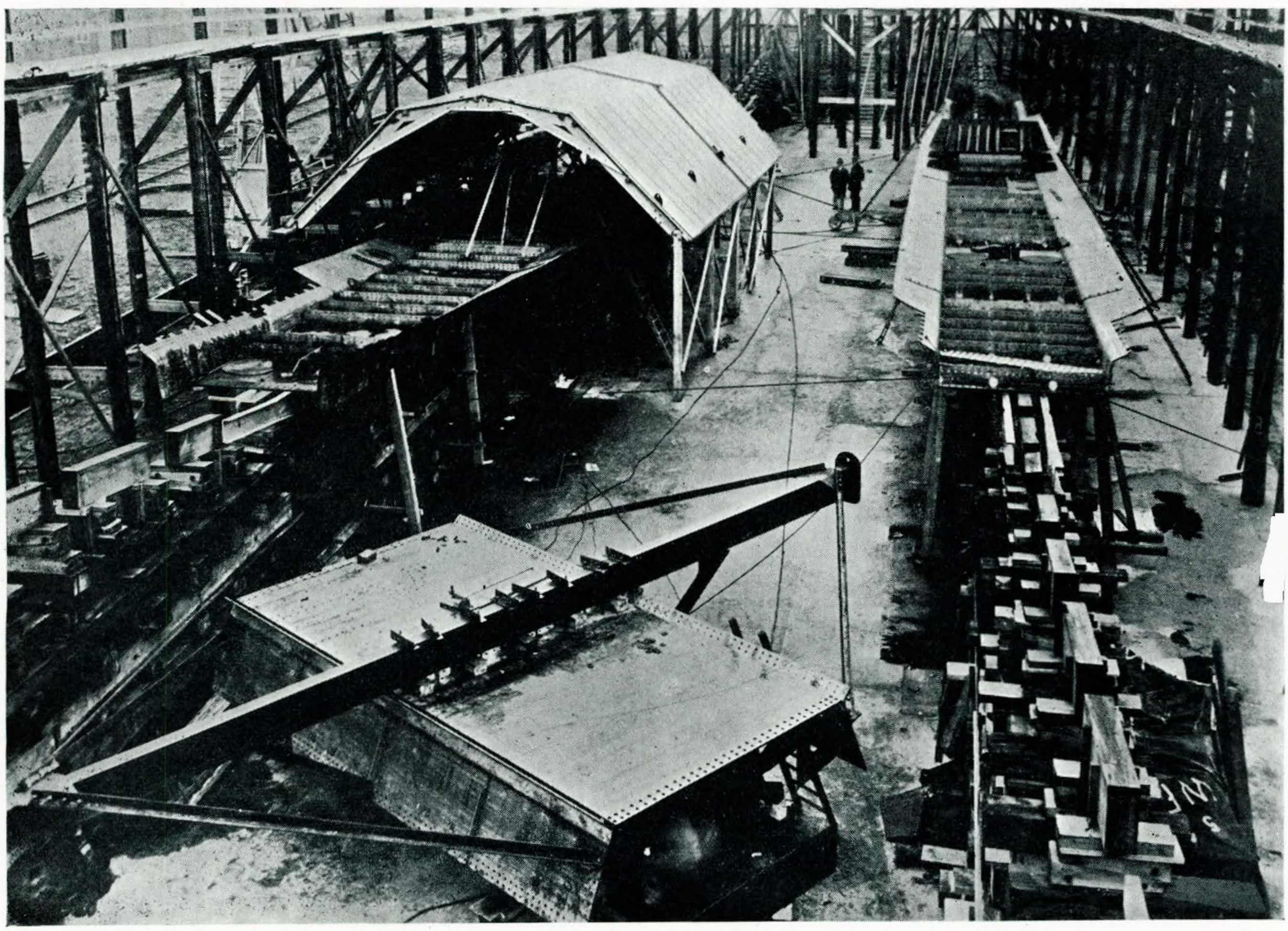


Welded watertight and oiltight floors.

Part of the savings can also be sacrificed in order to increase the safety coefficient of the compression strength of the hull, so that the official diving depth can, in case of distress, be exceeded to a greater extent than formerly, when the hull was made of riveted mild steel.

With destroyers the weight savings obtained will be largely utilised to increase the speed and radius of action. Although for these ships high-tensile steel has been used for a considerable time, the application of electric welding gives at least a saving in weight of about 3 per cent. of the displacement, or 45 tons. The armament, engine equipment or fuel capacity can, to this extent, be increased or the speed further augmented.

It is clear that welding in comparison with riveting shows a remarkable saving in weight and cost, but in comparing welded high-tensile steel with riveted mild steel, the weight economy is still more accentuated. The saving in cost, however, because of the higher price of high-tensile steel, is somewhat smaller.



Double bottom sections attached to keel plate.

