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Copper and Copper Alloys—Their Properties and Applications

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In presenting this paper a word of explanation may not be out of place. It was first suggested that the subject should be on "Non-Ferrous Metals and Their Application to Ships", but it soon became evident that such a wide subject was out of the question and could not usefully be condensed into a paper of a few thousand words. Further, certain aspects of the subject have previously been fully dealt with in papers read before your own and other institutions [1, 2, 3, 4] and in the technical press [5, 6] and in order to avoid undue repetition the author has ventured to bring to your notice some of the general characteristics of one main group of non-ferrous metals—the copper group—and to show how their properties can be more or less varied and controlled by alloying and fabrication processes, and further to indicate some applications for which their special properties render them of interest to engineers.

When considering applications, an attempt has been made to give these a bias towards marine engineering, but the wide overlapping of marine and more general engineering interests prevents any sharp demarcation in this respect. It is hoped that this limitation of subject, and manner of treatment will not detract from any interest the paper may have.

Properties of Non-Ferrous Metals.

When deciding on a material for some specific use, it is only common-sense to choose the cheapest that will adequately meet the demands of service. As compared with iron and steel non-ferrous metals are expensive, and it can therefore only be on account of their special properties that their use can be warranted.

Owing to the wide differences in properties between different non-ferrous metals and alloys, further generalization in comparison with iron and steel is impossible, and all that can be usefully said is that where high strength alone is involved, to the exclusion of all other properties, then the non-ferrous metals have to give place to steel.

The properties to be found amongst the non-ferrous metals which render their use more or less imperative for certain applications are those of good thermal and electrical conductivity, resistance to corrosion and wear, low density, ease of working, colour or appearance, thus making them superior to the ferrous metals where heat exchange, electrical, corrosion, bearing, weight saving, fabricating and decorative problems require to be solved.

Pure Non-ferrous Metals.

The major non-ferrous metals such as copper, zinc, nickel, aluminium, lead and tin are available commercially in a high degree of purity, in which condition they are soft, ductile, and of relatively poor strength, but important uses are made of the special properties that some of these pure metals possess. Examples are to be found in the use of copper for electrical purposes, of lead for chemical plant and of aluminium for resistance to atmospheric corrosion, but in each case the presence of quite small quantities [7, 8, 9] of impurities may seriously and adversely affect those intrinsic properties which it is desired to develop to the fullest extent.

The Effects of Alloying on Properties

The many uses for which non-ferrous metals can be profitably applied are due to the remarkable range of properties which can be obtained from them by the process of alloying, the characteristics of the pure metals being completely changed or modified when one or more other metals, and sometimes non-metals, are alloyed with them.

It will be evident that a relatively small number of elementary elements can give rise to innumerable alloys, and for the purpose of illustrating some of the effects of alloying on properties only a few examples can be taken.

Copper is a common major constituent of many non-ferrous alloys and its properties when pure are well known. The effect of small quantities of impurities on the lowering of its electrical conductivity, as shown in Fig. 1, serves to show what an important part composition can play in relation to properties.

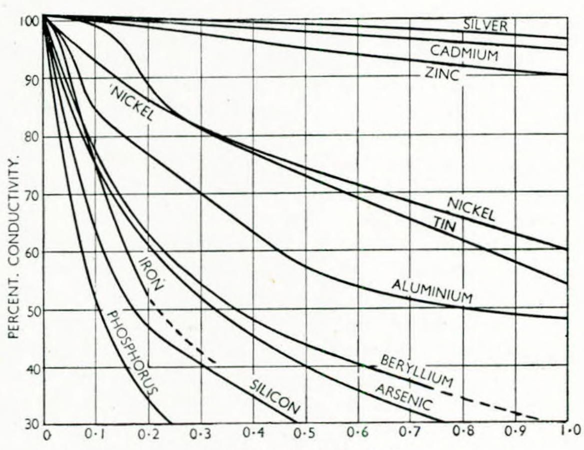


FIG. 1.—Effect of added elements on the electrical conductivity of copper. (C.D.A.).

Pure copper is inherently weak, malleable, and ductile, but it will be evident that any attempt to increase its strength by alloying with some other metal must lead to considerable lowering of its electrical conductivity. Increase in strength by alloying can only therefore be obtained by sacrificing conductivity, and as will be seen from Fig. 2,

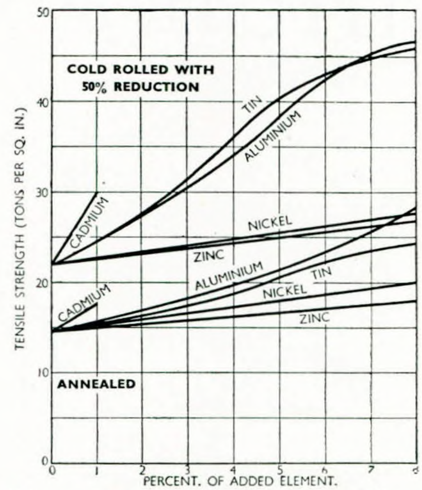


FIG. 2.—Effect of added metals on the tensile strength of copper. (C.D.A.).

alloying additions (with the exception of cadmium) which are most useful for increasing strength have a most deleterious effect on conductivity.

The problem of developing alloys for any special application can therefore only be satisfactorily approached by first making a detailed study of the conditions called for in service, and then deciding on a composition which will give the most happy compromise between those properties most desired.

Cadmium.

In the case of copper, high strength is not associated with high electrical conductivity, but by alloying with about 1 per cent. of cadmium, the tensile strength may be considerably increased with a relatively small loss in conductivity, and such an alloy[10] finds useful application therefore for overhead trolley wire where strength combined with reasonably good conductivity are demanded.

Chromium.

Whilst considering this combination of properties, mention might be made of more recently developed copper alloys in which chromium plays a similar role to cadmium, considerable increase in strength and hardness being developed without too great a loss in conductivity. The effect of additions of less than one per cent. of chromium to copper is different in several respects from that of cadmium, for it restricts crystal growth on heating[11] which leads to better maintenance of strength at high temperatures. Such alloys have become of special value therefore for resistance welding electrodes where maintenance of form at the high temperatures involved is important.

If improvement in strength were the only consideration, alloying additions of zinc, tin, nickel or aluminium, either alone or in combination, might all be used, but since these different metals influence properties other than that of strength, it is necessary to discriminate between them, and having some special application in mind, to choose one or more which will produce the most beneficial compromise between the several desirable properties.

Zinc.

Zinc additions of from 3 to 40 per cent. to copper give the well known brasses[12], the general effect of increasing zinc content being to increase strength and hardness, whilst the ductility is well maintained throughout the series of alloys. It will be seen from Fig. 3, that the best combination of strength and ductility is to be found in those alloys containing about 30 per cent. of zinc.

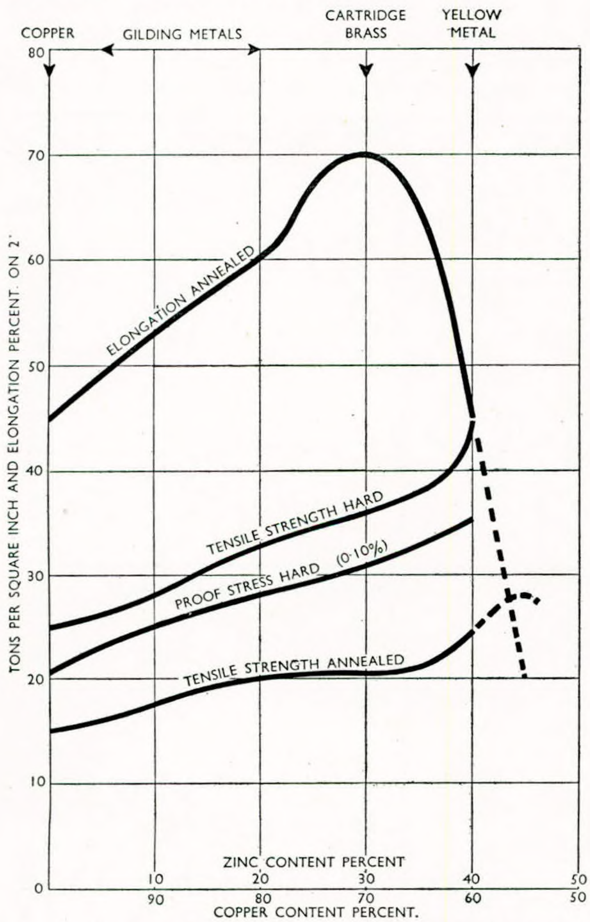


FIG. 3.—Comparative mechanical properties of wrought copper zinc alloys. (C.D.A.).

If it is desired to develop some special properties, such as ease of machinability, resistance to corrosion, or to oxidation at elevated temperatures, then small additions of from 1 to 3 per cent. of lead, of tin and of aluminium, may respectively be made. The strength of the zinc-rich alloys can be raised to from 40 to 50 tons by similar small additions of manganese, iron, and aluminium, giving what are known as the high tensile brasses[13].

Nickel.

The alloying of copper with nickel leads to a range of alloys which have several outstanding properties. The alloys with from 20-30 per cent. of nickel[14] are characterized by good strength and ductility, coupled with a high resistance to sea-water corrosion[1]. Their strength is also well maintained at high temperatures, but this important property is not fully developed until the nickel content rises to the region of 60-70 per cent.[15], as in Monel metal.

Nickel and Zinc.

Additions of nickel and zinc produce a range of alloys—the nickel silvers, the copper content being between 60 and 65 per cent. and that of nickel ranging from 10 to 30 per cent. Their mechanical properties[52] have much in common with those of the brasses, but they are white in colour, the whiteness increasing with nickel content. The presence of nickel improves their corrosion resistance as compared with that of the brasses.

Tin.

Tin hardens and strengthens copper, giving the tin bronzes which as a class are perhaps best known for their anti-frictional and bearing properties[16], but their good elastic properties in the wrought condition, together with a high resistance to corrosion, makes them of value for many applications. These alloys are commonly considered as falling into two groups, one including the malleable bronzes containing not more than 10 per cent. of tin, and the other the casting bronzes with higher tin, but recent investigations[39] show that if the casting and subsequent working conditions are carefully controlled, then most of these higher tin bronzes can also be fabricated in the wrought condition.

Gunmetal can be considered as coming within this class, containing as it does 10 per cent. of tin with 2 per cent. of zinc.

Lead.

A frequently sought property in metals and alloys is ease of machinability, and this can frequently be facilitated by making suitable alloying additions. Small additions of lead generally from 1-3 per cent. are often made to copper and copper alloys for this purpose. Higher percentages of lead, up to 30 per cent. may be added to copper or copper-tin alloys to form bearing alloys.

Silicon.

The addition of from 1-3 per cent. of silicon to copper results in alloys[22] of remarkable strength, associated with ductility and good welding properties. In the soft annealed condition, the tensile strength is about 25 tons with an elongation of up to 80 per cent., whilst by work hardening by drawing or rolling, the strength may be raised to from 50-60 tons.

Aluminium.

The aluminium bronzes[18] are in some respects not dissimilar to the tin bronzes, for they possess inherent high strength and good corrosion resistance, but they resist oxidation[19] and retain their strength at high temperatures much better than the tin bronzes. The useful additions of aluminium range from about 5-10 per cent.—the higher percentage giving the stronger but somewhat less ductile alloy. Small additions up to 5 per cent. of nickel[53] and/or of iron are frequently made for improving the strength of aluminium bronze castings.

Improvement in Mechanical Properties by Heat Treatment.

Until a relatively few years ago improvement in the mechanical properties of alloys resulting from suitable heat treatment was only known in the case of a few non-ferrous alloys. More recently a number of heat-treatable copper alloys have been developed, being based on additions of aluminium, or of beryllium, or of chromium, or of nickel together with aluminium[45], or with silicon[46], or with tin. Such alloys are characterized by containing constituents which are soluble in copper at high temperatures and which remain in solution if the alloys are rapidly cooled as by quenching, but which come out of solution or are precipitated after the quenched alloy is reheated to some lower, intermediate temperature. They are known as heat-treatable or temper-hardening alloys, and the process of hardening and strengthening by heat treatment of the soft quenched alloys is known as temper-hardening.

Aluminium.

The aluminium bronzes containing about 10 per cent. of aluminium are of special interest in this respect, since by heating to 800-900° C. and quenching in water an increase in tensile strength of nearly 50 per cent., with but little change in hardness and elongation, is obtained. If the quenched alloy be then tempered by reheating to 650° C. the tensile strength and hardness are but slightly reduced, whilst the elongation and limit of proportionality are appreciably raised.

Beryllium.

The addition of a small percentage of beryllium to copper gives an alloy having remarkable hardness, strength and elastic properties. With 2·5 per cent. of beryllium the alloy, as quenched from a high temperature, has a tensile strength of just over 30 tons, which by temper-hardening may be more than doubled to about 70 tons. If rolled or otherwise cold worked before heat treatment, still greater strength can be obtained, and the alloy having a high degree of elasticity is suitable for such articles as springs.

Beryllium is an expensive metal, and for economic reasons the use of beryllium copper is therefore limited to special applications where the quantities required are small.

Nickel and Aluminium.

Similar but much cheaper heat-treatable copper alloys[45] are now available which contain additions of nickel and another element such as aluminium[20, 21], or silicon[46].

Copper containing 6 per cent. of nickel and 1·5

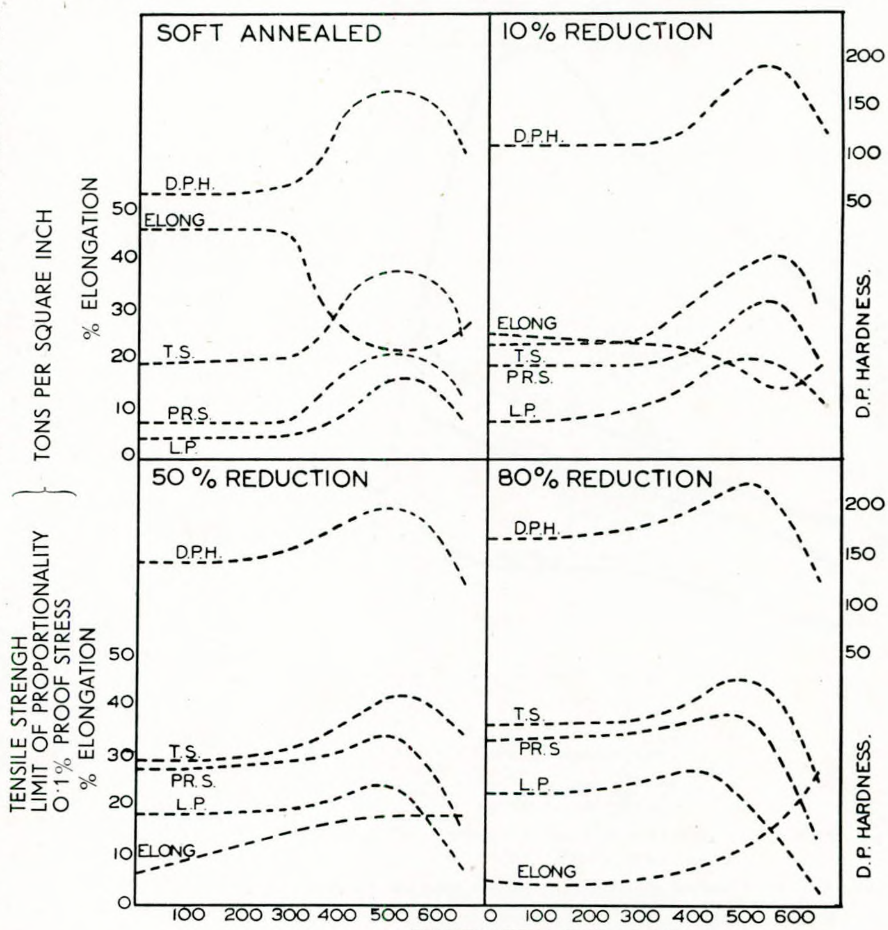


FIG. 4.—Effect of re-heating at different temperatures on the mechanical properties and hardness of Kunial copper strip in the soft annealed condition and after cold working by rolling. (I.C.I. Metals, Ltd.).

per cent. of aluminium, known commercially as Kunial copper, has in the soft condition as quenched from 900° C. a tensile strength of about 20 tons, an elongation of 46 per cent., a diamond pyramid hardness of 70, and a limit of proportionality of 4·0 tons per sq. in. By simply heating to 550° C. for two hours the tensile strength is increased to 38·2 tons, the elongation drops to 24 per cent., the hardness increases to 174 and the limit of proportionality is raised to 17·0 tons per sq. in. A very remarkable change. These properties can be still further modified if, after quenching, the alloy is strengthened by cold work, and strip, given a 50 per cent. reduction by cold rolling and subsequently heat treated at 550° C. for two hours, has a tensile strength of 42·6 tons with 19 per cent. elongation, a hardness of 198 and a limit of proportionality of 22 tons per sq. in. These changes in properties are graphed in Fig. 4.

Similar results are obtainable by the heat treatment of brasses containing nickel and aluminium[21], and of cupro-nickels containing small amounts of aluminium[45].

Copper alloys containing small amounts of nickel with silicon[46], and of chromium respond to heat treatment, but their effect is less marked than that of beryllium or of nickel-aluminium additions.

Effect of Hot Working on Mechanical Properties.

An important property of most commercially used non-ferrous metals and alloys is their malleability which facilitates their fabrication into both simple and complicated forms.

The starting-off point is invariably a casting, and whilst in some applications the casting may be used as such, in many others where a wrought product is desired, the casting must undergo a number of deforming processes in order to arrive at the final form[23].

The mechanical properties of a casting are invariably inferior to those of the wrought product, and reasons are not difficult to seek if all the variable conditions that can arise during the melting and solidification of a metal or alloy are taken into consideration. Gas absorption during melting and evolution on cooling, segregation and shrinkage all tend to produce unsoundness and heterogeneity.

The improved properties of the wrought product are due to a homogenizing of the structure and composition which results during the breaking down or deformation of the casting, and as these changes take place more readily at high than at normal temperatures, this breaking down is wherever possible done by a hot working process.

The form and mass of the casting are naturally chosen with regard to those required in the finished product, cylindrical billets being chosen for forging or rolling to rod and for extrusion, and rectangular ingots for rolling to strip or sheet.

The remarkable change in the properties of an alloy which can result from a single deformation process such as the extrusion of a round rod from a cast billet is well illustrated in the case of gunmetal, the well known alloy containing 88 per cent. copper, 10 per cent. tin and 2 per cent. of zinc. In the cast state, average mechanical properties are 17 tons tensile and an elongation on 2in. of 20 per cent. After extrusion of a $3\frac{1}{2}$in. diameter billet to $\frac{3}{4}$in. diameter rod, the tensile strength is increased to 31 tons and the elongation to 74 per cent. By cold drawing the rod to wire a tensile strength of 72 tons is obtained with a drop of elongation to 1·5 per cent.

The extent to which the mechanical properties of non-ferrous metals or alloys are influenced by hot working depends on their basic characteristics such as composition, structure or heterogeneity, but in most cases it is quite considerable. Hot working is generally carried out above the annealing temperature, so that any resulting change in properties is mainly due to structural rearrangement such as crystal reorientation and improved compositional and constitutional homogeneity. The metal being soft and plastic and the deformation considerable, these changes penetrate and affect the whole mass being worked.

Hot working is valuable, therefore, not only for facilitating change of form; it also improves malleability and leaves the metal in a most suitable condition for subsequent cold deforming operations.

Effect of Cold Working on Mechanical Properties.

The general effect of cold working[23] is to harden and strengthen all metals and alloys, but whilst the effect may be small with some, it may be considerable with others. With a soft ductile metal such as copper, the effect though appreciable is small, whereas with alloys such as brass and the tin, aluminium or silicon bronzes, it is considerable, and as a result the tensile strength may be more than doubled; always, however, at the expense of elongation. Changes in mechanical properties due to cold rolling a 5 per cent. aluminium bronze are plotted in Fig. 5.

One result of strengthening by cold working, not always appreciated but none the less of special interest to engineers, is that the effect may not uniformly penetrate throughout the mass of metal[24]. In cold drawing a rod for example, the effect is more marked towards the exterior than in the interior, so that the strength of the rod as a whole is a mean of decreasing strengths from the exterior to the interior. If the rod be machined to a smaller diameter for the purpose of tensile testing, the stronger outside portion will be removed and the test made on the weaker interior. Hardness tests made on the outside of the rod may also be quite misleading as to its hardness and strength as a whole. A rod of much more uniform properties throughout its section will result if, instead of relying on cold working for increasing strength, this is obtained by temper hardening a heat-treatable alloy.

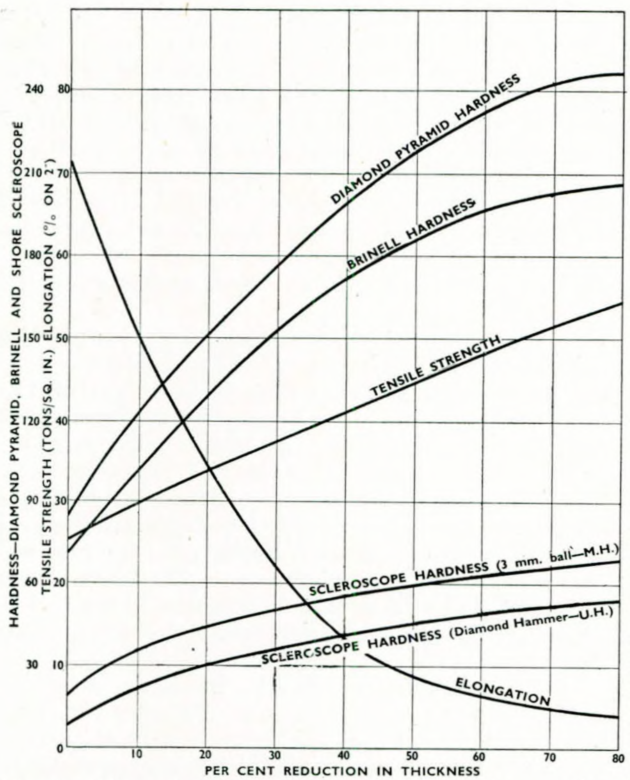


FIG. 5.—Effect of cold rolling on the mechanical properties and hardness of a 5 per cent. aluminium bronze (I.C.I. Metals Ltd.).

The uniformity in hardness throughout a heat-treated Kunial brass rod as compared with that of a cold drawn ordinary brass rod is diagramatically illustrated in Fig. 6.

Such an alloy is of special value for obtaining hard and strong complicated machined products, for the machining can be done in the soft quenched state and the product then simply raised to a suitable temperature for hardening and strengthening.

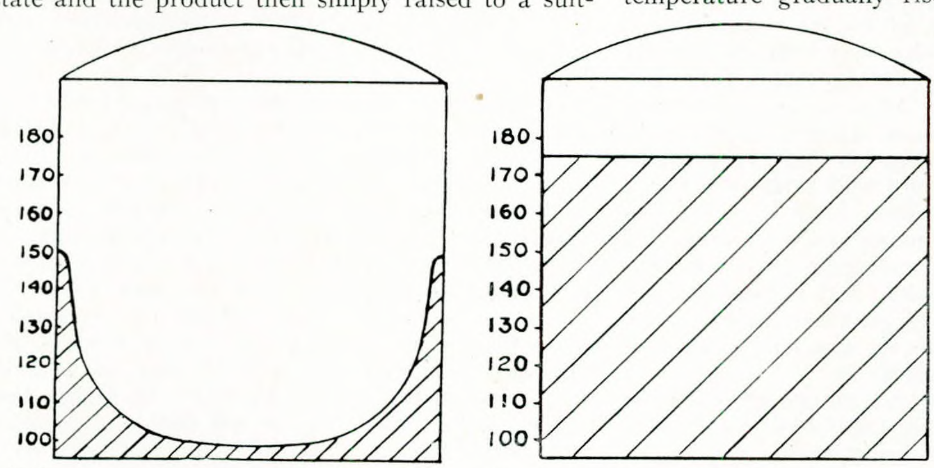
Season Cracking.

The localised effect of cold working leads to an uneven distribution of internal stresses in the metal and such tensional stresses, if over developed, may lead to fracture during working, or if not to immediate fracture, then to the possibility of this occurring later in the form of season cracks[25]. As a safety-first precaution, any heavily cold worked wrought product should therefore have such internal stresses relieved by a low temperature heat-treatment below the annealing temperature before being put into service.

Effect of Annealing on Mechanical Properties and Grain Growth.

The hardening effect of cold working has frequently to be removed so as to bring the metal into a suitably soft state for further cold deformation, or to leave the final product in the soft condition. This softening or annealing results when the hard cold worked metal or alloy is raised to a suitable temperature, this being different for different metals and alloys. Copper when hardened by cold working is softened by heating to a temperature of about 300° C., but in practice higher temperatures are generally used so as to hasten the process. The annealing temperature is invariably raised by the presence of impurities or added alloying additions, and suitable temperatures for most copper alloys lie within the range 500-700° C. Typical changes in properties due to annealing are shown in Fig. 7, which refers to a 7 per cent. aluminium bronze.

Metals are composed of crystal aggregates; the effect of cold working is to break up the crystal structure, and that of annealing is to bring about first a fine incipient recrystallisation, which as the temperature gradually rises, grows to larger and more clearly defined crystals. A soft condition suitable for cold working corresponds to an average crystal size of from 0·03 to 0·06mm., and the temperature and time of annealing are therefore generally adjusted so as to restrict grain growth within these limits. The crystal size obtained by annealing at any one temperature is very dependent on the purity of the metal or alloy, and also on the degree of cold de-



Cold drawn ordinary brass rod, 2in. dia. Hardness across longitudinal section.

Temper hardened Kunial brass rod, 2in. dia. Hardness across longitudinal section.

FIG. 6.—Comparison of hardnesses across sections of a cold drawn ordinary brass rod and of a temper-hardened Kunial brass rod. (I.C.I. Metals, Ltd.).

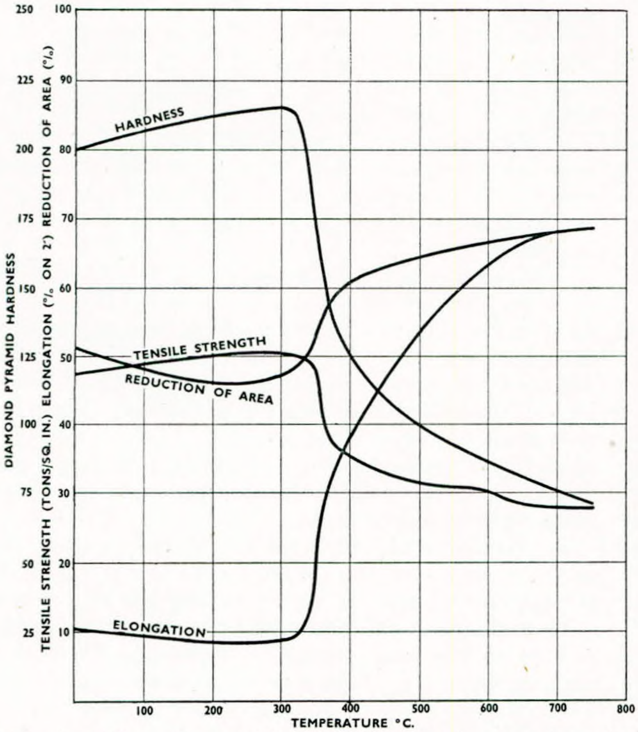


FIG. 7.—Effect of annealing on mechanical properties of a cold worked 7 per cent. aluminium bronze. (C.D.A.).

formation preceding the annealing. The purer the metal or alloy, the larger the grain size will be for comparable annealing conditions. As regards copper, the effect of small additions of chromium on restricting grain growth has already been referred to. Hard rolled pure copper having a D.P. hardness of about 110 is reduced to a hardness of about 40 if annealed at 500° C., and will have a grain size of about 0·03mm. If only 0·03 per cent. of chromium be added to copper[11], grain growth is hardly evident until a temperature of about 800° C. is reached when the grain size is less than 0·02mm., whilst that of pure copper increases to about 0·05mm. The relationships between the temperature of annealing, the chromium content and the grain size of copper are shown in Fig. 8.

Whilst the effect of chromium is very marked, that of other more common impurities such as iron, is quite appreciable, and such effects are not limited to pure copper but extend to copper alloys generally.

Grain growth on annealing is also dependent on the degree of cold working that the metal or alloy receives prior to annealing, and may be accelerated by either small or excessive reductions in cross-sectional area; for this reason reductions between cold working operations are usually limited to from 40-60 per cent., such limits being further determined by differences in malleability and rate of work hardening.

The properties of metals and alloys are so closely associated with their crystal structure that careful control of thermal processes such as annealing, is just as important as control of mechanical deformation processes, if the most desirable properties are to be obtained.

Effect of Structure on Mechanical Properties.

The changes in mechanical properties that result from hot or cold working, annealing, and other forms of heat treatment, are due to structural changes produced in the crystalline aggregate of which metals and alloys are composed, and are revealed by the microscopic examination of polished and etched surfaces. Whilst tensile and other mechanical tests indicate merely differences in mechanical properties, the microscope goes further and produces evidence bearing on some of the reasons for such differences, based on the deformation of the crystalline aggregate by work, and re-crystallisation or other structural change resulting from heat treatment. Further evidence becomes available by X-ray examination which reveals the internal arrangement of the atoms from which the crystals are built up.

The accompanying photomicrographs (Fig. 9) serve to illustrate some of the changes in microstructure associated with changes in mechanical properties already referred to.

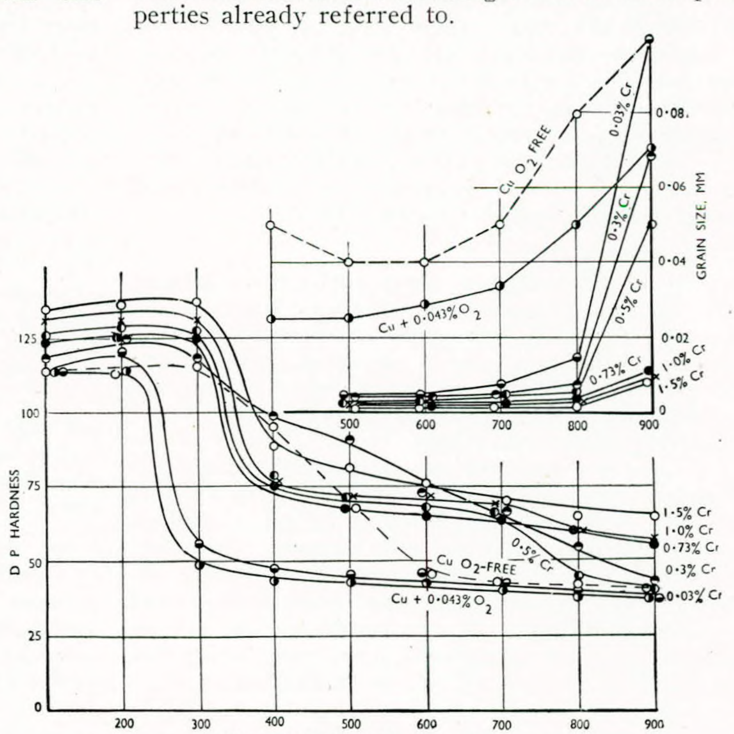


FIG. 8.—Effect of chromium on the hardness and grain growth of copper. (Alexander).

(*A*) and (*B*) (Fig. 9) show the change resulting from the extrusion of a cast gunmetal billet, the extruded section (*B*) having nearly double the tensile strength of the cast billet (*A*). (*C*) and (*D*) show a temper-hardening copper alloy (Kunial copper) containing 6 per cent. nickel and 1·5 per cent. aluminium as quenched at 900° C. (*C*), *i.e.* in the soft condition with a tensile strength of about 20 tons, and also after heating to 550° C. (*D*), the temper-hardened alloy having a tensile strength of 38 tons. (*E*) and (*F*) illustrate typical structures of cold worked (*E*) and annealed (*F*) 70/30 brass, but any simple metal or alloy would show similar differences in the cold worked and annealed conditions. (*G*) and (*H*) show the structures of copper annealed at 500° C. (*G*) and at 800° C. (*H*), the increase in grain size from 0·03 to 0·05mm. resulting from increase of annealing temperature being clearly evident. (*I*) illustrates the effect of the presence of 0·3 per cent. of chromium on restricting the grain growth of pure copper, the sample having been annealed at 800° C. as in the case of (*H*), but the grain size is only 0·01mm.

Applications.

The choice of a suitable metal or alloy for any particular application calls in the first instance for as full and complete knowledge as possible of all the variable conditions that are likely to be met with in service. Having obtained this, the wide range of metals and alloys must be reviewed in the light of their basic or compositional characteristics. Knowing also how these can be considerably modified as the result of fabricating processes, it becomes possible to arrive at a more or less satisfactory decision, for some compromise between incompatible properties is frequently inevitable.

Since applications are so closely linked up with properties, it will be convenient to consider them under headings relating to the latter.

Surface Properties.

It is surprising how many applications demand only surface properties rather than properties extending throughout the mass of metal, this being especially the case where corrosion, bearing and decorative problems are concerned and where strength or other mechanical properties may be of relatively minor importance.

This is a specially important field of application for the non-ferrous metals and alloys, since it permits of taking full advantage of many of their special properties in a most economic manner. Electroplating, galvanizing, tinning, and more recently, metal spraying, all lead to most important surface applications of non-ferrous metals, not on account of their mechanical properties, which are provided by the underlying basic metal, but of their corrosion resistance.

Chromium provides an example of an expensive non-ferrous metal which is hard, brittle and unworkable in mass form, but its remarkable tarnish resisting properties can be taken full economic advantage of by electro-depositing a thickness of a few ten-thousandths of an inch. The protection of iron from corrosion by galvanizing is too well known to require special mention.

Metal spraying[38] is finding increased application for the production of non-ferrous corrosion resistance coatings on a ferrous base. A purely mechanical use is for the building up of worn bearing parts.

When protecting one metal from corrosion by a coating of another, there is always a danger of local discontinuities in the coating leading to premature corrosion of the underlying metal, the danger being greater with thin than with thick coatings. Methods for producing a thicker coating of the protective metal are therefore sometimes employed, the product being known as a bi-metal, the thickness of the coating being from 5-10 per cent. that of the basis metal.

Starting with an ingot of the basis metal, a sheet or sheets of the protective metal having 5-10 per cent. thickness of the ingot are placed on one or both sides of the latter and the protective metal welded to the basis metal by rolling at a suitable high temperature. Nickel or cupro-nickel clad mild steel strip or sheet of any desired thickness can be produced in this way. A recent application of nickel clad steel[49] has been found for lining the holds of tankers carrying oil in bulk.

This process is extensively used in the light alloy industry for coating Duralumin with a thin layer of the much more corrosion-resistant pure aluminium.

Copper-coated steel rod is used for locomotive firebox stay bolts[26], and combines the corrosion-resistant properties of copper with the superior tensile and elastic properties of mild steel.

The production of bi-metals is an old process and follows on lines established years ago for the manufacture of Sheffield plate, a relatively thin coating of silver welded to a copper base, but what are of greater interest are the new and increasing applications for such products which combine the strength and low cost of mild steel with the special properties of the more expensive non-ferrous metals.

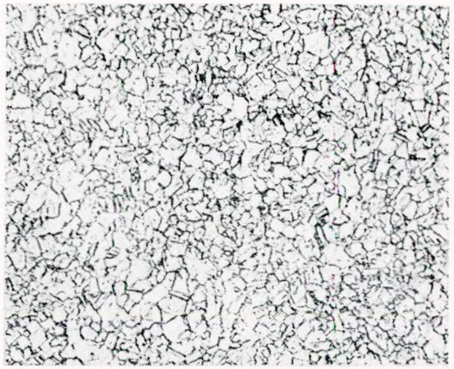
A quite modern development in automobile bearings is the use of a mild steel base coated with a thin layer of a non-ferrous bearing alloy in place of a larger mass of the more expensive non-ferrous metal.

Corrosion Resistance.

Corrosion resistance is dependent on the composition of the metal or alloy and the surface reactions which take place between the metal and the corroding medium, leading to the formation of protective films, and in this respect may be considered a surface property. It is not the metal as such, so much as the composition and physical character of the protective films formed on its surface, which determine its corrosion resistance.

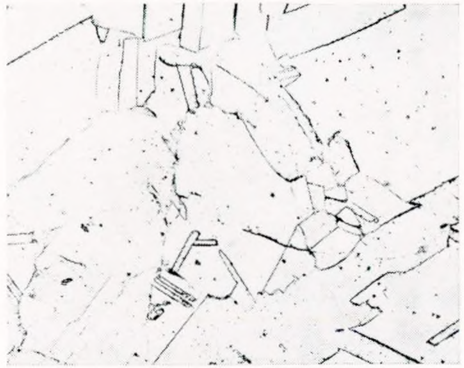
GUN METAL.

(*A*) Cast.



(*B*) Extruded.

KUNIAL COPPER.

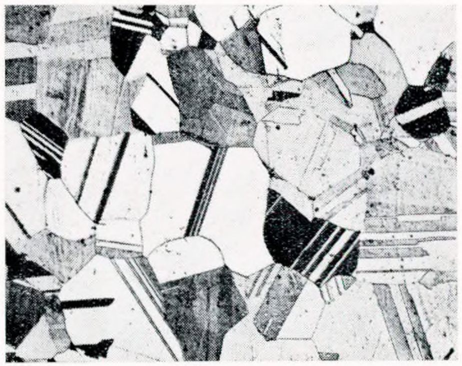


(*C*) Quenched at 900° C.

(*D*) Temper hardened by heating to 550° C.

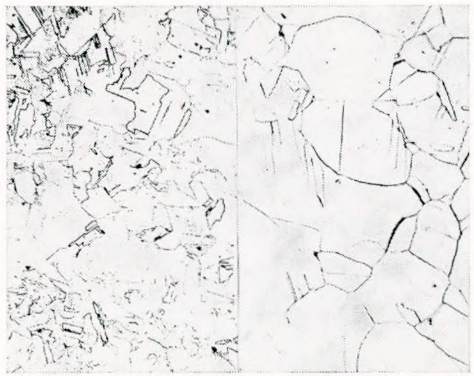
70/30 BRASS.

(*E*) Cold worked.



(*F*) Annealed at 700° C.

COPPER.



(*G*) Annealed at 500° C.

(*H*) Annealed at 800° C.

COPPER+0·3% CHROMIUM.

(*I*) Annealed at 800° C.

Fig. 9.
(Magnification of photomicrographs ×100).

Recent developments and improvements in corrosion-resisting non-ferrous metals and alloys have resulted from prolonged and detailed study of the effect of small additions of minor constituents on the protective value of the films formed on their surfaces in the presence of the corroding medium.

Problems associated with condenser tube corrosion have been so recently discussed by your Institute[1] that little further need be said on this important application of non-ferrous metals. It is of interest to note, however, that in the case of 70/30 cupro-nickel some improvement in corrosion resistance has been noted as a result of modifying both the quantities and ratio of iron and manganese, and an amended specification[27] has been approved incorporating this observation.

The beneficial effect of aluminium for improving the corrosion resistance of copper-rich alloys is well known and exemplified in the case of the brasses containing 76 per cent. copper and 2·0 per cent. aluminium[28]. The aluminium bronzes[18] also possess good corrosion resistance, and this, coupled with their considerable strength, should make a special appeal for certain applications.

When considering corrosion problems, it must always be remembered that the metal or alloy is only one of the many factors involved, and corrosion resistance is therefore only a relative term and associated with specific conditions of use.

The recent extended use of copper pipes[29, 31, 32], for domestic water and gas supplies in place of iron or lead is an interesting application of copper due mainly to its superior corrosion resistance, eliminating troubles associated with rusting and relatively short life, poisonous contamination, burst pipes during frosty weather, and mechanical damage. The use of thin-walled copper pipes reduces weight and fitting is facilitated and cheapened by the use of solder sweated sleeve joints[30].

A natural sequence to this application is that of copper pipes for sanitary services[29], where corrosion resistance, lightness, ease of jointing, and other properties all play important parts in the economic displacement of iron and lead.

These several combined desirable properties have led to the use of thin walled copper tubing for electrical conduit purposes[29], which, in spite of the higher basic cost of copper as compared with mild steel, is competitive on an installed cost basis.

With certain soft waters, high in carbon dioxide, which slightly attack copper, an alloy containing about 15 per cent. of zinc may be used with advantage, an illustration of how the composition of copper alloys can be adjusted to meet special conditions.

Resistance to Oxidation and Maintenance of Strength at High Temperatures.

Copper and most of its alloys readily oxidise at temperatures approaching a red heat or above, the important exceptions being those alloys containing 2 or more per cent. of aluminium, such as the aluminium brasses and bronzes, on which a protective film, largely composed of aluminium oxide, is formed.

The strength of copper and many of its alloys falls off gradually as their temperature is raised[33], but alloys containing nickel, aluminium, and chromium may maintain a reasonable amount of strength up to temperatures in the region of 400-500° C. Nickel additions become more effective the higher the nickel content, so that in the cupro-nickels with 20-30 per cent. of nickel, the effect is quite marked, but the best results are not obtained until 60-70 per cent. is reached as in Monel metal[15], which must be considered a nickel rather than a copper alloy. In the case of the aluminium bronzes, an alloy containing 10 per cent. of aluminium, having a tensile strength of about 38 tons at room temperature retains a tensile of about 20 tons at 450° C. without appreciable change in elongation, which remains at 30 per cent.[18]. The effect of temperature on the tensile strength of copper and some of its alloys is plotted in Fig. 10.

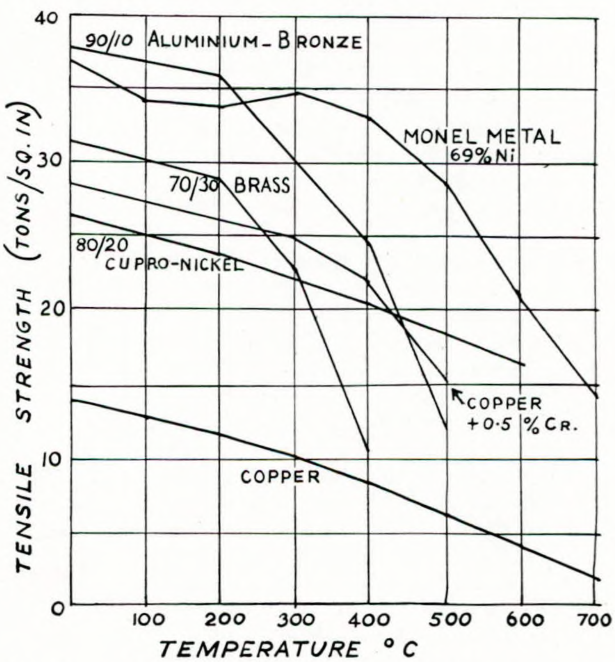


FIG. 10.—Effect of temperature on the tensile strength of copper and some copper alloys.

Electrical Conductivity.

Some reference to the manner in which this property in copper was influenced by composition has already been made in the earlier part of the paper, when improvement in strength by alloying was shown to be incompatible with maintained conductivity. For overhead electrical cables where both strength and high conductivity are required, a useful compromise is possible by using a composite or bi-metallic cable consisting of a steel core with outer concentric copper layer[47], the two metals being welded together by the extrusion or hot rolling of an original composite billet. Such a product has already been mentioned in connection with developments associated with stay bolts for locomotive fireboxes[26] in which the copper coating is for protection against corrosion, an interesting example of an identical product being used for two widely different applications, and taking advantage of two totally different properties of the metal copper.

Mention has already been made of the use of copper tube conduit for the carrying and protection of electric cables. An interesting recent development is the production of cables in which an outside copper cover (corresponding to the conduit) carries internal bare conducting wires, these being insulated from the cover and from one another, by compressed magnesia, such cable being known as "Pyrotenax". The advantages of such a product are many; not only is it fireproof up to the melting point of copper (1,083° C.), but it also facilitates installation, and though easily bent is very compact and solid and not easily damaged.

Thermal Conductivity.

This property is of importance in applications where rapid heat dissipation is desired as in internal combustion engines, heat exchangers and in bearings. Whilst pure copper stands out from other metals so far as this property is concerned, additional requirements such as strength, corrosion resistance or low coefficient of friction generally stand in the way of its use and some compromise has to be sought in the use of alloys in which high thermal conductivity is to some extent sacrificed for the obtaining of other desirable properties.

For the heads of I.C. engine cylinders, the use of copper strengthened by alloying with a small amount of chromium has been experimented with[34], such an alloy possessing good heat conductivity, and at the same time reasonably good strength, which does not fall off appreciably at the working temperature. Such a head is said to permit of the use of higher compressions with resultant improved efficiency.

In the field of heat exchangers such as condensers, radiators[48] and oil coolers, the problem arises of using alloys giving a happy compromise between good heat conductivity and corrosion resistance, but the latter is the more important from a service point of view and thermal conductivity then becomes a more minor consideration.

Again in bearings, whilst good thermal conductivity is desirable, other properties are more important.

Bearing Properties.

The properties demanded of a bearing metal[41] are so dependent on the conditions of service, such as load, speed and lubrication that they are difficult to define. In some respects they are incompatible, as for example softness to facilitate bedding down and the smoothing out of surface irregularities, and hardness or stiffness to prevent too easy deformation. Copper is a good basis metal for resisting wear when in frictional contact with steel, but its resistance to flow and deformation under load is low, and its properties as a bearing metal are much improved by alloying with tin to form the tin bronzes[16, 34]. Copper can be hardened to resist easy deformation by adding a number of other metals, but from a wear and bearing point of view tin is the best. The effect of adding increasing amounts of tin and of zinc on the wear of copper is shown in Fig. 11, from which it will be noted how increasing amounts of zinc increase wear, whereas additions of tin diminish wear. In this graph wear is indicated by the length of the oval impression made when a one inch diameter steel wheel, 0·10in. thick with a radius on the periphery of 0·05in. is rotated in loaded frictional contact with a flat sample of the alloy under the conditions stated[51].

For a number of years cast alloys containing

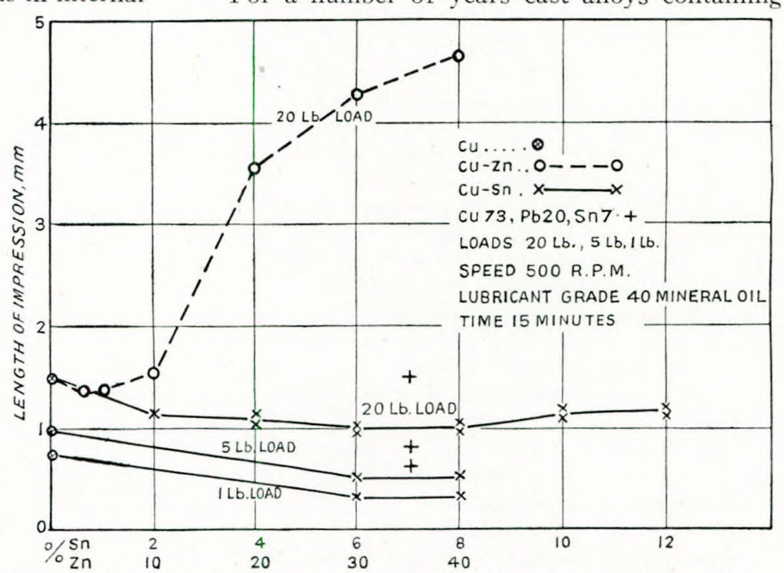


FIG. 11.—Effect of alloy composition and load on wear. (Brownsdon).

from 12-16 per cent. of tin have been largely used, such alloys being complex, *i.e.* consisting of a matrix of soft alloy of lower tin content in which hard crystals of richer tin content are dispersed, thus providing the compromise between softness in the mass to facilitate bedding down with localised greater hardness to resist wear. Equally satisfactory results are now being obtained by using the malleable bronzes of lower tin content from 5-6 per cent., one of the advantages of these being that they can be prefabricated in tubular form to very accurate dimensions so that the making up of the bearing is simplified and melting and casting operations eliminated.

The use of bearing linings formed from steel strip coated with a thin layer of a non-ferrous bearing metal has already been mentioned under the uses of bi-metals.

In addition to copper tin alloys, copper lead alloys containing up to 30 per cent. of lead, and frequently containing also a small percentage of tin, are finding extending applications, and have led to interesting development in alloy manufacture. Strictly speaking, lead does not form an alloy when added to molten copper, for it is insoluble, giving a matrix of copper containing particles of free lead dispersed more or less evenly throughout the mass. In order to obtain a more controlled and uniform distribution of the lead, such very heterogeneous alloys are being made by admixing copper and lead powders in the desired quantities, moulding under high pressure and then sintering the mass together by heating to a suitable temperature[34]. Other constituents such as graphite, may be incorporated in the copper in a similar manner. This method of producing alloys from mixtures of metallic or other powders, known as powder metallurgy[35, 36], opens up an interesting field for producing alloys and other semi-metallic products, and in some cases offers the only means for so doing, hard tungsten carbide tools being a case in point.

Non-Magnetic Properties.

Whilst these are not frequently called for, they may sometimes become of importance, as in the recent building of the non-magnetic ship "Research" in which copper alloys, such as the high tensile brasses and aluminium bronze, have been extensively used.

Welding, Brazing and Soldering.

The ease and certainty with which metals may be joined is frequently important when considering their use. Copper is not the easiest metal to gas weld autogenously[37], especially in the tough pitch or oxygen containing condition, but in the hands of an experienced welder, good strong welds can be obtained. Satisfactory welding is much facilitated when the metal is in the deoxidised condition and such deoxidised copper is therefore preferably used, the filler rod being of similar quality and frequently containing a small percentage of silver. Borax is a commonly used flux and the welds are improved by hammering whilst still hot.

The alloys most easily welded are those containing silicon; copper containing from 1 - 3 per cent. of silicon[22] not only gives strong clean joints, but being at the same time one of the strongest alloys finds wide application for tanks and other vessels made from sheet or strip and involving joints in their manufacture.

A small addition of silicon to the brasses also helps in the production of sound strong joints without appreciably interfering with their other desirable properties.

Copper alloys containing aluminium, such as aluminium bronze[18], have a thin aluminium oxide film on their surface and are not so amenable to the making of sound welded joints, but this difficulty is largely overcome by the use of special fluxes of the fluoride type as used for the welding of aluminium and its alloys. Better and more reliable joints are obtained with aluminium containing alloys if an arc rather than an oxy-acetylene gas method of welding is used.

Brazing, as distinct from autogenous welding, is generally applicable to copper and its alloys, and is largely used for jointing in numerous cases where welding is impracticable or unnecessary, as in pipe work for sanitary services[30]. The brazing alloys have a copper base with alloying additions such as phosphorus and/or silver and zinc to lower the melting point, such additions exerting a fluxing action which facilitates flow and good bonding of the metals to be jointed.

Lead-tin solders[40] make good serviceable joints with copper and its alloys, so long as the conditions of use do not demand strength at temperatures above 100° C., for soft-soldered joints are then liable to deterioration[17].

The aluminium bronzes offer difficulties in the way of producing sound soft-soldered joints for the same reason as that referred to in the case of welding, but the difficulty is again overcome by the use of special fluxes[18].

Fatigue and Corrosion-Fatigue.

A property of metals and alloys which becomes of importance in applications where the material is subjected to the action of repeated alternating stresses, is that of fatigue resistance, experimentally expressed as the maximum applied cyclic stress that the metal will withstand indefinitely without causing fracture, known as the fatigue limit. Such alternating stresses may arise in reciprocating components or as a result of vibration. Failure of metals due to fatigue[42] is accelerated by superficial corrosion which may therefore lead to serious lowering of the fatigue limit.

Copper itself has a low fatique limit of only about $\pm 4{\cdot}5$ tons per sq. inch. By alloying, the fatigue limit can be very considerably increased; with 3 per cent. of silicon or 70 per cent. of zinc, or 5 per cent. of tin to give Everdur, brass and tin-bronze, the fatigue limit is raised to about ± 9, $\pm 7{\cdot}5$ and ± 10 tons per sq. inch respectively. The beryllium (2·5 per cent. Be) and aluminium (9 per cent. Al) bronzes have much higher fatigue limits of from ± 14 to ± 16 tons per sq. inch, and figures as high as ± 22 tons are obtainable in special aluminium bronzes containing 10 per cent. of aluminium and about 5 per cent. each of nickel and iron, which is comparable with that given by a medium steel containing 0·5 per cent. of carbon. These figures are those obtained on tests carried out in the normal way in air.

When, however, similar fatigue tests for endurance are carried out under corrosive conditions as in a salt spray, then copper alloys, owing to their superior corrosion resistance, may show better endurance than the steels[44]. Under such conditions Gough and Sopwith give an endurance limit (5×10^7 cycles) for a phosphor bronze of $\pm 11{\cdot}7$ tons per sq. inch; for beryllium bronze of $\pm 17{\cdot}4$ tons, and for a special aluminium bronze of $\pm 14{\cdot}6$ tons, whilst that of a medium 0·5 per cent. carbon steel drops to only $\pm 2{\cdot}8$ tons; in fact the figure for beryllium bronze is higher than that given by a corrosion-resisting 18/8 Cr-Ni steel, this latter under the same conditions of test giving $\pm 15{\cdot}8$ tons per sq. inch.

Such figures illustrate the importance of knowing the conditions under which a metal or alloy will be used in service before deciding on one likely to prove most suitable, and further, they show how misleading figures for mechanical properties may be unless the results are carefully correlated with the conditions of testing.

Gough[43] has shown how even the corrosive effects of the ordinary atmosphere tend to reduce fatigue limits, since slightly higher limits are obtained when the tests are carried out in a partial vacuum.

These few observations on fatigue and corrosion fatigue should be of special interest to marine engineers since the metals and alloys they use have in some cases to prove serviceable under conditions simulating a more or less severe salt spray fatigue test, the sea atmosphere providing the corroding medium and vibration the alternating stresses.

Conclusion.

This brief review of properties cannot hope to be complete and is only intended to be a background to help towards the filling in of more complete details as and when occasion arises. It may in some respects be regarded as only an annotated index to the much detailed information available in the quoted references. It will not solve your problems, but may bring some facts and ideas to your notice which may lead the way to some partial if not complete solution of them.

Copper and its alloys offer such a wide and remarkable range of properties, dependent on composition, heat treatment and fabrication processes, that a full appreciation of their possible useful applications cannot be gained without some knowledge of their metallurgical characteristics[50].

Our more intimate and specialized interests are catered for by the learned societies of which we are members and the technical press, and whilst this is satisfactory so far as it goes, there are no sharp dividing lines in industry, and the marine engineer and the metallurgist, or in more general terms, the user and producer, have to work together for the mutual improvement of their products.

"Complaints" are a common and sometimes controversial meeting ground, but considered in the right spirit may easily lead to improvement in the product. The initiative in this case comes from the user. If the producer develops new and improved alloys, he may not know of some applications for which they may be well suited.

The problem is that of keeping in close touch with improvements in materials and taking advantage of the special properties they possess. Whilst much can be done in a general way through meetings and the perusal of publications, personal contacts followed by close co-operation offers by far the simplest, quickest and most satisfactory means for attaining the desired end. The only alternative would be for everybody to have a detailed knowledge of everybody else's business, but with the wide range of industries and of materials used, this is impossible.