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 8th December, 1938:—		
Cleall, Walter L.	1.C.	London
Hamilton, William L. ...	1.C.	"
Spearpoint, Harrie T. ...	1.C.	"
Vann, Clarence R.	1.C.S.E.	"
Wilson, George	1.C.M.E.	"
Cowie, George W.	1.C.	Glasgow
Moodie, Alfred N.	1.C.	"
Ronaasen, Harold	1.C.	"
Nicoll, David	1.C.M.	"
Ross, Angus	1.C.M.	"
Petrie, Donald S.	1.C.M.E.	"
Nicholson, Robert M. ...	1.C.M.	Hull
Blenkarn, Thomas J. ...	1.C.	Newcastle
Campbell, William B. ...	1.C.	"
Codd, Bernhard S.	1.C.	"
Symons, Leslie	1.C.	"
Turnbull, William	1.C.	"
Almond, George N. ...	1.C.M.	"
Clark, Ambrose	1.C.M.	"
Lugton, George W. ...	1.C.M.	"
McKay, Ernest	1.C.M.	"
Taylor, Thomas R.	1.C.M.	"
Kay, Edmund F.	1.C.S.M.	"
Little, Thomas R.	1.C.S.E.	"
Chandler, William J. ...	1.C.M.E.	"
Conaty, Robert H.	1.C.M.E.	"
Rooke, Stanley B.	1.C.M.E.	"
Turnbull, George	1.C.M.E.	Leith
Sykes, Herbert	1.C.M.E.	"
Faulkner, George	1.C.	Liverpool
Stevenson, Robert	1.C.	"
Keam, Robert A.	1.C.M.	"
Roberts, Cyril	1.C.M.	"
Voller, Leslie E. A. ...	1.C.M.	"
Hall, Herbert G.	1.C.S.M.	"
Maddick, George A. ...	1.C.S.M.	"
Cameron, Alexander C. ...	1.C.M.E.	"
McCormick, Archibald P. ...	1.C.M.E.	"
Rosindale, Charles	1.C.M.E.	"
Edwards, Henry S.	1.C.M.E.	Cardiff
Evans, Daniel R.	1.C.M.E.	"
Vaughan, Clifford H. G. ...	1.C.M.E.	"
Cochrane, John P.	1.C.	Belfast
Bellingham, James	1.C.	London
Campbell, John A. D. ...	1.C.	"
For week ended 15th December, 1938:—		
Farrell, Joseph A.	2.C.	Glasgow
Sawers, John	2.C.	Glasgow
Sharp, John	2.C.	"
Adam, Martin	2.C.M.	"
Baldie, Edward H.... ...	2.C.M.	"
Baldwin, Arthur E.	2.C.	Liverpool
Butchart, Charles S. ...	2.C.	"
Haworth, Herbert L. ...	2.C.	"
Jones, Harry G.	2.C.	"
Millington, George	2.C.	"
Walker, Edwin	2.C.	"
Bowyer, William H. ...	2.C.M.	"
Cook, George	2.C.M.	"
Bentley, John C.	2.C.	London
Smith, Frank C.	2.C.	"
Wilkinson, John H.	2.C.	"
Callaghan, Edward	2.C.	Newcastle
Landells, Kenneth E. ...	2.C.	"
Robson, John H.	2.C.	"
Taws, Hilton	2.C.	"
Wilson, Colin P.	2.C.	"
Craggs, George W.	2.C.M.	"
Hildreth, William H. ...	2.C.	"
For week ended 22nd December, 1938:—		
Anderson, William F. ...	1.C.	Newcastle
Chambers, Robert	1.C.	"
Chell, Charles E.	1.C.	"
Tapken, Bryan B. H. ...	1.C.M.	"
Foley, William R.	1.C.S.E.	"
Hancock, Alfred	1.C.M.E.	"
Turnbull, John H.	1.C.M.E.	"
Wright, Peter A.	1.C.	London
Bremner, Robert C. ...	1.C.M.E.	"
Doye, Nicolas	1.C.M.E.	"
Charlton, William	1.C.	Glasgow
Logan, Alexander McL. ...	1.C.	"
McAuslan, James C. A. ...	1.C.	"
McDiarmid, Allan	1.C.	"
Meiklejohn, James	1.C.	"
Milne, John	1.C.	"
Murchie, Alexander ...	1.C.	"
Caldwell, Hendry McN. ...	1.C.M.	"
Skinner, Richard W. ...	1.C.S.E.	"
Barclay, John	1.C.M.E.	"
Chapman, Colin P.	1.C.M.E.	"
Dick, John	1.C.M.E.	"
Hood, David L. S.	1.C.M.E.	"
Hislop, Robert McK. ...	1.C.	Liverpool
Seubert, Reginald W. ...	1.C.	"
Shaw, David	1.C.M.	"
Shearman, William	1.C.M.	"
Cassels, John L. G.	1.C.M.E.	"
Turner, Norman	1.C.M.E.	"
Walker, Alexander	1.C.M.E.	"