So far as available technical information is concerned, the non-ferrous industry is well served by the periodic free issue of publications by such bodies as the Copper Development Association (C.D.A.), the International Tin Research & Development Council and producing firms such as the British Aluminium Co., the Mond Nickel Co., I.C.I. Metals Ltd., and others, their publications being available to all interested parties, and containing up-to-date information on developments and new applications for non-ferrous metals. On the research side, the British Non-Ferrous Metals Research Association is actively engaged on problems associated with the development and improvement of non-ferrous metals generally, and of special interest to your Institute is their research on condenser tube alloys which has been a major investigation for a number of years. Quite independently of this co-operative research, the large manufacturers have their own research organisations. Mention must be made of the valuable work done by the Institute of Metals, which might be considered as the focus of non-ferrous metallurgical interests in this country; through its Proceedings, Abstracts and meetings it does for the non-ferrous industry what the Iron and Steel Institute does for the ferrous industry.

Finally, engineers must realize that there are limitations to what the metallurgist can do with the elementary metals at his disposal, and that where a number of properties are desired it is generally impossible to combine these in any one metal or alloy, and a happy compromise must be sought; further, the satisfactory replacement of one material by another may frequently call for some modification in design if full advantage is to be gained from a change in materials.

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International Congress of Naval Architects and Marine Engineers, Liége, 1939.

Notwithstanding the shadow of coming events and its inevitable effect upon such an assembly, the recent International Congress of Naval Architects and Marine Engineers convened and organised by the Union Belge des Ingénieurs Navals—the first congress of its kind to be held in Belgium—was attended by over 100 delegates from six countries.

The Congress activities, which were centred mainly in Liége, occupied the three days 18th, 19th and 20th August, 1939, the venue being chosen on account of the International Exhibition of Water Technique which was being held there during the summer.

The Exhibition marked the opening of the new Albert Canal, connecting Antwerp with Liége, which makes it possible for ships of upwards of 1,000 tons capacity to reach the important Meuse port direct from the sea. The occasion also marked the 10th anniversary of the founding of the Union Belge des Ingénieurs Navals.

The Comité d'Honneur of the Comité Belge de Patronage included M. le Ministre des Transport, M. le Ministre des Travaux Publics et de la Résorption du Chômage, M. le Ministre des Colonies, M. le Gouverneur de la Province de Liége, M. le Bourgmestre de la Ville de Liége, M. le Bourgmestre de la Ville d'Anvers, M. le Recteur de l'Université de Liége, M. le Recteur de l'Université de Gand, M. l'Administrateur-Inspecteur de l'Université de Liége, and M. le Commissaire

Général du Gouvernement près la Grande Saison Internationale de l'Eau, Liége, 1939.

The Comité d'Organisation consisted of M. R. Dauwe (Ingénieur en Chef du Chantier Cockerill, Hoboken), President; MM. G. De Winne (Ingénieur en Chef, Directeur à l'Administration de la Marine), F. Kraft de la Saulx (Ingenieur en Chef—Conseil à la Société Cockerill), and P. Chardome (Administrateur-Directeur du Chantier Naval de Rupelmonde), Vice-Presidents; MM. L. Gaukema (Ingénieur-Directeur du Chantier Naval de Liége-Monsin), E. Hanssens (Ingénieur Principal—Chef de Service de l'Otraco) and R. Spronck (Professeur de Constructions Navales à l-Université de Liége), Secretaries; M. P. Reynaers (Ingénieur Naval), Treasurer.

Names well known internationally in shipbuilding, naval architecture and marine engineering figured prominently in the list of those present at the principal functions. They represented the following societies: Association Technique Maritime et Aéronautique, Institution of Naval Architects, Institute of Marine Engineers, North East Coast Institution of Engineers and Shipbuilders, Institution of Engineers and Shipbuilders in Scotland, Schiffbautechnische Gesellschaft, Gesellschaft der Freunde und Förderer der Hamburgischen Schiffbauversuchsanstalt, and the Koninklijk Instituut van Ingenieurs.

The Institute was officially represented by Mr. A. R. T. Woods (Vice-President), accompanied by Mrs. Woods. There were also in attendance Messrs. F. W. Youldon (Vice-Chairman of Council) and Mrs. Youldon, A. C. Hardy (Associate Member of Council), W. L. Roxburgh (Past Member of Council) and A. Belch (Companion).

The Congress opened with a reception of the foreign delegates at the Hotel de Ville, Brussels on Thursday, August 17th, followed by a banquet and reception offered by the Société Royale Belge des Ingénieurs et Industriels.

On Friday the 18th, the Congress transferred to Liége and the proceedings were resumed at 10.30 a.m. in the Hall of Liége University. The morning session was devoted to the reading of papers, followed at 12.45 p.m. by a reception at the Hotel de Ville de Liége and lunch at the Vaxelaire-Claes restaurant. The afternoon was occupied by a choice of visits to the following works, viz.: S. A. John Cockerill à Seraing, S. A. d'Ougrée Marihaye à Ougrée, Fabrique Nationale d'Armes de Guerre é Herstal, and Cristalleries du Val St-Lambert. The evening was left free for a tour of the Exhibition.

The session for the presentation of papers was resumed at 9.30 a.m. on Saturday, the 19th at the Institute of Civil Engineering of Liége University, the session ending at 12.30 p.m. At 1.30 p.m. lunch was served at the Exhibition by the kindness of M. Dewandre, President of the Executive Committee of the Exhibition. A conducted tour of the Exhibition followed, the evening being left free.

On Sunday, August 20th, the delegates were given a boat trip on the Albert Canal, embarking at 9.30 a.m. and partaking of a buffet lunch on board. In the afternoon they made an excursion by car to Spa, returning for the closing banquet at 8 p.m. in the "Chez Francoise" Restaurant at the Exhibition.

The following day, Monday the 21st, was occupied in various social functions at Antwerp. At 10 a.m. the visitors were conducted round the Port of Antwerp in a saloon steamer kindly placed at their disposal by the Administration Communale. During the tour the party visited the repair shops and dry docks of the Mercantile Marine Engineering Company. Following a reception at 12.30 p.m. at the Hotel de Ville of Antwerp, the assembly proceeded on board the new mail steamer "Baudouinville", where lunch was served in the large first-class restaurant by the kindness of the owners, the Compagnie Maritime Belge. The "Baudouinville" had just returned from her maiden voyage to the Congo, and the many interesting technical features of the vessel were much admired by those who took part in this enjoyable function.

Finally, at 4 p.m., the visitors were entertained by Lt.-Col. H. J. P. Béliard, D.S.O., our esteemed Vice-President, President of the Antwerp Federation of Ship Repairers and President of Messrs. Béliard, Crighton & Co. at a garden party at his Chateau "De Bist" at Kessel. At the close of this delightful gathering, our host bid adieu to the foreign delegates, both personally and in the name of the Society to whom we are lastingly indebted for their hospitality and many kindnesses throughout this most successful congress.

The Papers.

At the technical session in Liége the object of the papers was to deal with questions "relative to naval architecture and marine engineering, especially in so far as they concern river navigation". Seagoing material was not, however, excluded despite the fact that only five hours were given to reading and discussion of 18 papers. Even so, in spite of the loquacity of some of the speakers, particularly those contributing on welding subjects, the discussions were fruitful; especially was this so in the case of the "tank" papers of Messrs. Kempf, Wigley, Yourkevitch and Troost.

The papers were, in effect, in three groups (*a*) river types, navigation and propulsion, (*b*) oil engine drive for small craft and oil engine development, and finally (*c*) the resistance subjects mentioned above.

The first group included papers by Professor E. Bogaert of Brussels University, on the resistance of Albert Canal ships and how this problem is tackled; M. Chardome on propulsion, and M. L. Tison on the influence of the canal section on tractive effort between Charleroi and Brussels. M. G. Aertssen's paper on the subtleties of tow-rope horsepower and contract conditions for river tugs might well be studied with advantage by Thames tug-owners, as the author shed some real light on towage problems.

M. P. Desmoins' paper on the application of oil engines to river craft is an important contribution to the subject, and was followed in section (*b*) by Mr. A. C. Hardy's discussion of the application of the oil engine to coasters, fishing craft and inland waterway navigation.

These papers were, in turn, connected with contributions dealing with the organisation of shipyards; M. D. Bosschart, who was trained at Delft, was particularly interesting in this respect, as also was M. Jaeger from the same university, on co-ordination in the Dutch shipyards. M. Jaeger is now at De Schelde Yard at Flushing, and may have a good deal to do with the building of Holland's proposed new battleship.

Other interesting papers discussed the psychological aspects of welding technique in modern shipyards. In this respect the contribution of M. Heurion is of the utmost importance and well worth study in this country. There was evidence of much research in this paper, as also in M. Ducrot's paper, which described what the Sulzer organisation has been doing to ascertain what goes on inside an oil engine cylinder during combustion. This was an important paper, well illustrated by slides.

After this general survey of the papers some particular points may be mentioned. M. Chardome, for example, discussed the progress of the Kort nozzle in propulsion, observing that his study dealt only with the improvement of propulsion as such, leaving on one side the improvement of hull form.

M. Bosschart brought considerable authority to bear on the problem of work organisation in shipyards and the difficulties of applying ideas in practice. Two points of interest in particular were made, one concerning the difference between mercantile and naval construction from the organisation point of view, and the other the effect of variations in the amount of work available in shops ashore and in shipyards—an interesting land-marine contrast.

This paper was related to that by M. Jaeger, of the Flushing shipyard, who examined the reasons for the establishment of a central design office for warships for the four main Dutch shipyards. This bureau will deal with plans for the Dutch Navy as well as those for export, and will act as a sales organisation for the latter purpose. Prices are also to be fixed.

Of the tank papers, M. Troost's gave interesting information of the new cavitation tank at Wageningen, and made a useful sequel to Dr. Kempf's study of the influence of width and depth of canals on ship resistance. Mr. Wigley's subject, wave resistance of ships, compared the calculated wave resistance of five forms, with systematic variations, with the residuary resistance deduced from the results of experiments with models of these forms by the use of Froude's values of frictional resistance; this paper may be regarded as the forerunner of further similar investigation.

M. Yourkevitch is a true hull form expert, for his paper discussed problems of bringing existing hulls up-to-date by modernisation of hull and machinery.

Attention has been directed above to M. Aertssen's paper; tug owners will note from it with interest that "the use of a dynamometer on acceptance trials tends to increase". Pulling against a fixed point seems to be a test of increasingly doubtful value in the scientific world.

M. Bosquet's description of the remedies for vibrations in five different Cockerill-built ships were as frank as they were useful; they concerned the "Prince Baudouin", in which the turbo-blowers were noisy at first, the "Prins Albert", her sister ship, the "Baudouinville", and two Diesel-electric hydrographic ships.

Mr. Hardy's paper discussed the use of oil engines in ships of up to 2,000 tons gross owned by a selected group of nations; it also dealt with trends in engine design up to about 800 horsepower.

Welding enthusiasts should read M. Heurion's paper in detail; it is one of the best and most practical from a shipbuilding point of view to have been presented for some time.

It is understood that the complete transactions with illustrations and discussions will be published in the near future, and when this takes place there will be available in handy form a collection of contemporary data on ship construction, shipyard organisation and ship propulsion of extreme value. Meanwhile, it is hoped that, although the first, this will not be the last of international maritime congresses in Belgium.

[Acknowledgments are accorded to the "Journal of Commerce" for the foregoing summary of the papers delivered at the Congress.—EDITOR.]

ELECTION OF MEMBERS.

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

Members.

Douglas Christie Carson, Messrs. Carson & Potts, 37, Mark Lane, E.C.3.

Alfred Snowdon, 228, Cleveland Road, Sunderland.

Robert Sommerville Stewart, 9, Marine Terrace, Waterloo, Liverpool, 22.

F. R. G. Turner, Eng. Rear-Admiral, Admiralty, London, S.W.1.

Robert McWilliam, 80, Minster Way, Hornchurch, Essex.

Associates.

David William Blyth, 16, Montpelier Gardens, East Ham, E.6.

Ernest Dale, 8, Beverley Park, Monkseaton, Northumberland.

Stanley Dale, 4, Langley Avenue, Monkseaton, Northumberland.

George Wallace Naismith Miller, Bridgeness Crescent, Bo'ness, Scotland.

Student.

Francis Allen Hay, 3, Queen Street, Seaham Harbour, Co. Durham.

Transfer from Student to Associate.

Theodore Berry, 9, Kayll Road, Millfield, Sunderland.

ADDITIONS TO THE LIBRARY.

Presented by the Publishers.

Rules for the Construction and Classification of Steel Ships and Their Machinery, 1939. British Corporation Register of Shipping and Aircraft.

A Study of a Nickel-Chromium-Molybdenum-Vanadium Steel Ingot. By Dr. W. H. Hatfield, F.R.S. Iron and Steel Institute.

The Vacuum Fusion Method for the Determination of Oxygen in Steel. A Carbon-Spiral Vacuum Fusion Furnace as in Use at the Brown-Firth Research Laboratories. By W. C. Newell, Ph.D., D.I.C., A.R.C.S., B.Sc., A.I.C. Iron and Steel Institute, Part 2 of Second Report of the Oxygen Sub-Committee.

Quenching Tests in Various Media. By G. Stanfield, M.Eng., B.Sc. The Iron and Steel Institute, Part 7 of Second Report of Sub-Committee A, Thermal Treatment.

The Effect of Shape of Bow on Ship Resistance (Part II). Paper read by A. Emerson, B.Sc. before Institution of Naval Architects.

Model Experiments on Twin-Screw Propulsion (Part II). Paper read by G. Hughes, B.Sc. before Institution of Naval Architects.

Rules and Regulations for the Construction and Classification of Steel Vessels, 1939-40. Lloyd's Register of Shipping.

The following British Standard Specifications:—

No. 874-1939. Definitions of Heat Insulating Terms and Methods of Determining Thermal Conductivity and Solar Reflectivity.

No. 210-1939. Lubricating Oils.

No. 869-1939. Toolmakers' Flats and High Precision Surface Plates.

No. 871-1939. Abrasive Papers and Cloths for General Purposes.

No. 872-1939. Abrasive Papers and Cloths (Technical Products).

Transactions of the Institution of Naval Architects, Vol. LXXXI, 1939, containing the following papers:—

"H.M.S. *Ark Royal*", by Goodall.

"Special Features in the Design and Loading of Self-trimming Colliers", by Mitchell.

"The Extraction of Condensate from Expanding Steam; Its Effect upon the Efficiency of the Ideal Heat-cycle and Its Influence upon the Selection of Initial Steam Conditions", by Meijer.

"Welding in Marine Engineering Construction", by Pemberton.

"Fatigue in Structural Steel Plates with Riveted or Welded Joints", by Haigh.

"The Effect of Shape of Bow on Ship Resistance (Part II)", by Emerson.

"Model Experiments in Twin-Screw Propulsion (Part II)", by Hughes.

"A New Method for Determining E.H.P. and Its Application to Atlantic Liner Design", by Tennyson.

"Heave, Pitch and Resistance of Ships in a Seaway", by Kreitner.

"The All-welded Hull Construction of H.M.S. *Seagull*", by Nicholls.

"Light-Alloy Ship Construction", by Devereux and Telfer.

"The Protection of Metal Surfaces against Marine Corrosion and Fouling", by Mardles.

"Some Notes on Ship Corrosion and Paint", by Skinner.

Audels Diesel Engine Manual—Questions and Answers. By A. B. Green and R. A. Zoeller. Sir Isaac Pitman & Sons, Ltd., 292 pp., copiously illus., 10s. net.

The presentation of this book is unorthodox, but nevertheless the method (question and answer) of imparting knowledge has certain advantages, and it should prove a useful manual to those who have an elementary idea of how a Diesel engine works, or who wish to refresh their memory. A more detailed alphabetical index would have been an improvement. The illustrations and diagrams are particularly clear for the size of the book.

While the chapter on fuel injection compressors is very clear and gives sound advice on maintenance, it seems much too long—some 15 pages being devoted to it—bearing in mind that airless injection engines have practically superseded the air injection type. The short chapter on scavenging air compressors makes no mention that these are almost universally used on modern two-cycle engines; this may lead to confusion if the reader has only a little knowledge.

Excellent advice is given on lubrication. If engine attendants would only act carefully on this, many engine makers would be saved expense of guarantee liabilities and risks of losing their reputation for good design and workmanship.

The final paragraph on air reversing (page 226) is not strictly accurate. Some designs of modern engines are arranged to admit air, so that its compression slows the engine rapidly. This avoids the necessity to wait until it comes to a full stop before moving the lever astern. The chapter on engine indicators, whilst informative, makes no mention of limitations of such instruments for the higher speed engines. Experience shows that the ordinary indicator is not accurate much above 400 r.p.m. The Okill type indicator is preferable though it does not trace a diagram.

The Electrical Power Engineers' Handbook. By W. S. Ibbetson, B.Sc., M.I.Mar.E. E. & F. N. Spon, Ltd., 250 pp., 110 illus., 12s. 6d. net.

This book has been written by an electrical engineer who understands the needs of the works maintenance engineer. In an easy way, step by step, the apparently mystical formulæ used by the electrical engineer are unfolded to him, so that they can be applied to his own particular problem. The formulæ and the methods of testing can be found in many pocket books, but owing to the briefness that has to be used in that type of book, they are often difficult for the ordinary man to follow.

This book can also be recommended to junior marine engineers. It will whet their appetites for further electrical knowledge, which will prove a useful addition to their qualifications.

With regard to power factor correction, the methods of improving it are given, but it would have been of interest if an example of a small works could have been taken and the saving in £.s.d. shown; this problem is a very difficult one for many works managers to grasp.

The trend of modern works to use a.c. three wire, and three wire and neutral systems, giving 440 volts for power and 250 volts for lighting, has been illustrated and explained, but a typical layout for a works would have been helpful, together with hints for balancing the load; the type of motors to use with this system for the improvement of the power factor is given in the chapter on motors.

The pages that have been devoted to the rectifier give a clear and simple explanation of its principles and methods of working, and will give confidence to any who in the near future will have them in their charge. Some very useful information has been given for the shopman to use for testing and finding faults on armatures.

As this book is intended for the practical man the author should have included the safety measures to be taken before overhauling H.T. switches, and the protective devices that are employed on both switches and transformers.

Tables for Converting Rectangular to Polar Co-ordinates. By J. C. P. Miller, Ph.D. Scientific Computing Service, Ltd., 16 pp., 2s. net.

The main object of these tables is to facilitate the conversion of rectangular co-ordinates (x, y) to polar co-ordinates (r, θ) by means of the relations

$$r=\sqrt{x^2+y^2} \qquad \theta=\tan^{-1}\frac{x}{y}$$

The arrangement adopted is the result of several years of experiment, and is believed to afford the maximum possible efficiency.

The tables are intended for use with a calculating machine or slide rule; it will be found that only one set-up of the machine or rule is usually necessary and that no intermediate working need be recorded. In the case of the slide rule, however, two settings are sometimes needed if the maximum accuracy is desired. Since the precise method of use is important, the examples are given in considerable detail.

Properties and Strength of Materials. By J. A. Cormack and E. R. Andrew. Macmillan & Co., Ltd., 383 pp., illus., 8s. 6d. net.

The authors, in the preface, state that this book has been written with the object of presenting the subject of strength of materials with the minimum amount of higher mathematics. Since the book has also been written for the purpose of covering the syllabuses of the National Certificates in Mechanical Engineering and those of the examinations of the engineering professional institutions, and bearing in mind that students taking these examinations are required to have a fair knowledge of the calculus, we fail to see why the applications of the integral calculus should be avoided, *e.g.* the proof using Simpson's rule on page 141 appears to us as unnecessary.

This is only a minor criticism of an excellently written book. It is excellent because the authors have included so much really useful information on the properties and testing of materials and have not confined themselves to a rehash of the theory of elasticity.

Chapter XII on general topics, which includes sections on fatigue, fatigue failures, corrosion-fatigue, overstrain, growth of cast-iron, plastics, etc., has been carefully written and a perusal of this chapter will give an engineering student sufficient information without having to wade through a mass of detail published in the proceedings of the engineering institutions.

Plenty of examples are included at the ends of those chapters dealing with the theoretical part of the subject and the authors have wisely given the answers after each example instead of at the end of the book.

Appendix A includes questions selected from recent examination papers of the various engineering institutions, and such a collection of questions will give a student a better idea of the standard required than can usually be obtained from a syllabus. It is hoped that in the next edition room will be found in this appendix for questions set at The Institute's Associate Membership Examination, for this book can be well recommended as a suitable text-book for candidates preparing for this examination.

In the next edition we suggest that the section of the beam in Fig. 55 should be drawn correctly (the section should be symmetrical about the plane of bending), and a more detailed explanation of Macaulay's method of dealing with deflection problems should be given. The book is well illustrated and at the modest price of 8s. 6d. it should be on the library shelves of every engineering student.

Steam Turbines. By Professor Pio-Oulski. Dunod—Editeur, 92 rue Bonaparte, Paris (6^{e}), 104 pp., 436 illus., 210 Fr. bound; 185 Fr. paper cover; postage and insurance 12 per cent.

This work, which is published in French, is notable for the originality of its presentation. Chapter I contains a description of the processes brought into play in the steam turbine (impulse and reaction), followed by the steam trajectory (axial or radial) and its utilization (including considerations of back pressure and bleeding, etc.).

In Chapter 2 the description is presented from the point of view of the shipbuilder, but with that impartiality and objectivity for which the author is distinguished. Chapters 3 to 9 comprise a well-arranged and up-to-date study of such components as distributors, rotors, casings, bilge pump gear, plummer blocks, etc. Chapters 10 and 11 differ from the earlier sections of the book (except for calculations concerning the resistance of materials of rotating discs), being of a descriptive nature, illustrated by well-chosen figures, and form an invaluable study for students and engineers. It will suffice to mention their titles, viz.: "Regulating of Turbines" and "Shafts Turning at High Speed and Their Critical Speeds". Both subjects are treated fully and clearly.

With remarkable brevity and admirably illustrated this work reviews all that an engineer should know about steam turbines. It is specially written for engineer constructors, supervisors, students and all who may be confronted by the complex problem of choosing a type of turbine.

Gas Charts for Steam Boilers. By J. Webster. Emmott & Co., Ltd., 31, King Street West, Manchester, 25 pp., illus., 1s. net.

In the preparation of this work, the needs of the practical man have been kept prominently in mind. The boiler engineer and designer looks for worked examples as he is then able to compare these with his own particular problems. If a few typical charts are prepared, it will be found that they cover quite a range of different sizes and arrangements of boilers, and they form a sound collection for ready reference. Furnace temperatures are sometimes kept purposely low in order to preserve the life of the walls, the possible CO_2 content of, say, 13 per cent. or 14 per cent. being kept down to about 8 per cent. or 9 per cent. In the first case the temperature might reach 2,800° to 3,000° F. and in the latter about 2,000° to 2,200° F. Such adjustment to standard curves is a comparatively simple matter. Rough charts on squared paper giving the temperature curves only, will be found extremely useful and take only a very short time to prepare, using the formulæ and data given in this monograph.

JUNIOR SECTION.

Electricity Applied to Marine Engineering (Section 9).

By W. LAWS, M.Sc., A.M.I.E.E.

The Tracing and Correction of Faults in D.C. Generators and Motors.

The most common faults to which a d.c. generator is liable are:—

(*a*) Sparking at the brushes.
(*b*) Overheating.
(*c*) Failure to excite.

Any one of these faults would of course be immediately obvious to the ordinary senses, and the problem of the engineer is to diagnose the cause of the fault and, if possible, rectify it.

(*a*) *Sparking at the brushes.*

This would normally be due to:—

(1) Wrong brush position.
(2) Dirty commutator.
(3) Brushes not properly bedded.
(4) Incorrect spring pressure on the brushes so that they "chatter" on the commutator.
(5) Micas projecting above the surface of the commutator.
(6) Worn and uneven commutator.
(7) Wrong grade of brush.
(8) Overloading.

(1) Wrong Brush Position.

On a generator or motor fitted with interpoles there should be one brush position which should be correct for all loads within the normal working range of the machine. On a generator not fitted with interpoles the correct brush position will depend on the load; the higher the load, the more "forward lead" should the brushes have. The reason for this was explained in Section 3, when dealing with armature reaction. Whether the machine has interpoles or not, if it is suspected that the sparking is due to wrong brush position, the obvious remedy is to try and find a better position. When doing this the brush rocker should be moved very gently and gradually in the direction of the edge of the brush which is sparking, if the sparking is taking place along one edge.

(2) Dirty Commutator.

This will be visible. Run the engine slowly, and with the brushes up. Clean it with a rag soaked in paraffin; then wipe the commutator clean, and run a wax candle across it while the armature is revolving. Some grades of brush with a high percentage of graphite are self-lubricating. The commutator surface should not be greasy, or carbon dust will adhere to the grease and may cause a short circuit between commutator segments.

(3) Brushes Not Properly Bedded.

When a new electrical machine is on the test bed the tester usually sees that the brushes are properly bedded. When, later, replacement brushes are fitted, these must also be properly bedded. If it is a small machine having a commutator only a few inches in diameter, this can be done very well by the method illustrated in Fig. 94. A long strip of emery cloth or glass

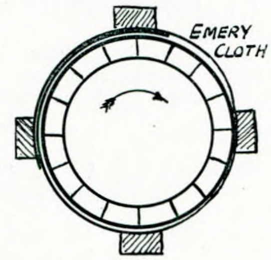


Fig. 94.

paper of very fine grade is wrapped round the commutator with an overlap of rather more than one brush arm pitch. The armature is then rotated by hand, and the brushes are ground to the same curvature as the armature surface. On larger machines it will probably not be possible to obtain a strip of emery paper long enough, and in any case it would probably be impracticable to turn the machine round slowly and smoothly by hand, so the

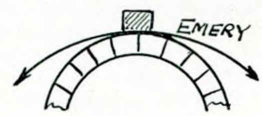


Fig. 95.

method illustrated in Fig. 95 may be used. The great thing is to be careful not to take the corners off the brushes.

(4) Incorrect Spring Pressure.

The correct spring pressure will depend on the grade of brush. If the brushes are obviously "chattering" and the correct spring pressure in lb. per sq. in. is not known, the spring tension should be increased until the chattering ceases. Too great a pressure will cause extra friction loss and overheating of the commutator.

(5) Projecting Micas.

These can be detected if not by the eye, then by running the finger tips over the commutator surface. The micas should be cut down a little below the surface; not too much, or the space left will become a collecting ground for dirt and carbon dust. This job is frequently done quite satisfactorily with a piece of broken hack-saw blade.

(6) Badly Worn Commutator.

A badly worn commutator, the surface of which has ceased to be perfectly cylindrical should be trued up. This can probably most conveniently be done in its own bearings, though naturally the job can be equally well done in a lathe if it is convenient to do so. A very light cut can be taken with a sharp tool, or what is perhaps the better way is to grind it true with an emery wheel.

(7) Wrong Grade of Brush.

There are certain firms who specialise in the manufacture of brushes. They can easily be found from the advertisements in the electrical press. They manufacture brushes in a great variety of grades to suit every service and condition of working. The uninitiated who think that one carbon brush is very much like another carbon brush, would be surprised at the number of grades there are. These companies carry a staff of engineers whose job it is to give expert advice on brush problems. They will probably try to sell some of their brushes. That is in the nature of things, but does not minimize the value of their expert assistance and advice. Persistent sparking and brush troubles have frequently been cured by changing the grade of brush.

(8) Overload.

Unless there is an actual defect in the machine, this should be visible from the ammeter. The obvious remedy is to reduce the load, if possible.

Sparking at the commutator may also be due to defects which have developed in the armature winding, e.g. short circuits, open circuits, or earths. The methods of testing for these will be dealt with later.

(b) Overheating.

There are certain maximum temperature rises laid down by the British Standards Institution for the various parts of electrical machines, depending on the materials with which they are insulated. Strictly speaking, the temperature *rise* does not matter in the slightest. It is the final maximum temperature that matters. This must not be high enough to cause damage to the insulation or materially reduce its normal life. These maximum temperature rises are therefore fixed on a basis of a certain maximum ambient air temperature. If an electrical machine were insulated entirely with asbestos and mica, it could work at a very high temperature indeed without damage. In this connection it may be remarked that a machine which feels very hot to the touch need not necessarily be dangerously hot from the electrical point of view. Probably the weakest spot in the insulation is the cotton covering or cotton tape. Our cotton underwear is washed in boiling water, and though it may sometimes come back in shreds, that is not usually attributable to the hot water. Yet there are very few people who would willingly put their hands in boiling water.

Overheating in the case of armatures is usually to be attributed to :—

(1) Overloading.
(2) Blocking up of the ventilation passages with dirt and fluff.

It may also be due to short circuits or earths in the armature, but these are abnormal conditions. The remedy for excessive heating caused by overloading is obviously to reduce the load. Overheating caused by a defect in the armature will not show up on the ammeter, but a severe overload owing to this should show up in the running of the engine. In these days of severe competition the design of electrical machines has become a very fine art. We are all trying to get quarts out of pint pots. Every manufacturer tries to produce a machine which will give as good or better service than that produced by his competitors, using less material if possible, and for less labour charges. The only way in which one can work with the use of less material, which means higher current densities in the copper and higher magnetic flux densities in the iron, is by arranging that the extra heat produced because of these high densities can be got rid of and so not raise the temperature of the machine above the permissible maximum. Remember that the temperature of a body remains stationary only when it gets rid of its heat as fast as it acquires it. The heat generated in the electrical machine is usually carried away by currents of air which enter the machine cold, and leave it warm. This necessitates the most careful design of the ventilation system, including a consideration of the cross-sectional area and form of all of the ventilation passages, and the calculation of the number of cubic feet of air which may be expected to pass through the machine per minute. If these carefully worked out ventilation passages are allowed to become clogged with dirt, all of these careful calculations go by the board. The machine should therefore be given a blow out with compressed air from time to time, particularly the ventilation passages through the armature core. Another point to be remembered is that metals are good conductors of heat. If bearings are running very hot, the heat will be conducted along the shaft to the armature core, and thence probably to the insulation on the armature windings. Field coils should not normally become overheated, unless one field coil is short-circuited, when that coil will remain cool, and the other coils become warmer than normal.

(c) Failure to excite.

This applies to self-excited generators and may be due to a variety of causes, the chief of which are :—

(1) Loss of residual magnetism.
(2) Too high resistance in the field circuit which may be due to :—
  (i) too high resistance in the field regulator;
  (ii) loose field connection;
  (iii) actual break in field circuit;
  (iv) too high brush contact resistance.
(3) Reversed magnetic polarity.

(1) Loss of Residual Magnetism.

If the machine in question is one which normally runs in parallel with others, and the others are all right,

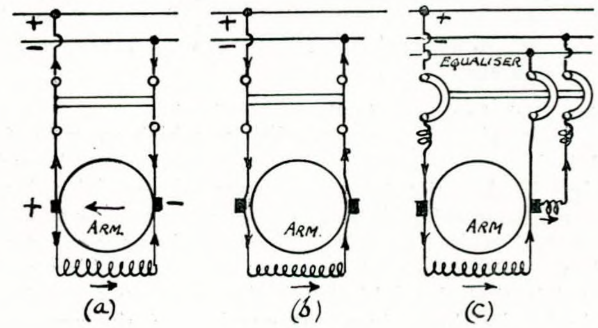


Fig. 96.

then the matter can be quite easily rectified. Lift the brushes off the commutator with the main switch open and the machine at a standstill. Close the main switch for a second; open it again; replace the brushes, making sure that they are pushed well home and sliding easily in their boxes. Then start up the set, and it should be found to excite satisfactorily. A study of Fig. 96 will show why this is. Fig. 96 (*a*) shows the normal current directions for a shunt generator when it is delivering current to the bus bars. Fig. 96 (*b*) shows the current direction when the brushes have been lifted and current flows from the bus bars through the shunt field. It will be noticed that the current flows in the same direction through the shunt field in both cases. Even had the machine been short shunt compounded, Fig. 96 (*c*), in which case the current would flow in the correct direction through the shunt field, but in the wrong direction through the series field, it would not make any material difference because the number of shunt field turns so greatly outnumbers the series field turns. Since it is the same current flowing through both windings in this particular case, the ampere turns of the shunt field would swamp the ampere turns of the series field, so that the poles would be magnetised in the right direction.

When there is only one generator on the ship the problem is not quite so easy. An old-fashioned remedy used to be to run the machine at overspeed and give the frame a few good blows with a hammer. This sometimes works. Another way is to fasten a piece of fuse wire across the brushes and run the machine up. After a while the fuse wire blows and the machine promptly picks up. One marine engineer told the author that he used to do this regularly, using a piece of fairly stout copper wire, obtaining a splendid firework display when the wire fused. He asserted that the machine invariably picked up all right. Another method which might be tried would be to beg, borrow, or steal as many accumulators as possible, connect them all in series, and then connect the positive of the battery thus formed to the end of the shunt field which would normally be connected to the positive terminal or brush of the generator, and the negative of the battery to the other end of the shunt field. Although the battery voltage would probably be less than the normal terminal voltage of the generator, it would probably still be sufficient to send a little current round the field windings sufficient to restore the residual magnetism. The field windings should be disconnected from the armature when doing this, and the machine should be at a standstill. The piece of fuse wire is, however, probably the simplest and most direct remedy to try for a start.

(2) Too High Resistance in the Field Circuit.

One of the necessary conditions which must be fulfilled before any direct current generator can be self-exciting is that the total resistance of the field circuit shall not be greater than a certain maximum known as the critical resistance. The theoretical reason for this need not concern us at the moment. The thing to be realized is that the field circuit does not consist only of the field coils themselves. It consists of the armature, the brush contact resistance, the brush resistance, the connecting wires, the field regulator, and the actual field coils. In the case of a series generator, the resistance of the external load circuit must also be included. Short of an actual break in the field circuit then, the field circuit resistance can exceed the critical resistance by having too much resistance in the field regulator, by the brushes not making good contact with the commutator, or by terminals not being screwed up tightly. The author has had cases of marine engineering students wiring up a generator which then refused to excite, and it being found that an extra half-turn on one terminal did the trick, and also of cases where a brush had been withdrawn from its box, and then replaced without being pushed well home, so that the machine refused to excite.

(3) Reversed Polarity.

This might occur if the machine had suffered a very heavy short circuit, or, in the case of a compound generator running in parallel with others, it might be caused by an excess reverse current flowing through the series windings on shutting down. The remedy is to raise the brushes, close the main switch, open the main switch, replace the brushes, and then run up the set, as described above.

There was a case of a new machine on the test bed for the first time which obstinately refused to give any volts whatever. In this case the machine was actually an alternator and therefore separately excited. After several hours of investigation, and some most ungenteel language had been spent on it, it occurred to someone to test the magnetic polarity of the poles. It was found that they were all north poles. This was due to an error in the drawing office, but the drawing had passed through four peoples' hands for checking without the error being detected. The point was that the various individuals through whose hands the drawing passed were not looking for that particular error, it being taken for granted that the point was so fundamental that it was bound to be all right. Which all goes to show that in engineering it does not do to take anything for granted. The poles should of course be alternately north and south. Such an error would naturally never get past the test-bed of the manufacturer. If, however, a spare field coil were fitted at sea, it might conceivably be connected the wrong way so that the pole had the wrong polarity. This point can be checked by bringing a small compass needle slowly up to the face of each pole in turn.

Testing.

Testing for actual faults in an electric machine can be divided roughly under three heads.

(1) Continuity tests.
(2) "Drop" tests.
(3) Insulation tests.

(1) *Continuity tests.*

The purpose of a continuity test, as the name might imply, is to ascertain whether a circuit which ought to be electrically continuous, really is electrically continuous. It can be carried out either with an accumulator and detector, which is a form of galvanometer for detecting small electric currents, or using a test lamp in connection with the mains. In Fig. 97 (*a*), if the circuit

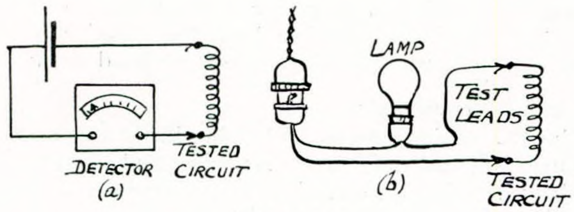


FIG. 97.

is continuous the detector will indicate. In Fig. 97 (*b*), if the circuit is continuous, the lamp will light. When applying the test to the field circuit of a generator which refuses to excite, the test should first of all be applied to the complete field circuit. If it is evident that there is a break somewhere in the field circuit, then the circuit should be sectionalised into field coils, leads, field regulator. This particular test will not detect a break in the armature because there are always at least two paths in parallel through an armature. A break in an armature coil is detected by a drop test, which will be described later. If the break is traced to the field winding itself then the individual coils should be disconnected and each coil tested separately until the faulty one is located. This should then be replaced with a spare if one is carried, which is not always the case. Actually it would be very rare indeed for one of the wires in a lower layer on a field winding to break, unless it were burnt out owing to a short circuit on the field. If any visible and get-at-able wire parted, then it should be a comparatively simple matter to repair it. If the break is in the field regulator, then it should be disconnected from the field circuit and the test leads attached to its terminals. The hand-wheel should then be slowly turned round, one contact at a time. A point will be found where the lamp lights at one contact, and does not light on a contact next to it. The break is then in the regulator coil connected between those two contacts. It may be possible to repair the break fairly easily. If not, no harm will be done by short-circuiting that section out altogether with a piece of copper wire of suitable size.

(2) *Drop Tests.*

A drop test which is used to detect armature faults depends on the fact that if a current is sent through a number of identical resistances in series, the voltage drop across each resistance will be the same. The individual coils of an armature attached to adjacent commutator segments are as nearly identical as human ingenuity can make them. If, then, a current is passed through an armature winding from brush to brush, the voltage drops measured in succession between adjacent commutator segments should be identical if the armature is perfect. As the total resistance of an armature winding is always very low, the resistance of individual coils is very low indeed, and even with full load current passing through them the voltage drop across the individual coils will be very low. It is therefore generally necessary to use a millivoltmeter which reads to one thousandth of a volt. If a millivoltmeter is not available, a detector or an ammeter might be used.

The faults which may exist on the armature are :—

(*a*) Short circuit.
(*b*) Open circuit.
(*c*) Earth.

Fig. 98 illustrates the method of testing for (*a*) and (*b*), coil *X* being short-circuited and coil *Y* open circuited. A short circuit really means that the short-circuited section has negligible electrical resistance. To

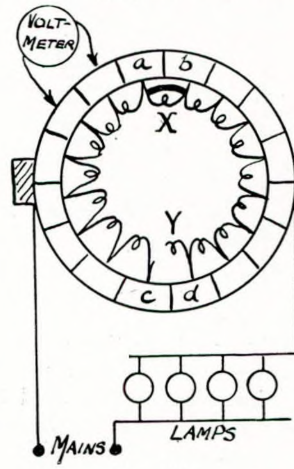


FIG. 98.

send a current through a negligible resistance requires only a negligible voltage. If current is passed through the armature from the mains through a bank of lamps in order to limit it to a safe value, and then the millivoltmeter is travelled round the commutator, being connected successively to two adjacent commutator segments it will read the same each time until it comes to the two segments to which the short-circuted coil is attached. Then it will read nothing, because the voltage across that coil is negligible. This would happen when the voltmeter is connected to segments *a* and *b*. On the other hand, if the voltmeter is travelled round the lower half of the armature, where the open-circuited coil *Y* is lying, it would read nothing at all until it was connected to segments *c* and *d*, when it would give a comparatively large reading. The reason for this is that until the voltmeter is connected to segments *c* and *d* there is no way through for current round the lower half the armature, so that there being no current there are no voltage drops.

When the voltmeter is connected to segments *c* and *d* the voltmeter itself bridges the break in the winding, and the resistance of the voltmeter being very much greater than that of the armature coils, practically all of the voltage now being expended on the lower half of the armature is expended on the voltmeter itself, which records it.

Earth on an Armature.

There should be no electrically conducting path between the commutator and the shaft on an armature. If the insulation of an armature coil has broken down so that there is an earth on the armature winding, there will be such a conducting path. If then, test lamps are connected as shown in Fig. 99, they should not light if there are no earths. If they do light it indicates that there is an earth on one (or more) of the armature coils,

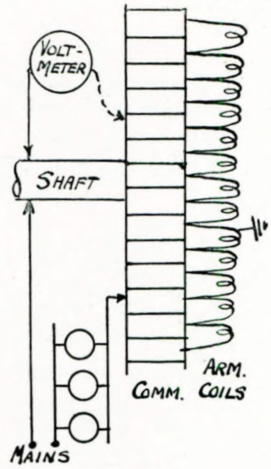


FIG. 99.

but it does not indicate where the earth is. This can be detected by attaching one of the millivoltmeter leads to the shaft and travelling the other round the commutator. There should come a point where minimum deflection is observed on the voltmeter. When this point is located the earth will be found on one of the armature coils attached to that commutator segment.

(3) *Insulation tests.*

These are carried out with a "Megger", usually when the machine has been subjected to excessively damp conditions, to ascertain that the insulation resistance has not decreased to an unsafe value without the insulation having actually broken down. Such a state of things might occur if a machine had been immersed, or partially immersed, in flood water.

The keynote of efficient testing is system. When looking for a particular fault start with the whole circuit and then gradually sectionalise it, testing each section in turn until the fault has been traced to as small a section as possible. It is remarkable how the locality of the trouble can be narrowed down by a little head-work.

Care and Maintenance.

The two main sources of trouble likely to occur on d.c. generators and motors are sparking and overheating. Provided that the machine has been carefully designed in the first place, and has been kept clean, there should be no trouble from overheating under normal load conditions. Most modern machines are fitted with interpoles, so that sparkless commutation should be obtained at all loads with one fixed brush position, the precise position of which should have been ascertained and marked on the test bed. The following points summarize what has gone before with regard to obtaining the best performance from a d.c. machine.

Clean the commutator occasionally with a paraffin rag and lubricate it very slightly.

See that the brushes are well bedded and can move freely up and down in their boxes.

If there is any tendency to spark, find the brush position which gives no, or minimum sparking.

Use the correct grade of brush as recommended by the makers.

Keep the micas cut down slightly below the commutator surface.

See that the "tails" between brushes and brush-holders are in place and functioning properly. The spring which holds down the brush should not be permitted to carry the current.

Keep all parts of the machine scrupulously clean, blowing the inaccessible places clear with compressed air. This is particularly important in the ventilating passages.

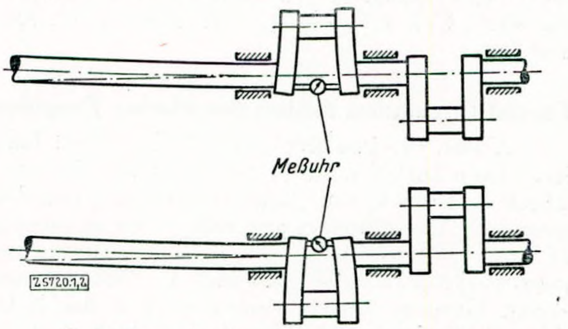
See that there is sufficient oil in the bearings and that the oil rings are running freely.

Occasionally check up on the insulation resistance of armature and field coils.

Abstracts of the Technical Press

Alignment of Crankshafts.

In cases in which internal combustion engines are coupled direct to electric generators and, more especially, where the flywheel is fitted between the generator and the crankshaft without a bearing between the former and the flywheel, the lining up of the main bearings may become a matter of some difficulty. The use of a simple dial distance gauge, however, enables even the smallest degree of misalignment to be detected without disturbing the main bearings. The dial distance gauge is inserted



Detecting misalignments in crankshafts.

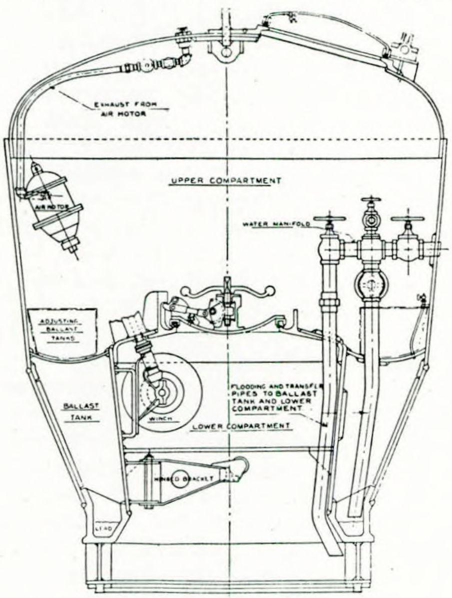
between the crank webs, as shown in the diagram, and the shaft is rotated; should there be any misalignment, and if the bearings are rigidly secured in place, the shaft will flex and the distance between the inner cheeks of the crank web will be altered, the extent of the alteration being registered on the dial of the distance gauge. In order to keep the points of the latter in place, it may be advisable to centre-prop the cheeks of the crank web. This matter of checking the alignment of the main bearings of Diesel generator sets in ships has been in use for some time past with satisfactory results. —*W. Schulz, "V.D.I.-Zeitschrift", Vol. 83, No. 27, 8th July, 1939, p. 805.*

Trials of Russian River Service Tug with Producer Gas Engines.

A series of trials were recently carried out with the producer gas propelling plant fitted in three of the river service tugs built at the Kostroma Shipyard. These tugs are vessels of about 21 tons displacement, a waterline length of about 50ft. 3in., a beam of 10ft. 6in., and a maximum draught of just under 2ft. 5in. The propelling machinery consists of a set of "Stalinets 60" four-cylinder vertical gas engines designed to give the tugs a speed of 8·6 knots in still water in a light condition. The fuel capacity is 106 cu. ft. of wood fuel. The trials included tests with two different types of gas generators, scrubbers and cleaners, and they proved eminently satisfactory. In the case of the producer gas plants of the "Sh.-5" model, the engines turned at 350, 440 and 530 r.p.m. respectively, giving towing pulls of 348, 682 and 858lb. and speeds of 1·67, 2·43 and 3·03 knots, while with the "LS-2" type of plant engine speeds of 340, 465 and 540 r.p.m. were attained, giving towing pulls of 324, 676 and 874lb. and ship speeds of 1·80, 2·63 and 2·93 knots respectively. The wood used as fuel in the gas generators had an average moisture content of 35 per cent. and the 105 hours' trials with the "Sh-5" type plant showed an average fuel consumption of 123lb./hr., while that for the 65 hours' trials with the "LS-2" type was 117lb./hr. Petrol was used for starting purposes, about 0·25 gal. being required in each case for a first start, a change-over to gas fuel being made in under 1·5 minutes provided the producer plant had been lit up at least 25 minutes before. The time required to generate gas for running purposes varied according to the moisture content of the wood fuel and the state of the weather, being 25 minutes to 2 hours under the least favourable conditions.—*J. P. Petrov, "Soudostroienie" No. 6, 1939, pp. 338-345.*

U.S.N. Submarine Rescue Chamber.

The diving bell or rescue chamber used for saving the lives of 33 members of the crew of the sunken submarine "Squalus", was designed by the U.S.N. Bureau of Construction and Repair. It is a steel structure 10ft. high with a maximum external diameter of 7ft. 9in. near the top tapering to a diameter of 5ft. at the bottom, the total weight being just under 9 tons. The chamber is open at the bottom and has a rubber gasket, $\frac{7}{8}$in. in thickness, fitted around its lower edge, enabling it to withstand an external pressure of 165lb./in.^{2}. The interior is divided into three compartments, the lowest of which is an annular ballast tank with a capacity of 400 gallons. The upper compartment of the rescue chamber is fitted with four watertight connections in its domed top. These are the air inlet, venting valve, telephone lead-in, and electric light cable, respectively. Air is supplied through a 1-in. armoured hose from the tender. The upper compartment is the one used by the salvage operators and passengers, and it contains all the operating gear with the exception of the reel for the down-haul wire. The fittings in the compartment include an air motor with air supply and exhaust pipes and valves, and the upper compartment blow and vent valves, as well as the blow and vent manifold for the lower compartment and ballast tank. There are also 14 portable ballast tanks, a caisson gauge, a sea pressure gauge, the lighting system, two portable battery lamps, four holding down rods, and a telephone for communication with the tender. The air motor is similar to a pneumatic drill motor and is geared to a reel located in the lower compartment on which is wound the wire for raising and lowering the unit. The controller is on the air supply line and the movement of this controller determines the direction of the motor's rotation. The motor is designed to stall before any part of the system is subjected to a breaking strain, so that it may be run at full speed without any risk of parting the wire cable. The air supply to the motor is taken through the control valve overhead directly from the air supply line from the surface connection, and exhausts through the overhead exhaust valve directly into the vent pipe running to the connection at the top of the chamber. For convenience and ready identification, the air supply line is



Cross-section of the Bell. The upper dry compartment accommodates ten men.

painted yellow, while the vent system is coloured red. Both hatches in the upper compartment, that at the top of the chamber and the connecting hatch to the lower compartment, are of the latest submarine escape type and may be easily worked from either side. The lower compartment contains the downhaul cable and reel, a snatchblock through which the wire is run, and a bracket which serves as a fairlead for the wire and centres it in the compartment when hauling in or veering. The wire cable is of ½-in. plough steel and has a total length of 450ft. One end is secured to the reel, while the other is attached to a special shackle which fits the spindle of the submarine's hatch. Both the snatchblock and bracket can be swung back out of the way after the cable has been unfastened from the submarine hatch. The blowing, venting, and flooding connections in the lower compartment are all controlled from the upper compartment. There are a number of equally-spaced slots in the circular web which runs round the inside of the hull in the lower compartment. The holding-down rods, stowed in the upper compartment, fit into these slots, their nuts being screwed tight against the web. The shackle on the bottom of the rod is secured to a pad eye outside the submarine's hatch and with four rods in use the chamber is held tightly to the hull of the submarine. The capacity of the lower compartment is almost exactly the same as that of the annular ballast tank, which runs round its interior. Access to the latter is obtained through handholes, closed by bolted plates, in the compartment. A cross-section of the chamber is shown in the accompanying drawing.—*"The Nautical Gazette", Vol. 129, No. 11, 3rd June, 1939, pp. 12 and 38.*

Forced Circulation Boilers for Marine Propulsion.

Within the last five years 23 La Mont boilers have been installed in 11 seagoing vessels, one of which is French, one Japanese and the remainder German. These boilers generate steam at pressures of from 178 to 710lb./in.^{2} at superheat temperatures varying from 518° to 842° F. The two most recent German vessels concerned are the N.D.L. liners "Minden" and "Nienburg", each with two coal-burning La Mont boilers fitted with Steinmüller mechanical stokers. The only merchant vessel to be equipped with Velox boilers for supplying steam to the main engines is the Finnish passenger steamer "Bore II" in which the two oil-fired Velox boilers generate steam at a pressure of 285lb./in.^{2} and at a superheat temperature of 608° F. The Messageries Maritimes liner "Athos" has, besides her original boilers, an additional Velox boiler supplying steam at a pressure of 682lb./in.^{2} and superheat temperature of 842° F. to a special high-pressure turbine which has been added to her original turbine installation. An experimental Velox boiler generating steam at a pressure of 265lb./in.^{2} and superheat temperature of 617° F. has been in use on board the German warship "Arcona" since 1935. A Sulzer high-pressure boiler generating steam at a pressure of 882lb./in.^{2} and superheat temperature of 707° F. was installed in 1936 in the Rotterdam Lloyd's fast cargo steamer "Kertosono" to supplement the original boilers and to provide steam for an additional high-pressure turbine. The boiler has given satisfactory service for over 11,000 steaming hours, although it has caused a slight rise in the fuel consumption of the ship. This is largely due to the fact that the auxiliary machinery is not of modern design. The merchant vessels to be equipped with Benson boilers within the last five years include the German steamers "Uckermark", "Potsdam", "Windhuk" and "Pretoria", and the Hamburg-American Line are now building a 36,000-ton vessel in which the whole of the steam will be supplied by eight Benson boilers.—*"Bulletin Technique du Bureau Veritas", Vol. 21, No. 7, August, 1939, pp. 140-141.*

The A.C. Diesel-electric m.s. "Wuppertal".

Recently the Hamburg-American liner "Wuppertal" was towed from Las Palmas to Hamburg owing to a break-down of her propelling machinery which was, however, in no way due to any trouble with the electrical equipment or with the Diesel engines. Among the new features in this vessel are the roller bearings utilised for the propeller shaft aft of the propelling motor. Owing to failure of the stern gland packing sea water leaked through the stern gland and reached the bearings, but it was only after the ship had proceeded at full speed for four days that these roller bearings gave way.—*"The Motor Ship", Vol. XX, No. 235, August, 1939, p. 156.*

U.S. River Tugs with Kort Nozzles.

Two river tugs of special design combining very small size with unusual engine power, were recently launched on the Ohio River at Pittsburgh. The tugs were built for use on construction jobs on inland rivers as well as at remote places inaccessible by water from Pittsburgh, for which reason the dimensions conform to those prescribed for rail shipments to any part of the U.S. The hulls are of all-welded construction, 45ft. × 11ft. × 5ft. 9in., with a draught of 3ft. 6in. on a displacement of 28 tons. The propelling machinery consists of a 125-h.p. Red Wing Waukesha-Hesselman engine running at 1,000 r.p.m. and driving the propeller through a 2 : 1 reduction and reverse gear. The engine operates on furnace oil using Bosch fuel injection and spark plug ignition. The fuel tanks hold 830 impl. gallons, which is sufficient for 11 hours' running at full speed. Electric starting is provided for from high-capacity 12-volt batteries. The engine is controlled from the pilot house. The Kort nozzle propulsion arrangement consists of a 4-bladed bronze propeller, 38in. in diameter, enclosed by a heavy welded steel-plate nozzle. The latter has internal framing and stiffening to ensure strength for resistance to grounding and drift shocks. The nozzle is self-buoyant. There are three rudders, two ahead of the nozzle for astern steering, and one aft on the centre line for ahead steering. These rudders are supported by bearings on the nozzle lip and are operated simultaneously by a hand screw-type gear connected by shafting and sprocket chains to the pilot house wheel. The Goodrich cutless rubber stern bearing is carried by a cantilevered cone-shaped structure which eliminates the strut and improves astern steering. The results obtained from dynamometer tests of one of the tugs were:—

Thrust ahead at dock ...	4,400lb.
Thrust astern at dock ...	3,500lb.
Steering power ahead ...	2,200lb.
Steering power astern ...	2,000lb.
Free running speed, m.p.h.	10 (−8·68 knots).

Measured mile trials with two barges measuring 135ft. × 27ft. × 8ft. 6in., each carrying 500 tons of cargo, showed a still water speed of 4·55 m.p.h., while with only one of these barges a still water speed of 6·05 m.p.h. was attained. The tugs turn ahead at full speed in a radius of about 1½ lengths, and astern in 1 length, pivoting about a point slightly aft of the bow. Full control ahead and astern, port or starboard, makes it possible for the tugs to handle very heavy tows in an emergency and provides an ample margin of safety under normal conditions. As a comparison, a sternwheel tug of conventional design, producing the same amount of power, requires dimensions of 89ft. × 16ft. × 4ft., with a displacement of 81 tons on a draught of 3ft. 6in. The excellent results obtained with the two small tugs have already led to a similar installation in a large twin-screw tunnel-stern river tug,. The improved towing and manœuvring performance offers possibilities of greatly reduced costs in river towing in the future with smaller tugs, less power and greater safety.—*C. R. Horton, "Marine Engineering and Shipping Review", Vol. XLIV, No. 7, July, 1939, pp. 337-338.*

Salvage of the "Stockholm's" Hull.

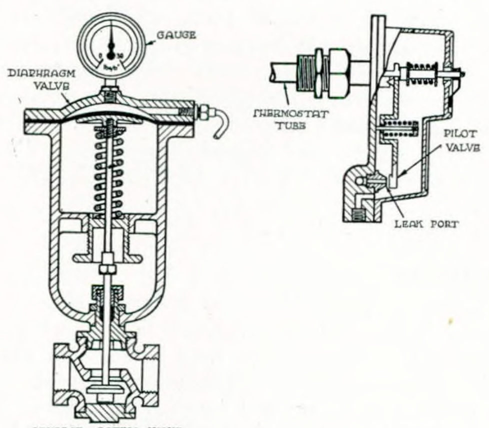
The after section of the hull of the Swedish liner "Stockholm", destroyed by fire last year while still under construction in the Monfalcone yard at Trieste, was found suitable for use, while the remaining portion of the hull proved unusable. The entire hull was drydocked and divided in two parts, after which it was refloated. The portion to be scrapped was towed to the fitting-out basin to be broken up, while the salvaged part, weighing some 800 tons, was placed in a floating dock to be fitted out. It was then floated out of the dock and towed to the slipway on which the remaining (new) portion of the hull is under construction in order that the two parts might be joined together.—*"The Nautical Gazette", Vol. 129, No. 13, 3rd July, 1939, p. 22.*

The Gas Turbine.

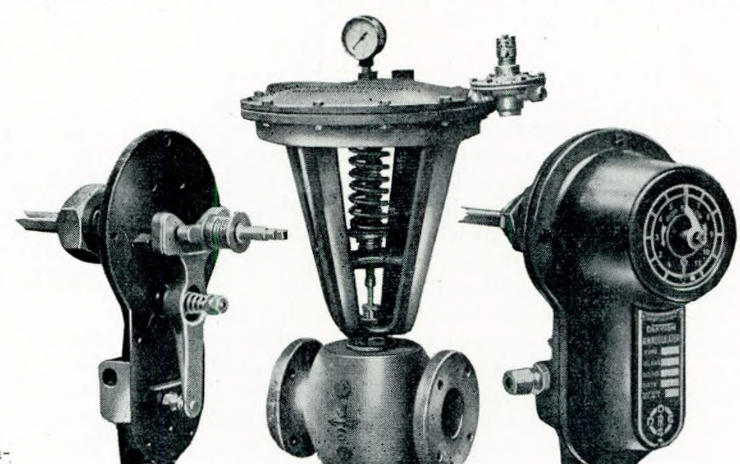
An article by J. W. Fidoe in a recent issue of the *Western Mail* includes a brief historical review of the gas turbine. The first turbine of this kind, designed by Stolze in 1900, consumed all its power in air compression and had an efficiency of zero. The next attempt was by Holzwarth, who abandoned the idea of a continuous combustion turbine and turned to the explosion or constant volume machine, which could be run on oil, gas or pulverised coal. The air pressure required was low and only a little excess air was necessary in view of the water cooling of the casing, blades, nozzles, etc. The machine suffered from the disadvantage of requiring a complicated valve gear and the cooling water had to be turned into steam for driving the air compressor. After 20 years spent in experiments, a machine running on blast furnace gas was put into operation, while another machine of 5,000 h.p. is now under construction. The development of new alloys has enabled renewed attention to be given to the simple continuous combustion gas turbine. Much depends on the highest temperature which can be used without damage to the turbine blades. In the case of exhaust-gas turbines used with Diesel supercharging sets, it has been found that up to 1,000° F. gas temperature is safe for uncooled blading if the temperature variations are not excessive. Efficiency depends upon gas temperature, and while 1,000° F. is on the low side for a gas turbine, the thermal efficiency is nearly 18 per cent. for a 5,000-h.p. machine. The author maintains that, comparing such a gas turbine with a steam turbine of about the same size and working at medium steam pressure with moderate superheat, the efficiency is very little different, and there is no complication of boilers, condensers, feed heaters, etc. The gas turbine is also cheaper, the design is simple and the space occupied is relatively small. A step in the right direction would be the utilisation of the heat of exhaust gases to preheat the compressed air supply. A 2,000-kW. generator set running with gas at an admission temperature of 1,000° F. and provided with a heat exchanger of 5,000ft.^{2}, would have a thermal efficiency of 21 per cent. as compared with 16·5 per cent. in the case of a similar plant without a heat exchanger, while by dividing the gas turbine into two casings with a heat exchanger between them, a unit of the same size could, in the opinion of the author, reach an efficiency of 22·5 per cent. He states that plans are in hand for the propulsion of ships of moderate size (say with main engines of 5,000 s.h.p.) by means of gas turbines, and claims that such combustion turbines would give an efficiency of 20 per cent. with air preheating and show a saving of about 25 per cent. in fuel consumption, as compared with reciprocating engines. There would be no steam boilers, condensers, feed or air pumps, and the plant would be light in weight and occupy a minimum of space, in addition to which it could be started very quickly. The use of new alloys might permit a general increase of the operating temperatures. Raising the admission temperature to 1,200° F. and the use of a moderate size of reheater, would enable an efficiency of up to 26·5 per cent. to be reached and higher efficiencies could be attained.—*"The Shipping World", Vol. CI, No. 2,407, 2nd August, 1939, pp. 137 and 140.*

Thermostatic Regulator for Circulating Water Temperature Control of Marine Oil Engines.

The accompanying drawings show a reverse-acting valve and regulator head as fitted in the circulating water system of the "Royal Daffodil". The normal working pressure required for operating the device is not less than 15lb./in.^{2}, and a reducing valve can be fitted to keep the pressure constant. A small pipe is led from this reducing valve—or from the main supply—to the regulator head, and so long as the pilot valve remains open, the water passes through the leak port and the pressure does not build up on the diaphragm which moves the main valve off its seat. The pilot valve is opened and closed by the thermostat, which comprises a copper tube carrying a non-expanding steel rod attached to its free end. As the water temperature rises the tube expands and moves the rod which, in turn, acts through a nut, on a lever. As indicated in the diagram, the pilot valve is formed



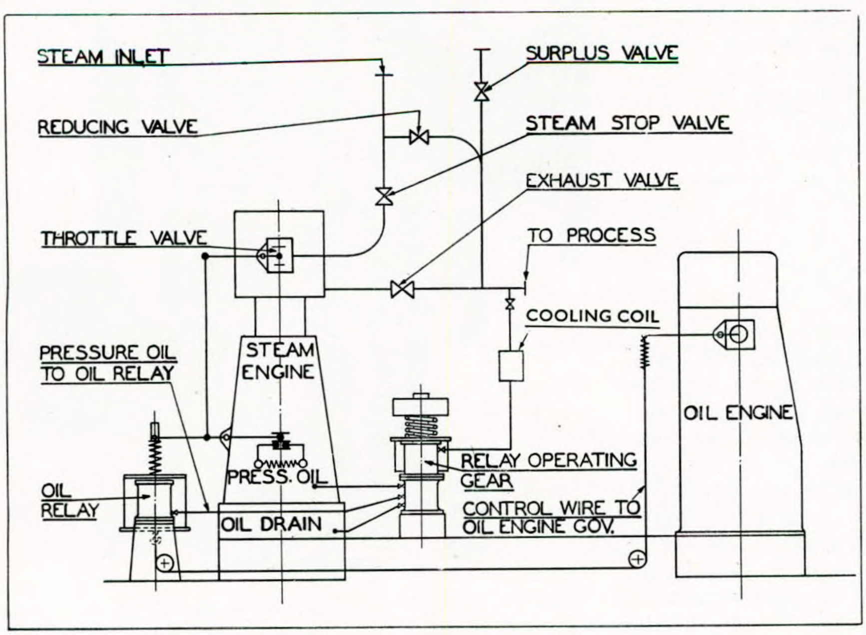
Section through the regulator head and diagrammatic section of diaphragm and connection to valve.


Temperature regulator and circulating water valve.

on the lower end of this lever. If the water temperature falls below a predetermined figure, the thermostat closes the leak port, the water passes to the main valve diaphragm, and the pressure overcomes that of the spring, thereby moving the valve off its seat and allowing the circulating water discharge, for example, to be by-passed in any convenient manner, according to the arrangement of piping.—*"The Motor Ship", Vol. XX, No. 204, July, 1939, p. 146.*

Steam and Oil Engines in Parallel Operation.

A firm manufacturing photographic films on the Continent required machinery to cope with a limited and fluctuating steam load together with a power that might at times be less or greater than that corresponding to the steam passing through a straight back-pressure engine. These requirements called for a scheme in which a back-pressure engine would operate in parallel with an oil engine and was met by the installation of a 150-kW. steam engine-driven alternator, designed for a steam pressure of 260lb./in.^{2} dry saturated, exhausting against a back pressure of 28½lb. gauge, and of a 70-kW. oil engine-driven alternator, both power units being designed to run at 500 r.p.m. The steam unit has a standard crankshaft governor acting directly upon the throttle valve, but having an attachment controlled by an oil-operated piston to which oil from an auxiliary lubricating system of the engine is led through a relay actuated by the exhaust steam pressure, a tapping from the exhaust main being taken to the relay through a cooling coil. The arrangement is shown diagrammatically below. A make-up reducing valve is provided between the steam supply to the engine and the exhaust main, and a surplus valve on the exhaust system is also fitted. The governors of the steam and oil units are accurately synchronized by means of an interconnecting control wire. When the steam engine *only* is in service, and (1) the load is constant and exactly balanced by process steam requirements which then increase, the engine runs with its own speed governor controlling the throttle valve, and both surplus valve and reducing valve are closed. An increase in the steam requirements is immediately followed by a slight fall in pressure in the process steam main which opens the reducing valve and allows some extra steam to pass direct from the boilers into the process steam main. (2) If the load is constant and exactly balanced by process steam requirements which then decrease, the conditions are similar except for the fact that the pressure rise due to the decrease in the outflow of process steam and the surplus valve is automatically opened to allow the excess process steam to escape to the atmosphere. This is a rare condition. (3) If the process steam requirements remain constant and are exactly balanced by a load which then increases, the engine speed tends to fall and the speed governor operates the throttle valve and admits more steam to the engine. As the process steam requirements are constant there is a rise of pressure in the process steam main and the surplus valve opens as in (1). This is also an exceptional case. (4) If the process steam requirements are constant and exactly balanced by the load which then decreases, the engine speed tends to rise and the governor closes the throttle valve. This causes the pressure in the process steam main to fall and the reducing valve to open as in (1). When the oil and steam-driven sets are operating *together* and (5) the load is constant while process steam requirements increase, there is a fall of pressure in the process steam main and the relay operating gear is actuated, causing the throttle valve to admit more steam to the engine. This tends to increase the speed of the latter and also that of the oil engine, which in turn results in a reduction in the load taken by the oil engine and an increase in that on the steam set. (6) If the load is constant and process steam requirements decrease, the pressure in the process steam main rises and the exact reverse of the procedure explained under (5) takes place. (7) If the process steam requirements remain constant, but the load increases, the speed of both units tends to fall. The oil engine governor allows this engine to take up



more load, and as the final speed of the two units is practically unaltered the operation of the steam engine also remains unchanged. (8) If the process steam requirements remain constant and the load decreases, there is a tendency for the speed of both units to rise and the exact reverse of the procedure explained under (7) takes place. The special nature of the installation called for some unusual running tests, but it was found that the permanent speed variation from full-load to no-load with the two sets operating in parallel was approximately 3 r.p.m., representing 0·3 of a cycle on a 50-cycle circuit. The make-up reducing valve and surplus valve maintain a constant pressure in the process steam system within 1lb. gauge from normal, and the heat-power balance of the factory is thus maintained within exceedingly close limits. —*"The Allen Engineering Review", No. 3, July, 1939, pp. 2 and 3.*

Meeting of the Berlin Steam Boiler Owners' Association.

At the meeting of this body held in Berlin on the 8th June, 1939, under the presidency of Dr. W. Lühr, a number of papers relating to current questions of high-pressure boiler construction and operation were presented and discussed. A paper by Dr. H. Föttinger dealt with problems arising from the flow of steam and gases on the water- and fire-sides of boilers. Engineer Commander H. Hellmich read a paper on recent boiler installations in ships and dealt with La Mont, Sulzer, Benson, Schmidt and Löffler forced-circulation boilers. Dr. F. Nehl read a paper on three processes for the manufacture of high-pressure boiler drums, these being gas welding, electric welding and solid-drawing by the Röckner Process. Herr W. Ellrich's paper dealt with the steam requirements of the auxiliary machinery forming part of a boiler installation, including feed pumps, oil fuel pumps, forced circulation pumps, forced draught fans and mechanical stoker power units. Dr. A. Splittgerber read a paper dealing with the effect of impurities in feed water on the operation of high-pressure boilers.—*"Schiffbau", Vol. 40, No. 15, 1st August, 1939, pp. 286-288.*

New Engines of the "Augustus".

The Italian liner "Augustus", a vessel of slightly over 30,000 tons gross, built in 1937, and equipped with six-cylinder M.A.N. two-stroke double-acting engines driving four screws and developing 28,000 s.h.p., was until recently the most powerful merchant motorship afloat. It has now been found necessary to increase the speed of this ship from 18 to 20 knots, and the original machinery is, therefore, being replaced by Fiat engines of the same type, but of about double the horse-power of the old engines. When these alterations are completed the "Augustus" will be the highest-powered mercantile motor vessel in service, or at present contemplated, as the power of her engines will then be well over 50,000 s.h.p., as compared with the 32,000 s.h.p. of the "Dominion Monarch" and the 37,500 s.h.p. of the "Oranje". The machinery of the former is of the Doxford opposed-piston type driving four screws, while the latter has two-stroke single-acting Sulzer engines driving triple screws.—*"Fairplay", Vol. CLII, No. 2,934, 3rd August, 1939, p. 207.*

Imo Pumps for Marine Use.

The patent pumps developed by the A.B. Imo-Industri of Stockholm are fitted in a number of Swedish warships as well as in the Dutch motorships "Bantam", "Japara", "Koningin Emma" and "Prinses Beatrix". The Swedish motor liner "Stockholm" will have 16 Imo pumps and the Dutch motorship "Oranje" 19. These pumps consist primarily of three screws which mesh with each other and fit a sleeve in the bore of a casing. The inner screw is driven, while those on the outside form idler or sealing rotors. The latter are disposed symmetrically, and when made to rotate,

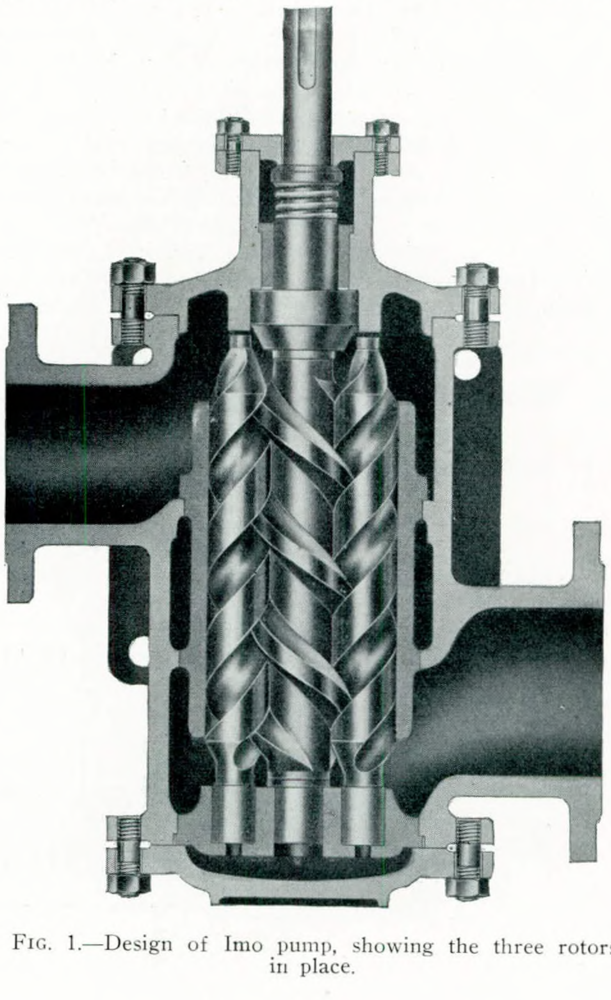


FIG. 1.—Design of Imo pump, showing the three rotors in place.

propel the surrounding liquid axially in a steady flow. The thread acts as a continuous piston which always moves in a forward direction, so that the liquid does not rotate, but flows smoothly, without turbulence and without pulsation. Even at high speeds there is no vibration. The idlers, of course, rotate in the opposite direction to the driver and merely serve as seals. By suitably dimensioning the rotor threads, it is possible to balance the torque on both sides of the idlers in order to obtain the full effect of the driver. As no gears are required to drive the idlers, no power is absorbed for this purpose. The chief characteristic of the Imo design is the shape of the thread faces. A detailed analysis of the form of the thread showed that it was possible to calculate it mathematically in order to obtain a perfect fit, and the rotors are manufactured to the theoretically correct shape. Another condition to be fulfilled is that the number of threads on the driver and the idlers must bear a certain relation to each other so that there will be no passage between the closures. The three rotors are double-threaded to give good sealing and to ensure that they are dynamically balanced. Furthermore, the diameter of the driver at the bottom of the thread must be the same as the external diameter of the idlers. When the length of the rotor is not less than a certain amount in relation to its diameter, there will always be one closure between the suction and the discharge sides for all angular positions of the screws. By making the rotors longer, it is possible to obtain several closures in series, and thus distribute the pressure at several sealing points. For low and moderate heads, it is sufficient to make the rotors with only one or two closures, while for high-pressure pumps the screws are made longer. In pumps operating at moderate heads, ordinary end bearings take the thrust of the rotors, but for high pressures the rotors are hydraulically balanced by means of pistons which compensate the axial thrust and so relieve the end bearings of practically all the load. The pumps may be operated either vertically or horizontally. Priming is not necessary, except to ensure that the rotors do not run in a dry casing when starting up for the first time or after the pump has been drained, and a foot valve in the suction pipe is not essential. Owing to the smooth flow of the liquid, and to the fact that there are no valves, it is possible to operate the pumps without difficulty at very high suction lifts. Other claims made for them are that they can be driven directly by high-speed motors; that they are noiseless and free from vibration; that on account of the high speed and the compactness of the design the weight and size are small, and that, as the idlers are driven by the liquid and rotate without friction, there is very little wear. An efficiency of over 90 per cent. has been obtained with small pumps of about 10 h.p. running with lubricating oil, while smaller pumps of only 1 or 2 h.p. pumping water, fuel oil, etc., show efficiencies of up to 80 per cent. The close fit of the rotors produces a high efficiency even at very high pressures, and Imo pumps are running satisfactorily in service at pressures up to 2,500lb./in.^{2}. It is claimed that the efficiency is practically constant from full load down to one-fifth load. Besides its use for lubricating oil, fuel oil and other similar liquids, this type of pump is used extensively as a fuel-oil pump for oil-fired boilers. It is also eminently suitable for dealing with liquids of varying viscosity, such as oil for lubrication and engine-cooling in ships trading in widely differing temperatures. Test results show very slight variation in capacity and power consumption, even when the viscosity of the oil varies considerably. The pumps installed in the Dutch m.s. "Bantam" are vertical units consisting of two pumps having a common shaft, and built together with only one stuffing box. The pumps are used for the lubrication of the main engines and run at 1,600 r.p.m. The large pump of each set of engines, which delivers oil to the bearings, has a capacity of 80 tons/hr., against a head of 30lb./in.^{2}, while the small pump, delivering oil for the crossheads of the Sulzer-type engine, has a capacity of 10 tons/hr. at 295lb./in.^{2} Imo pumps can be driven by oil under pressure to serve as hydraulic motors and are actually used as such in ships of the Royal Swedish Navy in connection with steering gears. The principle of this pump has also been adapted by its Swedish makers to a variety of other marine auxiliaries, such as windlasses, capstans, winches, etc. The pumps are manufactured under licence by firms in the U.K. and the Netherlands. The arrangement of the three rotors is shown in the accompanying illustration.—*"The Shipbuilder", Vol. XLVI, No. 358, July, 1939, pp. 438-439.*

U.S. Maritime Commission's Cadetships.

The U.S. Maritime Commission has selected 166 young Americans between the ages of 17 and 25, for an "available list" from which future deck and engine-room cadet appointments to American merchant vessels will be made. About 5,000 applications were received, but over 4,000 were eliminated because the applicants lacked the necessary qualifications. Four hundred candidates sat for examinations. There are now 266 cadets undergoing instruction in government vessels with a view to becoming deck or engineer officers in the U.S. mercantile marine.—*"Marine Journal", Vol. 66, No. 6, June, 1939, p. 27.*

Foster-Wheeler Boilers with Automatic Control.

The Foster-Wheeler separately-fired superheater boiler which, after several years of extensive service tests in American vessels is now also being built in this country, is illustrated in Fig. 4. This boiler unit is for closed stokehold operation, the evaporation being 12,000lb./hr., and the working pressure 600lb./in.², while the steam temperature is controllable at any figure between 490° and 850° F.

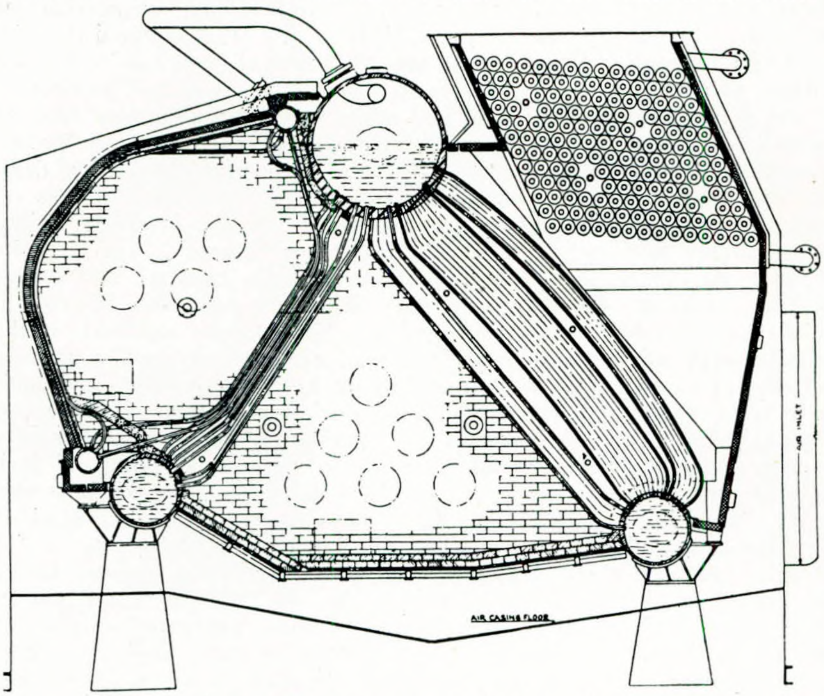


FIG. 4.—Foster Wheeler separately-fired superheater boiler. (*Courtesy Foster Wheeler Ltd.*).

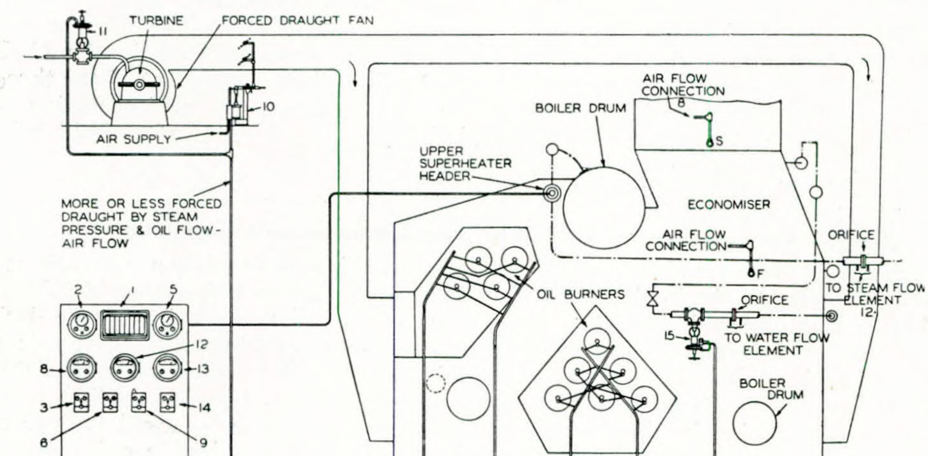


FIG. 5.—Layout of Bailey Combustion control system. (*Courtesy Bailey Meters and Controls Ltd.*).

(1) Multi pointer draught gauge; (2) master steam pressure indicator controller; (3) boiler fuel hand-automatic selector valve; (4) boiler fuel control valves; (5) steam temperature indicator controller; (6) superheater fuel hand-automatic selector valve; (7) superheater fuel control valves; (8) oil flow-air flow ratio indicator controller; (9) forced draught hand-automatic selector valve; (10) forced draught damper control drive; (11)) forced draught fan turbine control valve; (12) steam flow-water flow ratio indicator controller; (13) boiler drum water level indicator controller; (14) feed water hand-automatic selector valve; (15) feed water control valve; (16) control panel.

Steam generation is carried out in the main furnace and in the boiler convection bank, while superheating takes place in the independently-fired superheater furnace lined with radiant superheater elements. The gases from this furnace are discharged into the main boiler furnace through a shallow tube screen composed of superheater tubes on the superheater furnace side, and of boiler tubes on the main furnace side. Since the superheat is controlled directly by adjustment of the firing rate of the burners serving the superheater furnace, any desired superheat can be obtained regardless of the rate of evaporation. The use of radiant heat supply to the superheater makes regulation of the steam temperature particularly sensitive to control by the rate of firing, while the close proximity of the main furnace enables a small degree of superheat to be obtained without firing the superheater furnace at all, thus securing dry steam at all times. Fig. 5 shows the arrangement of such a boiler equipped with automatic boiler control, whereby the firing rate of the superheater furnace burners is controlled by steam pressure and temperature, and the firing rate of the main furnace burners by steam pressure alone. The forced draught damper is controlled in accordance with control impulses derived from steam pressure as well as from the oil flow-air flow. The system also includes automatic feed water control. The superheater is protected against overheating due to high steam temperature and also against overheating due to inadequate steam flow through the superheater, by means of automatic controls governing the fuel supply to the burners in the superheater furnace with a spring loaded valve in the fuel line, which valve is fitted with a solenoid-operated tripping device. The control has two elements, one actuated by the steam temperature, and the other by the steam pressure drop across the superheater. If the steam temperature exceeds the elevation for which the control is set, an alarm device notifies the boiler attendant of this condition, and if no action is taken and a further rise of 45° F. occurs, the control operates and shuts off the oil supply to the burners in the superheater furnace. If the pressure drop across the superheater falls below 0·1lb./in.², the pressure-governed part of the control system comes into action and shuts off the fuel oil valve. The rate of evaporation is, however, not affected by this, as the oil supply to the main furnace burners is not governed by the emergency control gear.—*"Engineering and Boiler House Review", Vol. 53, No. 1, July, 1939, pp. 31-36.*

Compact Ice-making Plant.

A new method of ice manufacture with a small plant, is now available by the introduction of "shell" ice. This crystal-clear ice can be quickly made at low cost, the plant working continuously and producing a steady hourly output of ice in the form of hollow tubes about 14in. long and 4½in. outside diameter, with walls about ½in. thick. The plant is light in weight and occupies a small floor space, while the use of ice cans and brine is eliminated. The light, easily-handled shells are readily convertible into crushed ice. and their rapidity of production does away with the need for storage. These shell-ice plants are self-contained, and comprise an ice-making tank, an automatic refrigerating unit, a small rotary air compressor of special design, an electric motor or other prime mover which drives both the air and refrigerating compressors, a special change-over valve controlling the flow of refrigerant, and automatic control gear. The insulated ice-making tank contains a number of vertical tubes (the actual number varying according to the size of the plant and the output required), 3½in. in diameter, with closed tops. The refrigerant circulates inside these tubes, while around them is the water which is frozen to form the shells. While the freezing is in progress, air from the compressor is introduced at the bottom of the tank to produce the agitation of the water which is essential for the production of crystal-clear ice. At the end of an hour, about ½in. thickness of ice will have formed around each tube, and the hollow tubes must then be released. This is effected by moving the change-over valve to the "defrost" position and thereby reversing the direction of flow of the refrigerant, so that warm gas, instead of cold liquid refrigerant, circulates through the vertical tubes. This quickly melts a thin layer from the inner surface of each cylindrical shell of ice which, as soon as it is thus freed from the tube, floats upwards until 3 or 4in. of its length project above the surface of the water, when it is easily removed with a specially-designed pair of ice tongs. When all the ice shells have been lifted out, the tank is replenished with water, the change-over valve is moved back to the "freezing" position and the process recommences. The low cost of ice production is due to the relatively small amount of power required which, in turn, is made possible by the fact that the ice is formed in actual contact with the direct-expansion surface whereby the evaporating temperature can be maintained at a higher level than with the conventional can system; also, only a comparatively small thickness of ice is formed and, therefore, heat transmission through the ice is maintained at a high rate. The small size and weight of this shell-ice plant enable the whole equipment to be mounted on a motor vehicle or railway truck, if required.—*"Cold Storage", Vol. XLII, No. 496, 20th July, 1939, p. 159.*

Snap-action Mechanical Trap for Compressed Air Lines.

An American firm in Three Rivers, Mich., has developed an automatic snap-action mechanical trap for draining water from compressed air lines, air receivers, separators and after coolers. The principal advantages claimed for the device are immunity from trouble due to dirt, ability to discharge water without any loss of air, positive opening and closing of the discharge valve, and freedom from any need for priming. The body of the trap contains a ball float connected by a flat strip of stainless spring steel to a short valve lever. In the closed position this spring is deflected downwards, but as water enters the body of the trap, the ball float rises, bending and storing up energy in the spring. Just before the ball float reaches the top of the trap, the spring bends past its dead-centre and the stored-up energy snaps the valve wide open. In this position the spring is deflected upwards, but as the water level in the trap body drops, the cycle is reversed and the valve snaps shut. This quick forceful closing action is said to prevent dirt from lodging in the valve and causing leakage. The capacity of the drain trap is given by the makers as 1,400lb./hr. of water at 125lb./in.² pressure and 1,000lb./hr. at a pressure of 250lb./in.².—*"Marine Engineering and Shipping Review", Vol. XLIV, No. 7, July, 1939, p. 338.*

Marine Heavy Oil Engines.

About two-thirds of the marine heavy oil engines built in the past few years are of the two-stroke cycle double-acting type, and although more complicated than the older type of oil engine, such two-stroke engines enable low mean pressures and speeds to be used, more especially for high-power installations. At moderate powers, the four-stroke supercharged engine, working at a fairly high mean indicated pressure, can compete with the two-stroke type in regard to fuel consumption, and such four-stroke engines are largely used in motor tankers. The all-round efficiency of heavy oil engines has improved in the last six years and has enabled a reduction of 15 per cent. in fuel consumption to be achieved, but the main development of the Diesel engine has been in the direction of increased power, rather than in that of thermal efficiency. The overall thermal efficiency of the older type of four-stroke single-acting engine, with blast injection of fuel, was about 35 per cent., and that of the most modern oil engines with air injection, supercharging and exhaust gas boilers, is about 42 per cent. This improvement is, however, much smaller than the 30 per cent. improvement in efficiency which has taken place, since 1923, in the machinery of steam-driven cargo vessels. Theoretical considerations practically preclude any chances of radical improvements on standard designs of present-day marine heavy oil engines, the weight of which has already undergone an appreciable reduction owing to the substitution of electrically-welded mild-steel sections and plates for the castings used in the construction of the framework. The progress made in this and other directions has already enabled a saving of some 50 per cent. to be effected in the weight of a modern installation as compared with an earlier one of the same power, while the corresponding reduction in the space occupied is even more remarkable. —*"Fairplay", Vol. CLII, No. 2,934, 3rd August, 1939, pp. 206-207.*

Preventing Oil Emulsion.

A correspondent writes concerning the trouble he has frequently experienced with totally enclosed high-speed steam engines on account of the water from the steam packing glands passing down the piston rods and into the crank chamber, causing the oil in the latter to emulsify and lose its lubricating qualities. He states that after experimenting with

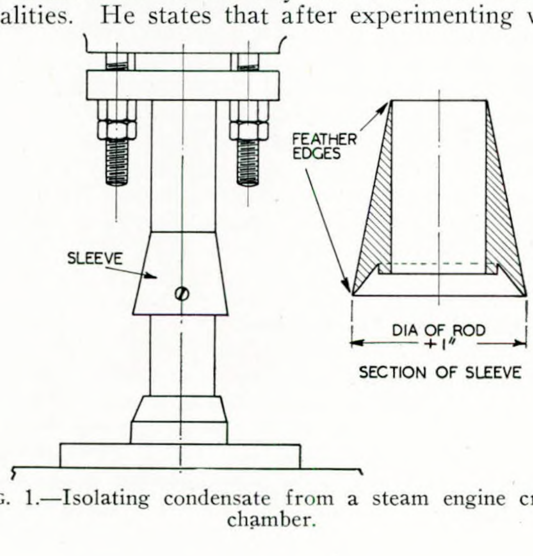
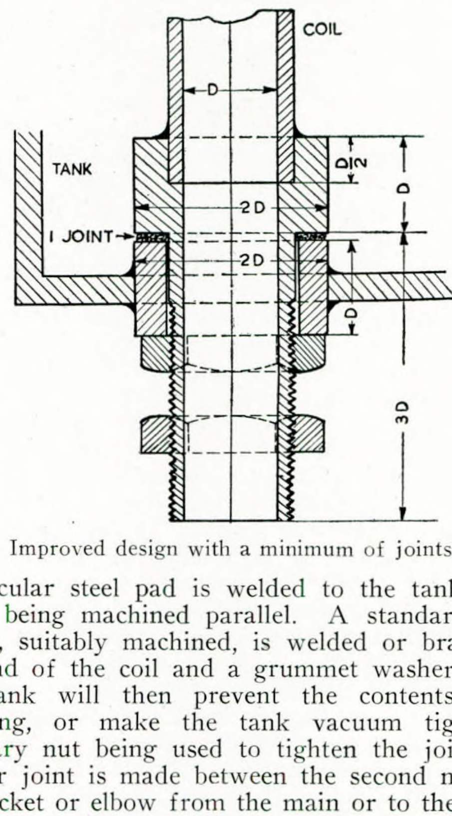


FIG. 1.—Isolating condensate from a steam engine crank chamber.

several ideas in the bottom scraper gland, he came to the conclusion that the device illustrated in Fig. 1 proved the most efficient and inexpensive, and that it enabled a large saving in oil to be effected. The gunmetal sleeve should be a good fit on the rod and kept in position by a small set-screw.—*"Mechanical World", Vol. CVI, No. 2,742, 21st July, 1939, p. 56.*

Steam Coil Joint Design.

A correspondent writes of the scores of different designs of coil joints in use, many of which he regards as expensive, inefficient or lacking in provision for expansion. In some designs, deterioration of the jointing allows steam to escape inside the vessel—a most serious defect, in certain cases. The writer states that he has introduced a form of coil end, either inlet or outlet, which is efficient, easy to make and fit, and which allows the coil to expand without affecting the joints. The arrangement is shown in the accompanying drawing.



Improved design with a minimum of joints.

A circular steel pad is welded to the tank, both faces being machined parallel. A standard steel fitting, suitably machined, is welded or brazed to the end of the coil and a grummet washer inside the tank will then prevent the contents from escaping, or make the tank vacuum tight, an ordinary nut being used to tighten the joint. A similar joint is made between the second nut and the socket or elbow from the main or to the steam trap. The writer maintains that no steam will enter the tank if the inside joint should fail.—*"Mechanical World", Vol. CVI, No. 2740, 7th July, 1939, pp. 15-16.*

Boiler Gauge Glasses.

In choosing boiler gauge glasses it is necessary to consider the nature of the feed water as well as the working pressure to which they will be subjected, particularly in the case of ships which may obtain their water for make-up feed purposes from different ports of call. Moreover, the quality of the feed water entering the boiler will also depend upon the subsequent treatment adopted for reducing its hardness and so on. A trade publication issued by a British firm specialising in problems connected with boiler feed water, contains some notes on the subject of the choice of gauge glasses. Thus for boilers having a working pressure up to 200lb./in.^{2}, it is essential to choose a glass having a high resistance to the solvent action of the water, and this is indicated by the colour of the glass when looked at end on. A high resistance glass has a characteristic light green shade, and the paler the colour, the lower is its resistance. Again, the more alkaline the water in the boiler, the greater is the solvent action, and the consequent thinning of the glass is very likely to occur at the top end, due to the steam condensing and the water thus formed running down the glass. For pressures of 400lb./in.^{2} and over, the flat-type gauge glass rather than the tube is recommended.—*"Shipbuilding and Shipping Record", Vol. LIV, No. 4, 27th July, 1939, p. 103.*

Pegged v. Floating Oil Engine Piston Rings.

Technical opinion is still somewhat divided on the subject of pegged rings in oil engine pistons and this is probably due to the unsound principles applied to earlier attempts to prevent rings from turning in their grooves. The pegs were originally round or square pins screwed into the bottom of the piston groove and fitting into corresponding slots cut in the ring in the way of the gap. This design was mechanically unsound as it weakened the ring section at a vulnerable point and resulted in many breakages. Instances also occurred in which the liner walls and piston grooves suffered damage through the pegs slackening back. For these and similar reasons pegged rings fell into disfavour. In modern practice rings are anchored rather than merely pegged by means of rectangular-shaped lugs machined integral with the upper land of the ring opposite the gap, and fitting into a slot in the ring groove. Such rings, of course, require an increased width of bar between adjacent grooves in the piston, but this method of locating the ring in the groove is based on much more scientific principles than the old way of pegging. The question of whether the extra cost of manufacture is justified remains a debatable point. The wear of the ring and groove landings should, of course, be eliminated. and the life of the piston and the rings lengthened accordingly. Gaps in individual rings are also prevented from working into line, which otherwise nearly always occurs in service. The effect of the gas blowing through the diagonal gap of the ring is to impart a circumferential motion to the latter in its groove. This action is intensified by the wear of the ring and liner, resulting in an increased gap clearance and consequent heavier blow past. The ill effects of the ring gaps working into line can, to a certain extent, be minimised by staggering the gaps in alternate rings, *i.e.,* by having the gap in any particular ring cut at a right angle to those of its neighbours, thereby causing the rings to tend to turn in opposite directions. Unfortunately, this procedure is rarely followed in practice. Another advantage claimed for the anchored ring is that it bears more accurately on the liner walls than a floating one. All liners distort in service proportionately to their diameter, and an anchored ring will more readily assume and retain the exact shape of the liner than one which is free to assume varying peripheral positions. In this way wear of the ring and blow past are also minimised. Piston-working clearance is another factor which has a close bearing on the subject of pegged rings. Advocates of the anchored ring claim that breakages at the port in two-stroke engines are prevented by its use. It is probable that a large percentage of such breakages are caused by excessive clearance of the piston in the liner. In theory, the specified clearance is halved at any point in the piston circumference, due to the position of the piston in the cylinder, but in practice the piston can, and does, take up a position such as that the total clearance all appears one one side. Considerable gas pressure is then exerted on the exposed land of the upper ring, leading to breakage, or at least, to wear of the rings and grooves. In such circumstances, anchoring the rings will have little or no beneficial effect. Piston clearance should be reduced to the absolute minimum permissible, and lead bronze bands fitted below the working rings to reduce the risk of seizure. Floating rings tend to wear the piston groove wedge-shaped in service, *i.e.,* a vertical measurement taken at the piston periphery would be greater than a similar measurement at the bottom of the groove. This action is largely caused by the circumferential motion of the ring, and also by the tendency of the latter to lag behind the piston during some portion of the stroke. This last phenomenon is often referred to as "piston-ring flutter" in small internal-combustion engine practice. Wear will naturally be intensified by excessive piston clearance, where gas pressure causes the upper ring to exert considerable force on the lower land of the groove. On opening up a cylinder for examination of the piston, it is not uncommon to find some of the rings stuck in their grooves due to carbon deposits. Anchoring a ring increases its tendency to stick in the groove, as a floating ring offers less opportunity for an accumulation of carbonaceous material.—*L. J. Holman, "The Journal of Commerce" (Shipbuilding and Engineering Edition), No. 34,778, 20th July, 1939, p. 1.*

Infinitely Variable Speed Control Gear.

An improved form of drive unit, combining in one self-contained assembly any standard make of constant-speed motor, a speed-controlling device by means of expanding pulleys and (if required) speed reduction gears in addition, has been developed by an engineering firm in the U.S.A. The arrangement is shown in the accompanying diagram, and the method used is based on the principle of an expanding V-pulley, each pulley being formed by a pair of cone-shaped discs which can be adjusted to form an infinite number of diameters between minimum and maximum. The two pairs of discs embodied in the unit are mounted on parallel shafts, one of which is driven at constant speed by the motor, while the other transmits power at various adjustable speeds as the connecting belt

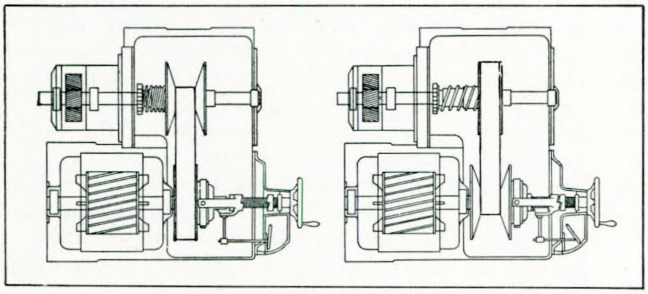


Diagram showing principle of the speed control system.

between the two pulleys assumes different diameters of contact against each set of discs. The inside disc of the pair mounted on the shaft of the motor is keyed and set-screwed to the shaft, but the other disc is spline-mounted, and movable laterally by means of a speed-change screw operated by a handwheel, by which the throat between the two discs can be set at any effective diameter which may be required between minimum and maximum. In the case of the pair of discs forming the pulley on the variable-speed shaft, the disc immediately opposite the fixed disc on the motor shaft is likewise keyed and set-screwed against lateral movement, but the other is movable laterally, its position being governed by a tension spring which keeps it in proper contact against the V-belt, thus providing the exact amount of tension necessary to transmit full load without belt slip. At maximum speed setting the discs on the motor shaft are in the closed position, while those on the variable-speed shaft are as wide apart as possible, ensuring that the V-belt runs over the largest diameter on the motor shaft and the smallest diameter on the output shaft. At minimum speed these conditions are reversed. The belt maintains a straight line of travel at all times. Forced lubrication is provided for the enclosed unit (excluding motor and reducing gear) and a system of thorough ventilation maintains a uniform working temperature of the motor and speed-control mechanism. The unit may include a helical reduction gear, the teeth of which run in an oil bath. This type of drive is built in two designs, either horizontal or vertical, and is suitable for use with any standard make of constant-speed motor within normal standard dimensions. The motors can be of any power between 0·25 and 10 b.h.p., and the speed variation from 2 : 1 to 6 : 1. The reduction units of the helical gear type which can also be incorporated permit of many different combinations of sizes, ratios and gears, for output speeds of from 1·35 to 3,480 r.p.m.—*"Electrical Review", Vol. CXXV, No. 3,217, 21st July, 1939, p. 80.*

Board of Trade Engineers' Examinations.

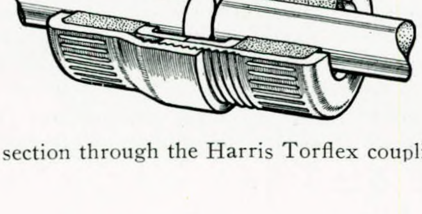
In a notice which has been issued by the Board of Trade with regard to the approved courses for the examination of engineers for the Merchant Navy, it is stated that the Board has indicated its approval of the course of instruction leading to the Ordinary National Certificate in Mechanical Engineering. The approval covers the Courses and National Certificates. also the Higher Courses and National Certificates of Scotland and Northern Ireland, as well as England and Wales. The Board has also approved, it is announced, the courses of instruction leading to the Ordinary and Higher National Diplomas in Mechanical Engineering in England and Wales, Scotland and Northern Ireland, and those for the Diploma in Mechanical Engineering of the Royal Technical College, Glasgow. Certificates in Mechanical Engineering which have been issued prior to this notice by the Ministry of Education of Northern Ireland, will also be accepted, provided that the holder has passed all the Ministry's examinations up to and including those of the third year. The Board also signifies its recognition of all university degrees and university college diplomas awarded in England and Wales, Scotland and Northern Ireland, provided that candidates have followed courses of study covering the subjects of the Board's own examinations. Where the courses taken, and the degrees, diplomas, or certificates which have been obtained do not cover precisely the same ground as the Board's examination, the circumstances of each case will be considered on its merits by the Board of Trade with a view to the granting of a partial exemption from the Board's own examination. The notice also gives a list of schools approved by the Board, covering all parts of the United Kingdom, which are now added to those already given in Appendix E of the official regulations governing the examination of engineers for service in the Merchant Navy.—*"The Engineer", Vol. CLXVIII, No. 4,366, 15th September, 1939, p. 278.*

Proposed Norwegian "Hull Factory".

The Norwegian Department of Commerce is reported to be giving favourable consideration to a recommendation of the Government's "New Enterprise Committee" providing for the construction of a covered twin slipway for the sideways launching of large hulls which would be built in series according to size requirements. It is proposed to begin by concentrating on the construction of 15,000-ton all-welded hulls, which, after launching, would be fitted-out and engined by various private Norwegian shipbuilding and engineering firms. As only large sizes of hulls would be manufactured, the proposed "hull factory" would not affect the interests of such private firms. Estimated to cost upwards of £300,000, the new plant would be operated by a joint stock company with a capital of between £50,000 and £150,000. With a staff of 500 workers the output capacity of the plant would be one big hull per month. Details of the scheme are said to have been examined and approved by British and American shipbuilding experts, and the prospective operating company is in the process of being founded, so that the construction of the factory may be proceeded with as soon as the Government and City Council of Oslo decide to support the scheme. It is estimated that the factory can be completed in 18 months, in order that under favourable conditions it should be ready for operation early in 1941. The scheme is the subject of extensive comments in the Norwegian press, and it has been pointed out that there is already one "hull factory" at Stavanger which does not build marine engines, but obtains machinery from other firms for the hulls which it constructs. This yard is capable of building hulls up to 18,000 tons, and given the capital for modernisation and new machine tools, together with an adequate staff of skilled operatives, the firm should be able to turn out a 15,000-ton hull every two or three months.—*"The Journal of Commerce" (Shipbuilding and Engineering Edition), No. 34,184, 27th July, 1939, p. 2.*

Coupling Without Frictional Loss.

A new method of employing rubber in a special coupling whereby, it is claimed, full power can be delivered through two coupled shafts without resultant loss from friction or misalignment has been recently introduced into this country from America. Known as the Harris Torflex flexible coupling, this device is self-aligning and consequently cannot whip. It is also self-fastening and requires no keying or milling of the shafts. The coupling consists of two "thimbles", one of which screws into the other. Into each thimble is fitted a rubber bush, abutting against the inner faces of which are two metal collets. The fitting is slid over the ends of the two shafts to be coupled and, when the two thimbles are screwed into each other, the rubber bushes are compressed endwise as the two collets come into contact with one another. The rubber is then caused to take a firm frictional grip of the end of the shaft. Torflex couplings can be used for direct drives on shafts having a diameter of up to 1¼in.—*"Flight", Vol. XXXV, No. 1,591, 22nd June, 1939, p. 644.*



A section through the Harris Torflex coupling.

Pump Impellers.

An article entitled "A New 'Flow Sheet' Hydraulic Runner" by H. F. Schmidt, in the current issue of the *"Journal of the American Society of Naval Engineers* describes a method of obtaining the most efficient form of air or water impeller for a given size of forced draught fan or centrifugal pump. The method in question is based upon the path of a stream sheet, in preference to that of a stream line, which is the usual basis of design. Having determined the angle of entry and exit of the blade to the rotor disc surface, the curve of the blade at its intersection with the disc can be laid down and a groove cut in the disc to represent the blade. If now a "sweep" is made to traverse this groove as the shaft rotates, it will generate a continuous surface or sheet, every element of which has the theoretically correct angle. The author constructed a blower on this principle by bending celluloid sheet against the blade form modelled in clay and built up the parts with acetone, the overall diameter of the impeller being 6⅝in. He was able to obtain an efficiency of over 90 per cent. on a test during which the impeller was run at a speed of 6,000 r.p.m.—*"Shipbuilding and Shipping Record", Vol. LIV, No. 4, 27th July, 1939, p. 103.*

Air Heaters.

In the majority of air heaters used in the accommodation spaces on board ship, the convection principle is employed, *i.e.*, a source of high temperature is provided, using either steam or electricity, and the air coming into contact with the heated surface rises owing to the decrease in its density, cooler air taking its place and thus setting up a convection current. In a recent development of this principle, a fan is incorporated with the heater in order to assist the circulation of the warmed air and the bringing of the cold air into intimate contact with the heating element. Two types of heater which utilise this idea are in use, the one being all-electric, with a small motor-driven fan arranged behind the electrically-heated elements, both taking their current from the same source, while the second is a combination of a steam or hot-water radiator and an electric motor driving a fan. Although designed to take steam up to a pressure of 150lb./in.^{2}, this latter unit has an output of 26,800 B.Th.U./hr. with an initial air temperature of 30° F. when supplied with hot water at a pressure of 5lb./in.^{2}, and of 17,500 B.Th.U./hr. if hot water at a temperature of 150° F. is employed instead of steam.—*"Shipbuilding and Shipping Record", Vol. LIV, No. 4, 27th July, 1939, pp. 103-104.*

An Illuminated Magnifier.

An illuminated magnifying device originally designed for use in the medical profession, is now available for certain engineering applications, as it can be used in awkward positions where the usual microscope cannot be employed. The instrument should, it is claimed, be of considerable value for the examination of worn parts, finishes, flaws, and the surfaces of sheets, etc. It comprises an illuminated cylinder of white bakelite fitted with a lens system and an electric torch. As the lens system is 2in. in diameter, a considerable area can be examined, and very powerful magnification is obtained. The illumination from the torch is concentrated in the cylinder to a power 400 times that of daylight and affords visibility to the extreme edge of the observation field. Light driven into the surface of the specimen reveals the depths of fractures and fissures with a clarity said to be unobtainable by other means. An aperture at the side of the cylinder enables the user to work upon the object while it is illuminated and under high magnification, while a transparent celluloid "magnicrometer" provided with each instrument is claimed to make it possible to take measurements to within 1/256th of an inch. The daylight electric bulb and battery are of standard size. It is stated that such magnifiers are in use in 900 hospitals.—*"The Engineer", Vol. CLXVIII, No. 4,357, 14th July, 1939, p. 48.*

Overall Efficiency of Motorships' Propelling Machinery.

Increased utilisation of the heat of the exhaust gases and also, in a lesser degree, the avoidance of heat losses in cooling water, is now leading to an almost new phase of standards of efficiency for the overall working of the machinery and ship as a unit, in the case of the latest motor vessels. In the Dutch passenger liner "Oranje" up to 300 tons of fresh water per day can be obtained without any additional fuel cost, as steam for three 100-ton evaporators is supplied from the exhaust gas-heated boilers. A vessel of this type normally carries 10 days' supply of fresh water, plus 2 days' reserve. The requirements would, therefore, be in the neighbourhood of 3,600 tons, whereas the "Oranje" actually has tanks for only 800 tons; hence there is a saving of 2,800 tons which is reflected in larger cargo capacity, reduced canal dues and lower fuel costs. The exhaust boilers generate 12·6 tons of steam per hour at 145 r.p.m. of the main engines, 7 tons/hr. at 130 r.p.m. and practically nothing at 100 r.p.m. Taking the exhaust heat recovery plant into consideration, the total thermal efficiency of the whole plant is raised from 41·6 per cent. for the machinery alone to a total of 54·2 per cent. At the same time the whole of the heat required for fresh and salt water for baths, etc., throughout the ship is obtained from the jacket water of the auxiliary engines. Out of 300 tons of fresh water that circulates around the jackets of the four engines which are normally run in service, 135 tons (or 45 per cent.) is by-passed through a heat exchanger before entering the cooler, the remainder going to the cooler direct. The whole, after leaving the cooler, is recirculated through the engines. Sea water is circulated round the cooler and raised to about 122° F. for use in baths, whilst fresh water is heated in the exchanger to about the same temperature, for use in baths and lavatories. The results achieved are, it is stated, satisfactory in every way, and the new Rotterdam Lloyd liner which will be placed in service next year, will be similarly equipped.—*"The Motor Ship", Vol. XX, No. 235, August, 1939, pp. 156 and 160-168.*

Soot-blowers.

An improved type of soot-blower operated by an electric motor, has recently been put on the market. The usual form of retractable nozzle is employed in this blower, the motor driving the nozzle through reduction gearing by means of a screw thread cut on the steel pipe which supplies steam to the nozzle, the mechanism also controlling the delivery of steam to the latter. When the motor is started up from the control panel in the boiler room, it first of all rotates the steam pipe, causing the nozzle to advance until at the end of its travel with the jet projecting into the boiler casing, the two elements lock together and rotate as one. This causes a cam to operate the steam valve so that it opens and closes at the appropriate points in the revolution, while on reversing the motor the valve instantly closes before the nozzle is wound back.—*"Shipbuilding and Shipping Record", Vol. LIV, No. 3, 20th July, 1939, pp. 71-72.*

American Firm's Fuel Injection Equipment School.

The American Bosch Corporation, Springfield, Mass., are about to open a school in which courses of instruction will be given in everything relating to the operation and maintenance of fuel injection equipment for Diesel engines. The school will be located at the firm's works in Springfield and is to be equipped with all the most modern tools and data required for this purpose. Students will be given opportunities to visit and inspect the works departments in which the different components are actually manufactured and will be taught the correct functioning of the various injection units. No charge will be made for the courses, the duration of which will be from one to two weeks, but attendance will be limited to persons directly concerned with the design, installation, operation and maintenance of Diesel engines and accessories.—*"Motorship and Diesel Boating", Vol. XXIV, No. 7, July, 1939, p. 386.*

Pulverised Coal as a Fuel for Cylindrical Boilers.

The water-tube boiler with its relatively large and potentially variable-size furnace is particularly suited for pulverised fuel, whereas the cylindrical boiler with its limited furnace area and long flues presents difficulties, especially in regard to dust deposits and high temperatures. The dust problem has been satisfactorily overcome at the expense of a considerable quantity of live steam or its equivalent and the provision of a dust-collecting chamber, while the furnace is protected from damage due to initial high temperatures by a firebrick lining. One of the advantages claimed for pulverised-coal firing is that a large overload can be carried without any appreciable reduction in efficiency, and even if it is doubtful whether a larger continuous output of steam can be obtained from a pulverised fuel boiler than from a similar boiler fitted with mechanical stokers, the former system is undoubtedly capable of responding more rapidly to a sudden heavy load. Pulverised fuel firing consists of a stream of finely divided dry coal intimately associated with the necessary air for combustion, projected into the furnace, where it ignites and burns in the same manner as atomised oil. Two systems are in use, or three if the bulk supply system is included. In the "Unit" system coal is stored in a bunker whence it is fed as required to a dryer and pulveriser which reduces it to combustion size. Each boiler has its own pulveriser and incorporates a fan to supply primary air and convey coal particles to the burner, with a second fan to supply secondary, and in some types of burner, tertiary air. A blower or system of steam pipes and nozzles for periodically clearing the flues of dust, together with a dust extraction chamber, complete the equipment. In the "Central" or storage system the fuel is taken from the main bunker to a dryer where the free moisture is extracted, and then to one or more pulverisers where it is reduced and then withdrawn by an air stream produced by a fan, cyclone separator or dust-collector, and conveyed to a pulverised fuel bin for use as required at the burners. In some cases a combination of the two systems is adopted, each boiler having its own pulveriser, with a storage bin for the pulverised fuel. This allows the pulveriser to work at its most economical load and not according to the steam requirements. In order to burn pulverised coal in cylindrical boilers it is essential that it should be reduced to the smallest practicable size because the nearer it approaches a gaseous state, the more intimate the mixture of air and fuel and the more rapid the combustion. Coal with a low volatile content such as anthracite and hard steam coal requires finer and more uniform grinding than bituminous coal. Free moisture and excessive ash are undesirable; the former must be removed by drying in a special dryer or in the pulveriser by hot air, and the latter must be intercepted before reaching the uptake. The best results in cylindrical boilers are obtained with a high-grade bituminous fuel having a calorific value of 13,000 to 14,000 B.Th.U. with a volatile content of about 25 per cent., with not more than 4 per cent. ash and 3 per cent. moisture and a fineness of 98 per cent. through 100 mesh or 85 per cent. through 200 mesh B.S. sieve. Many types of pulverisers are in use, the simplest form of machine consisting of a cylindrical or conical tube containing a large number of hardened steel balls which are constantly lifted and dropped as the cylinder revolves, thus crushing the fuel by impact. The energy required to pulverise 1 ton of bituminous coal in a 8ft. by 4ft. "Kennedy" mill so that 60 to 75 per cent. would pass through a 300-mesh sieve, is about 16 kW.-hrs. The burners used in pulverised fuel firing are quite simple in construction. The "Grid" burner intended for cylindrical boilers and developed by the Fuel Research Station, Greenwich, is of cast iron and square in section. The primary air intimately impregnated with pulverised fuel is discharged to the burner where it is projected through a series of shot-shaped nozzles into the furnace, the first 3ft. of which is lined with thin layers of refractory bricks. Secondary air from a forced-air draught fan enters a register surrounding the burner and is discharged through the burner interspersed between the mixture of fuel and primary air in such a manner that there are thin parallel layers of alternately primary air and fuel secondary air. Tertiary air can be supplied through slots in the firebrick surrounding the burner. This arrangement renders it possible to adjust the proportion of primary air and fuel to secure the correct mixture in relation to flame propagation and stability. Ash deposits can be dealt with by a series of nozzles in the furnaces and flues. The first ash blowers are placed in the burners, the second in the furnace flues, and subsequent nozzles in the centre and side flues. The blowers are operated in proper sequence by a manifold valve which sets each series of blowers in operation so that ash from the first series is taken up by the second and so on until the ash reaches and is discharged into a collecting chamber. During the blowing period the main flue dampers are closed, and dampers leading to the collecting chambers are opened. When the ash is blow into the chamber a number of water spray nozzles are brought into operation and the ash is separated from the flue gases and deposited on the floor of the chamber, whence it is washed away by the water from the spray nozzles to an adjoining sump. Dry pulverised fuel can be readily transported by air pressure, screw or worm conveyors and pumps. It can be conveyed pneumatically through flexible tubes horizontally, vertically and round easy bends. A device known as the "Buell" bunker level indicator can be used to give visible or audible signals or a combination of both, when loading bunkers or storage bins. The unit consists of cast-iron box containing a rubber diaphragm and contact switch component fitted at the side of a bunker over a port-hole which allows the diaphragm to be exposed to the interior. If no fuel is present the diaphragm remains in its normal position, but immediately the bunker contains fuel this exerts pressure at the level where the indicator is located. Deflection of the diaphragm causes electrical contact to be made, with the result that a coloured light or an audible signal immediately becomes operative.—*E. Pull, "The Power and Works Engineer", Vol. XXXIV, No. 397, July, 1939, pp. 273-274.*

Steam Steering Engines.

In some ships in which careful measurements have been taken, up to 10 per cent. of the total steam generated has been found to pass through the steam steering engine. This loss of efficiency is due to a variety of causes, the greatest loss being brought about by wire-drawing the steam when the control valve is almost closing the ports and the engine comes to rest. This results in a continuous flow of steam until the next movement of the control valve, and makes the steam steering engine the most extravagant and wasteful of all the auxiliaries to be found in modern ships. This continuous passage of live steam through the control mechanism is very detrimental to the valves and valve ports, in addition to which it increases the work of the auxiliary condenser plant. It also involves a waste of fuel. It is claimed that this waste of steam can be eliminated by the use of a Lyall's patent economic valve which can be fitted to any make of vertical or horizontal type of steam steering engine. The combination of such a valve with the hunting gear of the engine constitutes a mechanical pressure reducing and regulating system which, it is stated, only passes enough steam at a pressure sufficient to work the engine in accordance with the power required to turn the rudder. It is generally found that 20lb./in.^{2} is ample for this purpose. The casting containing the valve and carrying the operating mechanism is incorporated in the body of the steam stop valve and is fitted between the latter and the usual control valve. An adjustable connecting link attached to the control valve operates a roller cam mechanism, and when this gear has once been set it requires no further attention beyond occasional lubrication. The only alteration necessary with the standard type of steering engine is the removal of any lap of the control valve from both the steam and exhaust edges. The valve itself must then be adjusted so that it will only just cover the ports. The connecting lever and roller gear are designed to allow the control valve to open in advance of the economic valve, which thus allows the engine to start freely as soon as the movement of the steering shafting or telemotor control requires it to do so. This gear therefore closes the economic valve in advance of the control valve, thereby ensuring a positive cut-off. It is claimed that the valve reduces the wear and tear of the engine and its packing, in addition to which the saving in steam results in a corresponding reduction in the consumption of fuel. Over 600 such steering engine economic valves have, it is stated, already been fitted in ships.—*"The Journal of Commerce" (Shipbuilding and Engineering Edition), No. 34,778, 20th July, 1939, p. 3.*

A Floating Garage.

The L.M.S. Railway Company's new motorship "Princess Victoria", built at Dumbarton by Wm. Denny & Bros., Ltd., for the carriage of passengers, freight, livestock and motor-cars between Larne and Stranraer, is a vessel of 2,400 tons gross, 305 by 48 by 29ft., propelled by two sets of seven-cylinder, single-acting, two-stroke Diesel engines designed to give her a service speed of 19 knots. The ship can carry 1,500 passengers and there is special accommodation for livestock on a 'tween deck between the generating room and the garage deck, which is reached by a ramp from the latter. The garage is situated on the main deck and will hold about 80 cars of average size. The 'tween deck height of 12ft. 6in. enables lorries to be carried if necessary. Two turn-tables are provided, one at each end, to facilitate the handling of motor vehicles. The cars run on board under their own power through a large full-length opening arranged centrally at the stern and fitted with half-height hinged doors; four similar openings, one at each side forward and one at each side aft, fitted with side-sliding doors, are provided through the ship's side, for shipping either motor vehicles or livestock.—*"The Shipping World", Vol. CI, No. 2,405, 19th July, 1939, p. 81.*

Extracts.

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

Starters and Controllers for d.c. Motors.

"The Allen Engineering Review", April, 1939.

Starting equipment has been regarded by not a few semi-technical executives as an evil consequent upon the general introduction of electrical power and, although nowadays it is usually conceded to be a necessary evil, it frequently falls to the lot of the electrical engineer to explain why a client should sometimes pay nearly as much (or perhaps even more) for his control gear as for his electric motor.

Electric motors are unlike most mechanical sources of motive power in having their starting and regulating equipments in the majority of cases mounted apart, and hence the cost of such equipment is shown as a separate figure, which is never the case with say the valves and governor gear of an oil engine or steam turbine where they form an integral part of the engine proper.

Choice of Starting Equipment

Motor control gear probably offers the occasional buyer more trouble than most electrical equipment on account of the diversity of types listed by the different manufacturers at prices ranging from one to many pounds, all purporting to be suitable for starting a motor of a given size. They probably are, but under what conditions and how frequently?

Considerable assistance in the choice of suitable control gear can be obtained from the relevant British Engineering Standard Specification No. 587 of 1935*, which is an amalgamation of ten earlier specifications, each dealing with an individual class of control gear. Starting equipment may be classified under two headings, viz. :—

Automatic: in which the equipment is self-acting under the control of some actuating device such as a push button, a float or pressure switch—or perhaps a thermostat; and

Hand operated: in which the switching mechanism requires to be moved manually from the "off" position to "full-on".

Types of Starters.

Each of the two groups can be sub-divided into a number of different types, each with its particular sphere of usefulness, and the following are some of those more generally met with in practice.

Automatic starters.—The Allen standard automatic starter is of the multiple contactor pattern—each consisting of an assembly of two or more single or double-pole contactors mounted together with relays and other essential fitments in a suitable enclosure.

A contactor is a switch designed for frequently opening and closing the main circuits of electrical equipment, and may be mechanically or electromagnetically operated. Contactors for automatic starters are usually of the latter type and the construction of both large and small sizes is shown clearly in Figs. 1 and 2.

Each contactor is provided with a powerful operating coil capable of closing the contacts against adequate spring pressure. When the magnet coil is de-energised the contacts separate rapidly, the final break taking place on the sparking tips situated in a powerful magnetic field to ensure rapid extinction of the arc.

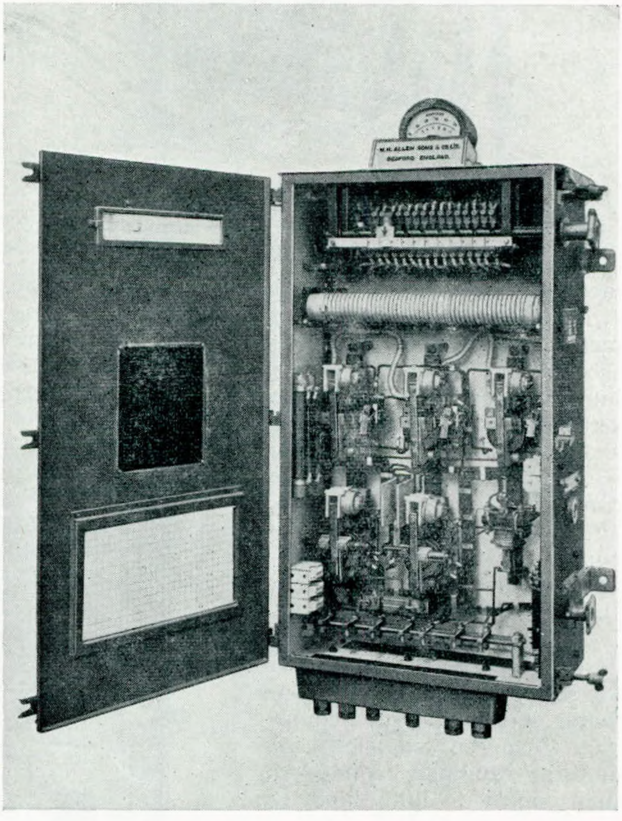


FIG. 1.—Interior of 20 h.p. Allen automatic variable speed starting equipment, showing unit construction and increased accessibility obtained by the use of bar mounted components.

In Fig. 1 is depicted a 20-h.p. 220-volt automatic starter supplied for pump duty on board ship. In this case the actuating device consisted of a float-operated switch set to open and close its con-

* British Standard Specification for Motor Starters and Controllers (exceeding Liquid Starters). No. 587—1935.

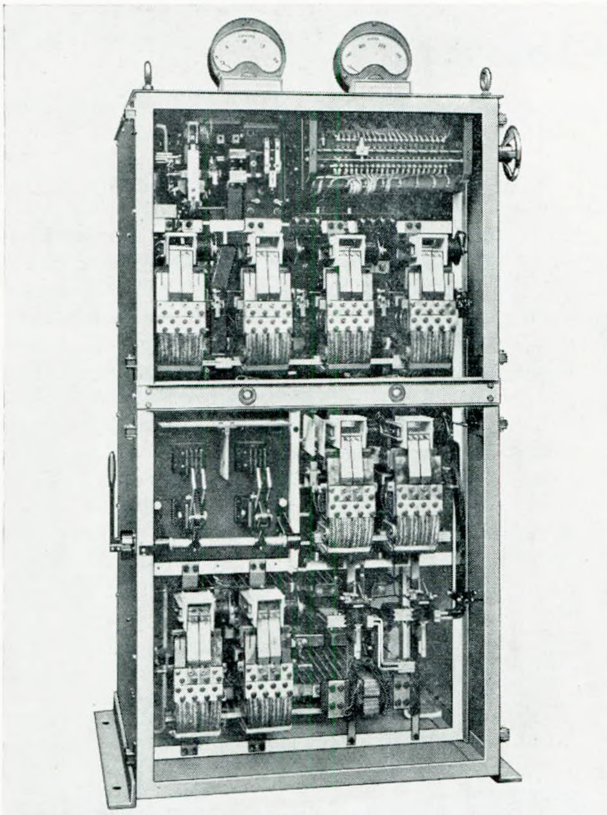


FIG. 2.—Front view (door removed) of 375 h.p., 220 volt Allen automatic variable speed starting panel.

tacts at predetermined water levels. When the float switch closes, the magnet of the line or first contactor is energised, causing it also to close. The accelerating contactors operate in succession, at intervals dependent upon the setting of the control relays shown on the right-hand side of each of the upper three contactors in the illustration, and the motor continues to run until stopped automatically by the float switch or shut down by hand.

The foregoing is a brief description of the operation of a typical automatic contactor starter and such equipment can be supplied for motors ranging from less than one up to 1,000 h.p.

A larger automatic starter is shown in Fig. 2, this having been supplied for the Hampton Pumping Station of the Metropolitan Water Board, for use with a 375-h.p. 220-volt, 1,482-amp. d.c. motor. The equipment is of the variable speed type with automatic acceleration to the speed predetermined by the regulator setting.

Automatic starters are employed primarily where equipment is to be completely under the control of a self-acting pressure, temperature or similar control required to work without supervision.

Equally numerous, however, are the instances where automatic starters are used to relieve a workman of a series of manual operations—giving him a master controller or push-button box by means of which to initiate the automatic functioning of the machinery. Contactor starters are particularly suitable for heavy and frequent starting duty. Maintenance is practically restricted to the contactor sparking tips which have a long life, but which are readily and speedily renewable.

Hand-operated Starting Gear

Face-plate starters.—This term is usually applied to starters whose contacts and switch parts are mounted on a flat insulating panel or base. In its simplest form it represents the least expensive construction with limited application to starting motors against light and medium loads such as line shafting, centrifugal pumps, etc., requiring less than full load starting torque. A face-plate starter according to B.S.S. 587 is rated for *ordinary duty* which means it shall be suitable for a service not requiring more frequent starting than twice per hour, each start not exceeding ten seconds for 10 h.p. and less, and five seconds plus ½ second per h.p. for larger sizes. Of all types of starters, the usual face-plate variety is most susceptible to misuse, and in order to overcome this disability "heavy duty" faceplate starters or "face-plate breaker starters" have been introduced, though in our opinion the inherent disadvantages of the "face-plate" out-

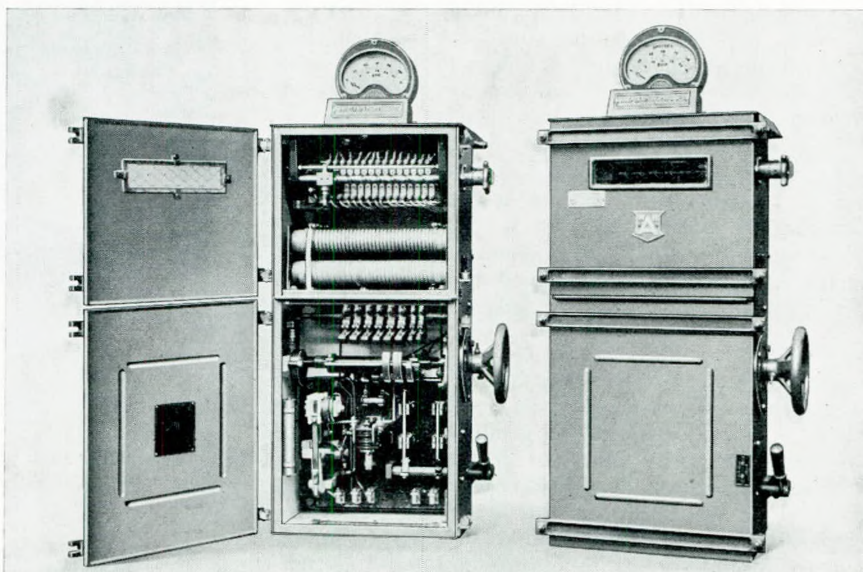


FIG. 3.—Typical marine and industrial Allen variable speed drum pattern starting panel, incorporating a single-pole contactor, overload relay and d.p. isolator.

weigh any advantages deriving from the special construction and in cases where the service demands something better than a simple ordinary duty starter, the requirements are best met on a drum type starter.

Drum type starters.—The specification (B.S.S. 587) defines this type as "a starter in which the moving contact parts are arranged upon a cylindrical surface". This point is shown up in Fig. 3 in which is depicted an Allen variable speed starting panel. The main contact drums are mounted on the centre drum shaft rotated by the external handwheel, shown on the right-hand side of the case. Above the drum assembly is the finger bar, carrying the finger contacts which make contact with the drum contacts when the handwheel is turned. Both drums and fingers are mounted on baked mica wrapped bars, an ideal insulation absolutely impervious to moisture, and free from "carbonisation" which sometimes occurs with synthetic resin insulations. The contact drum is interlocked with a single-pole contactor circuit breaker ensuring that the latter takes the full make-and-break of the main circuit. The contactor and overload relay are mounted with the isolator on the panel below the drum unit.

Drum type starters are eminently suitable for starting against either light or heavy loads, the rating of the resistance and number of steps being chosen to suit the requirements of the duty cycle.

Thus a large centrifugal pump would not require more than 75 per cent. full load current on the first notch and a resistance rating allowing an average of four starts per hour and permitting several starts in succession, in an emergency, would be adequate. On the other hand, a compressor running in oil might require 150 per cent. full load current on the first notch, and with certain types, a resistance allowing a two minutes starting period in every fifteen, *i.e.,* two-minute rated, would be desirable.

When producing our first starting gear, many years before the War, we chose a drum type construction, and it is interesting to observe that although new designs have been evolved from time to time to meet the changing requirements of the market, the drum and finger principle has been retained. This fact can be attributed to two reasons: Accumulated experience, which has shown an excellent performance in service, and capacity for withstanding rough handling, as well as working for long periods without attention. For this reason drum type panels have been specially favoured by marine engineers. The limitations to their use are few and they are readily adaptable to special requirements.

Mechanical Contactor Starters have been developed for use with motors beyond the range of a drum type starter. Fig. 4 illustrates a starter of this type which consists of a number of switches closed in succession by cams mounted below the switch hubs.

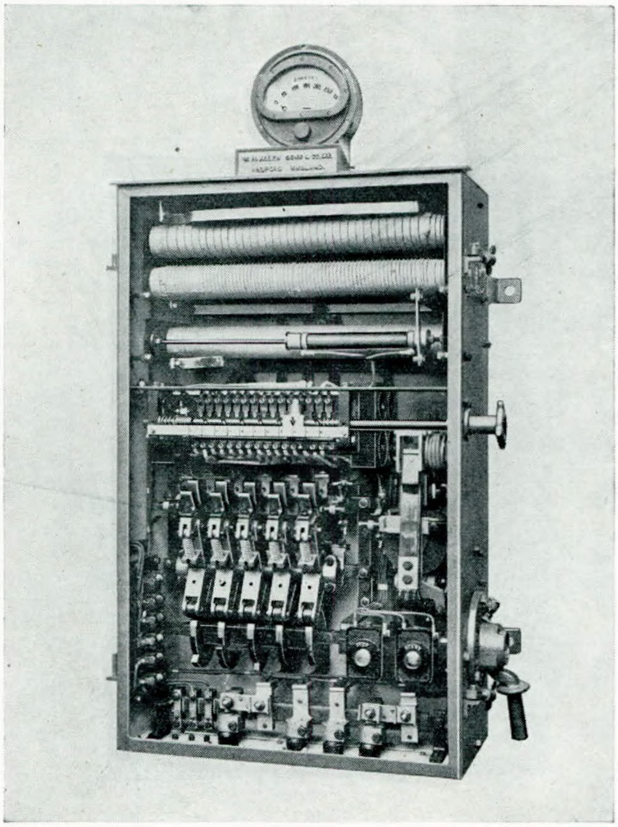


Fig. 4.—Interior of 60 h.p. Allen mechanical contactor starter with slow motion ratchet operating device and single-pole contactor.

The cam shaft is attached to a ratchet mechanism operated by the handle on the right-hand side of the case. The mechanical contactor starter is similar to the fully automatic starter already described in that each switch is a contactor which is operated mechanically instead of magnetically.

It is impossible for any switch to be closed out of sequence, and the ratchet mechanism prevents too rapid operation. As in the case of the drum type starter, the resistance switches of the mechanical contactor starter are interlocked with a line contactor of the self-closing type (shown on the right-hand side in Fig. 4), so that the contacts of the latter, provided with a powerful blow-out, take all the making and breaking of the main circuit.

This has the effect of greatly enhancing the life of the starting contacts and reducing maintenance to a minimum. Although the interior is readily accessible from the front of the case, the fact that the switch assembly can be withdrawn *en bloc* after removal of the retaining bolts is worthy of mention.

Variable Speed Control Gear.

Excluding special schemes of control, there exist two common methods of varying the speed of d.c. motors, viz.:—

(*a*) Speeds above the normal full field speed

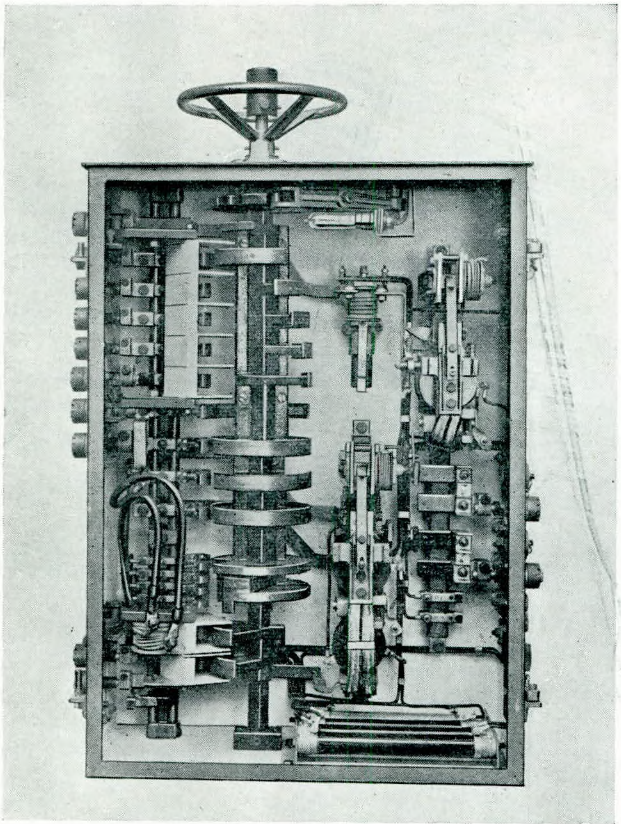


FIG. 5.—Interior of a heavy duty Allen reversible drum controller suitable for crane, winch and capstan applications.

of a shunt or compound motor may be obtained by means of a shunt regulator in the field circuit—provided that the motor is designed for variable speed working.

(*b*) Speeds below the normal full load speed of a series, shunt or compound motor are obtainable by series regulation in the armature circuit.

On hand-operated equipment the provision of shunt regulators is fairly simple matter and with suitably designed motors, speed increases of 50 to 100 per cent. are commonly met with, and 150 to 250 per cent. are not unusual.

The provision of a shunt regulator on an automatic controller is complicated by the fact that a shunt field must not be weakened until all resistance has been cut out of the armature circuit. This may mean introducing a field accelerating relay or a motor-operated shunt regulator and attendant control relays.

Several of the panels illustrated include shunt regulators—Fig. 3 is a variable speed drum type starting panel with a screw-operated shunt regulator at the top. The automatic panels shown in Figs. 1 and 2 are both fitted with shunt rheostats. and the field accelerating relay is shown to the left of the shunt regulator in Fig. 2.

Series or armature regulation is frequently required on material-handling machinery such as cranes and winches where series motors are employed. The series regulator must be provided with contacts for reversing the motor, and must be of extremely robust design to withstand arduous service conditions.

Except where contactor gear is employed, drum type controllers are universally used, and a typical electric winch controller is shown in Fig. 5. The construction is similar to that employed for drum-type starters, but differs in that all main contacts are provided with powerful blow-outs and designed to carry the current continuously.

Resistances for cranes and winches are usually given "five minute" or "limited continuous" B.S.S. ratings, and in general are mounted apart from the controllers on account of their size and also because of the heat generated in them.

Ship Slipways.

An Article for Students.

By STANLEY C. BAILEY, Assoc.M.Inst.C.E., F.G.S.

"The Dock and Harbour Authority", July, 1939.

Early Slipways.

Slipways for ships or slip docks, for raising vessels above high water level so that the exterior of the hulls may be repaired, scraped, and painted or tarred, were invented by Thomas Morton, of Leith, the first being constructed at Dundee in 1837. Slipways at that time were chiefly used by fishing vessels and consisted of an inclined plane or "hard" with two or three lines of railway from above high water level to low water mark, and the cast iron rails in 3ft. lengths were either fixed direct to stone blocks, or to longitudinal baulks of timber, secured to the hard stone setts of the slipway.

The timber-built cradle to carry the ship was mounted on numerous cast-iron flanged wheels which travelled on the rails. The ship was floated over the cradle at the lower end of the slipway at high tide, and as the tide fell, it gradually rested on the cradle blocks, the bilge blocks and the arms carrying them, known as "cobs", being shaped to the bilge curves of the vessel, retained it in an upright position. The cradle and ship were then drawn up out of the water by means of iron links about 12ft. long, attached to the cradle at one end, and at the other to an iron chain in connection with a double purchase hand or steam winch, or to a capstan worked by horses.

When about 48-ft. length of chain was hauled up, the four upper lengths of the links were removed, and the chain pulled down and connected to the links *in situ*. Similar slipways worked on this method are still in use for fishing boats and other small craft at various ports, but it is a slow process.

Previously vessels were either dry docked, or floated at high water over a level stone platform, or an inclined hard, prepared just above low water spring or neap tide levels, and as the tide fell, the ship was propped up; or else it was floated over a "grid" consisting of parallel longitudinal and cross timbers, with or without keel and bilge blocks, bolted down to the stone hard, or fixed to timber piles, just above low water neap tide level.

The repair work on the exterior of the ship was therefore tidal, and required to be rapidly done, but hards and grids were comparatively cheap, as little or no underwater work was involved in their construction, and they are still in use in many fishery ports.

Modern Slipways.

Most modern slipways are constructed so that the ship can be brought on the cradle at H.W.N.T. or H.W.S.T. levels, others are built so that the vessel can be lifted at all states of the tide. This involves the construction of the slipway well below L.W.S.T. level, which is expensive work, but must be faced in such situations as in ports on the coasts of the Mediterranean Sea, where the range of tide is only about 1ft.

Hydraulic Gear.

With the introduction of hydraulic power by Lord Armstrong in 1849, for motive purposes, Daniel Miller in 1850 first used a horizontal hydraulic direct-acting ram as the power for hauling up ships, and about the same period Messrs. S. H. Morton, of Leith, also adopted an hydraulic ram with a 10ft. stroke, the water supplying the ram being pumped into a vertical accumulator by a steam engine and pump. The advantage of using hydraulic rams is that the efficiency of direct-acting ones is from 85 to 90 per cent.

The ram was fixed at the head of the slipway with its crosshead pointing up the slope, and from the crosshead a pair of parallel links or bars, joined together in 10ft. lengths extended down the whole length of the slipway, one on each side of the central track rails, and bearing on flanged rollers at suitable intervals. The links were either circular or rectangular in cross section, and were connected together by a pair of joint plates with pins through them and the eye bar holes of the links.

Iron pawls pivoted to the cradle engaged with the links at the joints, and after each forward stroke of the ram, a 10ft. length of each line of links was removed at the upper end by means of a small hand crane. The ram head was drawn back and reconnected to the lines of links ready for the next forward stroke. In the meantime the cradle was prevented from slipping back by pawls pivoted on it, which engaged with a continuous cast iron rack fixed at rail level on the slipway between the two centre rails, and extending the whole length of the slipway.

Generally, two or three parallel rams were used, attached to the same crosshead, according to the load to be lifted, including the weight of the links, and the friction of the cradle, links, and machinery. Rams have been constructed with a 15-ft. stroke, the ram cylinders being 18in. in diameter and weighing 17 tons each, while the weight of the rams was five tons each.

There are a number of slipways still in use worked on this system, but it is a slow method due to the slow motion of the rams, and the loss of time, averaging eight minutes for disconnecting and reconnecting each set of links, while the average speed is from 3 to 4ft. per min.

To overcome this difficulty Messrs. T. B. Lightfoot and J. Thompson employed a system of three parallel rams, the crosshead of which, carried in the middle, the piston of a fourth retaining or constant pressure ram, at the head of the parallel rams. From the crosshead, link bars extended on each side of the rams to another crosshead below the rams, from which two parallel lines of links in 10-ft. lengths, bearing on rollers, extended down the whole length of the slipway, one on each side of the two central rails, with a rack between.

The operation of the rams was as follows, *viz.:* water from the accumulator was forced into the main rams pushing them up, and driving the piston on the crosshead into the retaining ram cylinder. A hand lever in connection with the valves on the pipes from the accumulator to the main rams enabled the water to be cut off from them at the end of the stroke, and the rams were opened to exhaust, while the constant pressure on the smaller retaining ran forced the main rams downwards, so that by moving the lever backwards and forwards, an up and down motion was imparted to the rams and the links.

A number of iron pawls pivoted to the cradle engaged with the joints of the links, and so pulled the cradle up 10ft. at each forward stroke, while pawls in the centre of the cradle engaged with the rack on the slipway, and prevented the cradle from sliding back between the strokes of the rams. A more or less continuous motion was thus obtained in hauling up the cradle.

Messrs. Hayward Tyler and Co. employed in their slipways, two independent rams, one on each side of the central rails of the slipway at its head, with a line of continuous iron links from each ram extending down the slipway. The rams were arranged to work alternately, so that while one ram was making an upward stroke, that of the other was downward. The cradle was thus drawn up continuously by means of the pawls engaging with the joints of the links.

When it is required to lower ships into the water, the pawls engaging with the rack and the links are knocked up or raised by means of levers, the cradle and ship thus move slowly down the slipway, the resistance of the water against the vessel increasing as she descends into the water thus gradually slowing up the motion.

Haulage Power.

The power required of hydraulic rams to haul a vessel of 3,000 tons plus the cradle of 100 tons and links weighing 40 tons, a total of 3,140 tons up a 600-ft. slipway on a gradient of 1 in 20 will be as follows:—

Pull required $= \frac{3,140}{20} = 157{\cdot}00$ tons.

Friction of cradle and ship $= 3,100 \times 40$lb. $=$ 55·35 ,,

Friction of links $= 40 \times 20$lb. $=$ 0·35 ,,

212·70 ,,

Friction of rams $= 212{\cdot}70 \times 8\% =$ 17·01 ,,

Starting friction, and to overcome inertia $= 212{\cdot}70 \times 5\% =$ 10·63 ,,

240·34 ,, say 240 tons.

240 tons = 537,600lb., and allowing for a pressure of 700lb. per sq. in. on the rams, a total of 768 sq. in. will be required, and if three rams are used, the area necessary will be 256 sq. in. per ram, and as a ram 18in. diam. = 254·4 sq. in., this will meet the case. The actual pull on the links is 212·7 tons, and allowing 7 tons per sq. in. safe stress, then 30·4 sq. in. will be required, and for two lines of links 15·2 sq. in., therefore links 4in. by 4in. or 5in. by 3in. will suffice, and their weight will be about 60lb. per lin. ft., including joints for each line of links.

Steam-Driven Slipway.

In order to obtain greater speed in the working of ship slipways, Messrs. Day, Summers & Co., of Northam Ironworks, Southampton, patented in 1879, a slipway worked by a steam-driven winch, the barrel of which was grooved or scored to prevent the wire hauling rope between the cradle and the winch from riding on the drum. The steam engine had two cylinders, 10in. diam. by 12in. stroke, and a worm on the engine crankshaft, geared with a large worm wheel, on the shaft of which was a pinion 19in. diam. which in turn geared with a spur wheel 10ft. in diam., this was bolted to the winding drum. The hauling speed varied from 12 to 20ft. per minute according to the load to be lifted.

Electrically-Operated Slipway.

In the Port of Dublin there is an electrically-operated slipway by Messrs. Day, Summers & Co., on a grade of 1 in 16, for ships up to 900 tons and cradle 100 tons. The machinery consists of an electric motor of 100 b.h.p. running at 750 r.p.m. which is supplied with current from the mains at 500 volts. The ratio of the gearing is about 4 to 1.

A worm on the shaft of the electric motor gears with a worm wheel on the shaft of which is mounted a pinion at each end, these pinions gear into large spur wheels that are bolted to two main drums on the same shaft, the drums having scored barrels. On the worm wheel shaft there are sliding clutches to throw the pinions in or out of gear, and on this shaft is the lowering drum, which is half the diameter of the winding drums, and can be worked independently, also on the shaft is a patent automatic friction clutch geared to the lowering drum which enables the latter to unwind the rope at the same speed as the main drums wind the hauling rope.

The rope from the lowering drum passes down to the lower end of the slipway round a fixed pulley block and then to the lower end of the cradle to which it is attached. The hauling speed is 10ft. per min., and the downhaul speed up to 30ft. per min.

In most of the modern slipways, this more expeditious method of hauling the cradle is adopted, and the machinery is either driven by steam, oil or petrol engines, or electric motors with worm gearing.

Alternative Models.

Some slipways for steam trawlers and tug boats are worked on another principle, *viz.*, the cradle is hauled by means of a single line of iron eye-bars or links in 10ft. lengths with pin joints. At the upper end of the slipway the end of the line of links is attached to gusset plates on an endless linked chain which passes round two horizontal sprocket wheels 2ft. diam. and 15ft. apart centres, lying parallel with the draw bar links, but to one side of the centre line, and just below the ground level.

The endless chain is operated by gearing in connection with a vertical 8-armed hand capstan, or by a horizontal steam engine. As the draw-bar links and cradle are handed up, the 10ft. length attached to the endless chain is removed, and the next length is fixed to another set of gusset plates which are 10ft. away from the former on the endless chain.

The process is repeated until the cradle has been hauled up, but it is a slow procedure.

Slipways have also been constructed for loads up to 550 tons, where the power is applied by an hydraulic capstan. A block with double sheaves is fixed to the cradle, and another two-sheave block at the head of the slipway is anchored to a concrete block in the ground. The steel wire rope passes round these sheaves and is conveyed round a capstan having a pull of 15 tons, from which it passes to a hand winch to take up slack rope, so that there is a 5-part tackle.

There are a few slipways in which runners in lieu of wheels are attached to the cradles, which travel on three or four lines of greased timber baulks anchored to the slipway, but the friction absorbed is twice as much as that for cradles carried on rollers.

The strains imposed on a vessel when being raised on a cradle are no worse than those due to launching or dry docking, or to the pitching of a ship in a heavy sea; and the risk of overturning in a gale when raised on the slipway is very small, there being a factor of safety of at least 20 under a wind pressure of 30lb. per sq. ft.

Most slipways are constructed in sheltered positions, sometimes alongside a jetty or pier for convenience in getting the vessel in alignment over the cradle, and when the slipway is sited normal to the current of a river, such training jetties are occasionally a necessity.

Relieving Slipways.

Slipways on which a ship can be hauled up and deposited at the head of the slipway, while the cradle is run down to raise another vessel are known as "Relieving Slipways", in one form of which the main longitudinal cradle carries another longitudinal cradle the wheels of which are placed normal to those of the main cradle. When the ship is hauled up, the upper cradle carrying the ship is pulled laterally off the lower cradle by steam or electric winches, on to parallel lines of rails clear of the slipway, and the main cradle is run down to take another ship. Sometimes a third cradle from the opposite side of the slipway is run on to the main cradle, so that three ships can be dealt with.

This type of slipway entails the upper portion being in a cutting with low retaining walls on each side, so that the lateral shore rails shall be close to and level with the transverse rails on the main cradle; the slipway also requires to be extended further into deep water than for a single cradle to obtain sufficient depth of water over the upper cradle.

Another method adopted when using two longitudinal cradles, is to haul up the cradles and vessel, and to run the top cradle and ship off to one side of the slipway. The ship is then blocked up with timber baulks and screw jacks between the framing of the cradle, on a concrete platform. The cradle is then partially dismantled where necessary to clear the blocking-up timbers, run out from under the ship, re-erected, and run on to the main cradle ready to lift another vessel. This method is also occasionally used when there is only one longitudinal cradle, but the upper portion of the slipway requires to be lengthened so that the vessel may be deposited. The cradle travels on six lines of rails, two under each line of blocks, the upper cross beam and triangular framing of the cradle are removed, so that the cradle can be run down clear of the ship.

Broadside Slipways.

One other form of relieving slipway is known as "broadside slipping"; this method is adopted in cases where there are small tidal ranges, and to avoid building the slipways a considerable distance into the water. The cradle lies transversely with the line of the slipway, and is run down on numerous lines of rails, according to the length of the cradle and weight to be carried, but usually the rails are about 8ft. apart, and the vessel is brought broadside on to the cradle. This method involves constructing the slipway wide enough to take the longest ships to be lifted, and additional racks, machinery, gearing and hauling ropes are necessary.

In some broadside slipways, the main cradle carries a longitudinal cradle with wheels placed normal to those on the main cradle, which run on three lines of rails laid on the latter. The upper cradle and ship are hauled laterally off the lower cradle at the head of the slipway, and the ship and cradle dealt with as already described.

With cradles of this type having a number of hauling ropes, it is difficult to obtain an even pull on all the ropes when new, unless the ropes have previously been equally strained, for one rope will stretch more than another, and the cradle being pulled more on one side than the other, will jamb on the rails, and the pawls will not engage with the ground racks in unison.

New steel wire ropes, unless previously strained, will stretch considerably; for instance: an 8-tons pull on a 2in. diam. steel wire rope, 400ft. long, will stretch it 2ft., and a 10-tons pull will lengthen it by 3ft. 6in.

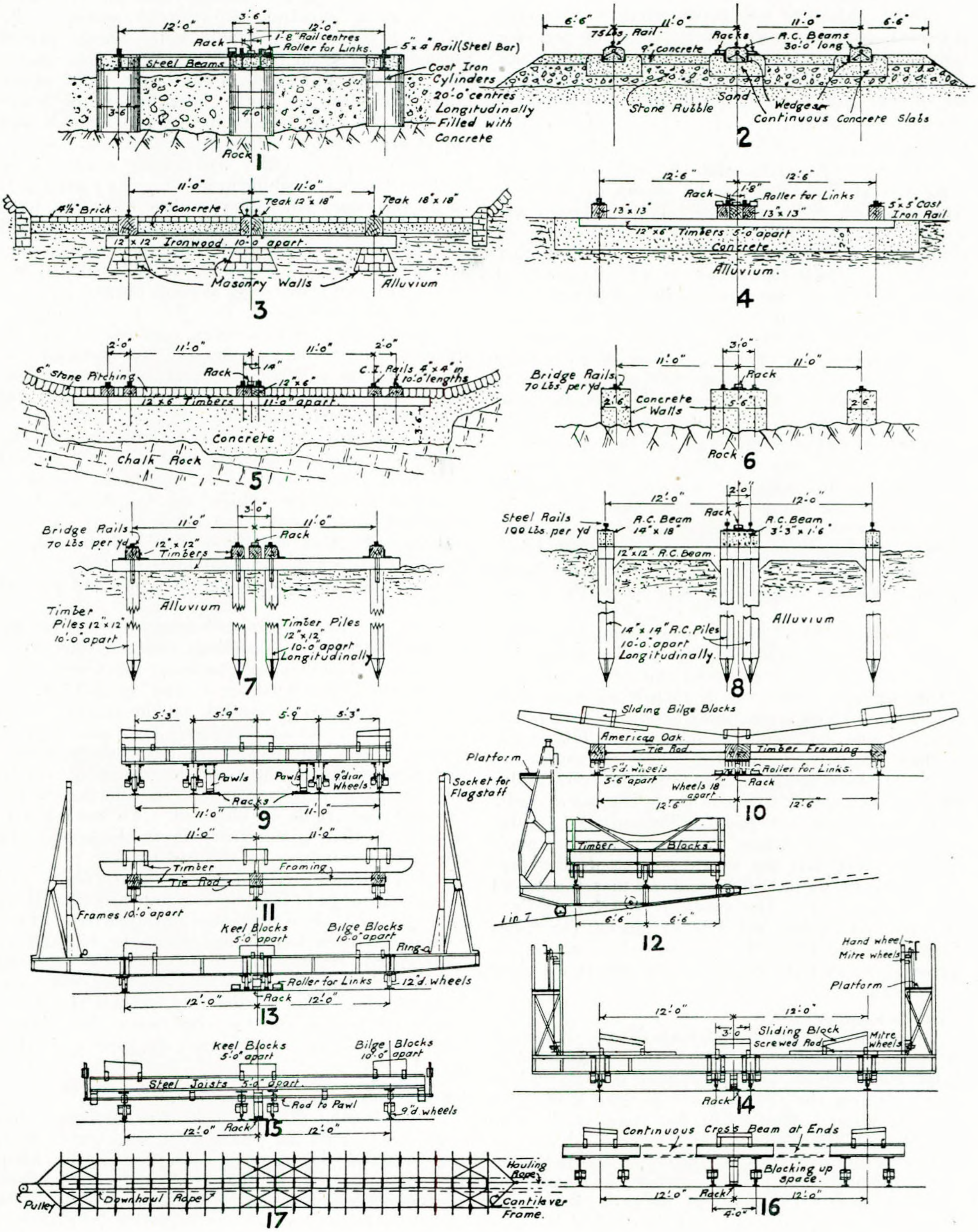
When ships of various lengths have to be raised by broadside slipping, and to avoid pulling up a long cradle for a short vessel, the cradle is arranged in sections which can be detached as necessary, and consists of a series of parallel trucks, each about the beam width of the ship in length; each travels on two lines of rails on the slipway, and has its own hauling rope and ground rack.

To synchronise the movements of the trucks, a steel shaft, having couplings between each truck is fixed right across the trucks at the lower ends, on which is mounted gear and ratchet wheels engaging with pawls pivoted on the trucks. Each truck thus carries on each side two gear wheels, ratchet wheels, and pawls; the gear wheels engage with pinions on the shafts of the travelling wheels, thus uniformity of movement in all the trucks forming the cradle is obtained. To cut off any trucks, all that is necessary is to disconnect the cross shaft couplings of the end trucks.

Each truck carries keel and bilge blocks, and they are arranged fairly close together, so that there is no great length of the vessel unsupported. When a ship has been hauled up, it can be blocked up between the trucks, then wedges in the keel and bilge blocks of the cradle are knocked out, thus lowering them clear of the ship, so that the whole cradle of trucks may be run down the slipway without any dismantling ready to receive another vessel.

Slipway with Radiating Arms.

A relieving slipway at Lorient in France has been constructed, in which there is a turntable at the head of the slipway with five cradle roads radiating from it, so that the longitudinal cradle carrying the vessel can be berthed on any of the radiating lines clear of the turntable; the ship is then blocked up, and the cradle is released ready


12'-0"
3'-6"
12'-0"
1'-8" Rail centres
Rack
Roller for Links
5 x 4" Rail (Steel Bar)
Steel Beams
Cast Iron Cylinders
20'-0" centres Longitudinally
Filled with Concrete
Rock
1
6'-6"
11'-0"
11'-0"
6'-6"
75 Lbs. Rail
Racks
R.C. Beams 30'-0" long
9" concrete
Stone Rubble
Sand
Wedges
Continuous Concrete Slabs
2
11'-0"
11'-0"
Teak 12" x 18"
Teak 18" x 18"
4½" Brick
9" concrete
12" x 12" Ironwood 10'-0" apart
Masonry Walls
Alluvium
3
12'-6"
12'-6"
1'-8"
Rack
Roller for Links
13" x 13"
13" x 13"
5" x 5" Cast Iron Rail
12" x 6" Timbers 5'-0" apart
Concrete
Alluvium
4
2'-0"
11'-0"
11'-0"
2'-0"
14"
6" Stone Pitching
Rack
12" x 6"
C.I. Rails 4" x 4" in 10'-0" lengths
12 x 6 Timbers 11'-0" apart
3'-6"
Concrete
Chalk Rock
5
11'-0"
3'-0"
11'-0"
Bridge Rails 70 Lbs. per yd.
Rack
2'-6"
Concrete Walls
5'-6"
2'-6"
Rock
6
11'-0"
3'-0"
11'-0"
Bridge Rails 70 Lbs per yd.
12" x 12" Timbers
Rack
Alluvium
Timber Piles 12" x 12" 10'-0" apart
Timber Piles 12" x 12" 10'-0" apart Longitudinally
7
12'-0"
2'-0"
12'-0"
Steel Rails 100 Lbs. per yd
R.C. Beam 14" x 18"
Rack
R.C. Beam 3'-3" x 1'-6"
12" x 12" R.C. Beam
14" x 14" R.C. Piles 10'-0" apart Longitudinally
Alluvium
8
5'-3"
5'-9"
5'-9"
5'-3"
Pawls
Pawls
9" diar. Wheels
Racks
11'-0"
11'-0"
9
Sliding Bilge Blocks
American Oak
Tie Rod
Timber Framing
9"d. wheels
Roller for Links
5'-6" apart
Wheels 18" apart
Rack
12'-6"
12'-6"
10
Platform
Socket for Flagstaff
11'-0"
11'-0"
Timber
Framing
Tie Rod
11
Timber Blocks
1 in 7
6'-6"
6'-6"
12
Frames 10'-0" apart
Keel Blocks 5'-0" apart
Bilge Blocks 10'-0" apart
Ring
Roller for Links
12"d. wheels
12'-0"
Rack
12'-0"
13
Hand wheel
Mitre wheels
Platform
12'-0"
12'-0"
3'-0"
Sliding Block
Screwed Rod
Mitre wheels
Rack
14
Keel Blocks 5'-0" apart
Bilge Blocks 10'-0" apart
Steel Joists 5'-0" apart
Rod to Pawl
9"d wheels
12'-0"
Rack
12'-0"
15
Continuous Cross Beam at Ends
Blocking up space
12'-0"
Rack
12'-0"
4'-0"
16
Hauling Rope
Pulley
Downhaul Rope
Cantilever Frame
17

for another vessel. The slipway is on a gradient of 1 in 16, and the hauling speed is 7ft. 6in. per min., while the power working the two main hauling drums, with a downhaul drum between, consists of a 55-b.h.p. electric motor.

Traverser Slipways.

In another form of relieving slipway, the longitudinal cradle is run up over a traverser sunk in a cutting at the head of the slipway. The traverser is in separate parallel sections, and travels on rails at right angles to the slipway, so that the cradle and ship can be pulled to either side of the slipway, where the vessel is blocked up between the sections of the traverser, the bilge blocks on the cradle are slid outwards and can be turned round on pivots to clear the ship.

The traverser and cradle are then run out to the slipway, and the cradle is lowered if required for another ship.

Rolling Friction.

With regard to the rolling friction of loaded cradles on slipways, this depends upon the accuracy with which the rails have been laid, and the amount of mud on the rails. Experiments have been made on several slipways, and in one the rolling friction was found to be 46·5lb. per ton which was equivalent to 2·08 per cent. of the weight lifted, exclusive of machinery friction, while in others the total friction, including that of the machinery amounted to from 74·7lb. to 87·4lb. per ton lifted, or 3·33 to 3·9 per cent. of the weight. The rolling friction of the cradle alone may be taken at 20lb. per ton, and of the loaded cradle at 40 to 60lb. per ton, while that of sliding links on rollers will be 20lb. per ton, and including the machinery and winches from 70 to 90lb. per ton.

The friction of direct-acting hydraulic rams is from 5 to 10 per cent. of the load to be lifted, while that of the machinery, winches and gearing will be about 30 per cent. An allowance of 5 per cent. must be made on the total power required to cover the starting friction, and to overcome inertia.

Haulage Power.

The calculation of the power required to haul a ship weighing 1.415 tons, cradle 80 tons and rope 5 tons, a total of 1,500 tons up a slipway on a grade of 1 in 20, at a speed of 10ft. per min., using a power winch and steelwire rope is as follows, *viz.*:

Pull on rope to overcome gravity $\frac{1,500}{20}$ =	75·00 tons.
Rolling friction of ship and cradle 1,500 × 40lb. =	26·78 ,,
	101·78 ,,
Machinery friction, 101·78 tons × 30% =	30·53 ,,
Total =	132·31 ,,

The total friction is 57·31 tons, and is equivalent to 85·58lb. per ton lifted or 3·82 per cent.

The h.p. required on the level to overcome friction $= \frac{F \times V}{14 \cdot 73} - \frac{57 \cdot 31 \times 10}{14 \cdot 73} = 38 \cdot 90$ h.p. where F = total friction in tons, and V = velocity in ft. per min.

While the h.p. necessary to lift 1,500 tons on a grade of 1 in 20 at a speed of 10ft. per minute is as follows:—

10ft. per min. $= \frac{10}{20} = 0 \cdot 5$ft. height raised in one minute.

h.p. $= \frac{W \times H}{14 \cdot 73} = \frac{1,500 \times 0 \cdot 5}{14 \cdot 73} = 50 \cdot 90$ h.p.

h.p. required on level to overcome friction	38·90
	89·80
Starting friction and to overcome inertia 89·8 × 5% =	4·49
Total	94·29, say 95 h.p.

The total pull on the rope is 101·78 tons, say 106 tons, allowing for the starting pull, therefore a steel wire rope 12in. circum. or 3·82in. diam. having a b.w. of 455 tons, and a safe load of 113·75 tons with a factor of safety of 4 will answer the purpose, and the winding drum will require to be 30 times the diam. of the rope or 9ft. 6in. diam.

Construction of Slipways.

With regard to the construction of slipways various methods are adopted according to local conditions, the land available, the character of the subsoil, the materials available, the range of the tides, the depth of water required over the cradle blocks, and the estimated cost.

The grades for ship slipways range from 1 in 6 to 1 in 24, and of course the steeper the grade, the more power is required to raise the vessel, but the flatter the gradient, so much the better, for then there is less strain put on the ship, when the bow is on the cradle and the stern is water-borne.

The most usual gradients are from 1 in 12 to 1 in 20, and the live load to be raised including the ship and cradle varies from 5 to 6 tons per lin. ft., but may be so much as 8 to 10 tons per lin. ft.

For slipways in which the vessel is hauled longitudinally, there are at least three lines of rails with the rack to one side of the central rail, but in most cases there is a double central line of rails, with the rack placed between, as these rails carry a slightly greater load than the outer ones, amounting to 40 per cent. of the load per lin. ft., while each of the outer rails carry 30 per cent. of the load.

In some slipways all the rails are doubled, and in broadside slips the number of rails depends upon the length of the ships to be raised, and the type of cradle used.

If the slipway is in a cutting, the slopes must be clear of the longest ship, the bow and stern of which may project 10ft. beyond the cradle.

When slipways are constructed on a rocky shore, it will be sufficient after a general clearing to the gradient required, to cut the rock in steps on the lines of the rails, say 2ft. wide for the outer, and 3ft. wide for the central rails, the underwater work being carried out by divers. The ways for the rails may be constructed of cement concrete in the proportions of 1-2-4 for the portion above water level, and 1-1½-3 for that below, inside timber, or metal shuttering. The rails should be fixed to the concrete by rag bolts and cleats, and the ends of the rails at each end of the slipway should be turned up to the radius of the cradle wheels.

Should there be no training jetty alongside the slipway, and no trestle framework on the sides of the cradle standing above high water level, then steel stanchions or concrete piles forming dolphins will require to be constructed, standing above high water, one on each side of the cradle, clear of the ship, at the upper and lower ends of the cradle to mark its position when submerged.

Another method of carrying out the underwater work is to place short mild steel or cast iron cylinders 3 or 4ft. in diameter at intervals of about 10 to 15ft. apart longitudinally under each line of rails, and fill them with 1-1½-3 cement concrete. Steel beams with fish plates and bolts, or pre-cast reinforced concrete beams can then be laid both longitudinally and transversely between the cylinders, and embedded in concrete at each support. The rails and rack may then be bolted to the top flanges of the beams.

Occasionally the underwater portion is carried out inside a cofferdam, but this is not an economical method.

In cases where the ground consists of alluvial material, it will be necessary to drive either timber or reinforced concrete piles from 10 to 15ft. apart longitudinally under each line of rails, and fix timber or concrete cross-beams on the piles, and on top of these the longitudinal rail and rack bearers. Two or more piles may be required at each support according to the load to be carried and the bearing capacity of the piles.

The timber rail bearers should have butt joints with steel fish-plates and bolts in lieu of spliced joints, which are liable to split. The weight of steel in straps, bolts and pile shoes in a timber-built slipway amounts to 3·25lb. per cub. ft. of timber, and excluding the piles to 6·5lb. per cub. ft.

It is always advisable to have the same type of construction where possible, throughout a slipway, to avoid unequal settlement, as this will cause breakage of the cradle wheels, due to unequal distribution of the loads on the wheels.

The rails for slipways should be flat-bottomed steel rails or bridge rails of a heavy pattern, fish bolted together at the joints. The weight of the rail should not be less than 10lb. per lin yd. for each ton weight on the cradle wheels. To obtain more bearing area for the wheels, steel bar rails 4in. by 3in. or 5in. by 4in. are sometimes used, the bars having the upper edges bevelled off. They are fixed by angle cleats riveted to them 6ft. apart zig-zag, and attached to holding-down bolts on the slipway. The gauge of the outer rails depends upon the beam of the ship and may vary from 20 to 50ft.

The rack may be made of cast iron or cast steel in about 6ft. to 10ft. lengths to avoid warping, the saw-like teeth being 6in. wide and 6in. pitch by 1½ to 2in. deep, having a bottom flange 12in. by 1in. thick, for bearing area, and for fixing to the holding-down bolts, at 3ft. pitch.

When hydraulic hauling power is used, with links that have to be removed at each stroke of the ram, the rack should extend the whole length of the slipway, but with modern winches and wire rope hauling gear, it will be sufficient for it to be limited to half the length of the slipway or even less.

In some slipways in which no racks are laid, the cradle when being hauled up is held by chains attached to the cradle and to hand winches at the head of the slipway to hold the cradle while links are being removed. The sketches, Fig. 1 to 8, show cross-sections of various types of slipways that have been constructed.

Cradles.

Cradles are constructed either of timber or mild steel framework, which vary considerably in design and are not in single lengths except for short vessels, but consist of a series of trucks closely coupled together, and mounted on cast steel single of double flanged wheels or rollers from 6 to 12in. diam. with simple cast iron plummer blocks, from which the wheels can readily be removed by jacking up the cradle in cases of breakage. Gun-metal bearings are sometimes used to reduce friction. The framing should be diagonally braced together at each end and in the middle, each end being triangular in plan.

Some cradles are constructed with framed stanchions on one or both sides at intervals, fixed to the ends of the cross-beams, and which project above high water level when the cradle is lowered. In others, the stanchions are connected together by top gangways for operating the bilge blocks and pawls.

When it is necessary on account of the high cost to shorten the underwater portion of slipways, the cradle is arranged to be lengthened or shortened as required, and consists of a number of independent sections each from 20 to 30ft. long. Each section is connected to the next by sliding bars, perforated with holes at intervals in the length into which pins are driven according to the extension required.

When the cradle is run down, the sections are telescoped together, and when the bow of the ship bears on the upper cradle section, the vessel is secured to it by chains or ropes, the cradle is then drawn up with the ship attached, and as each section is pulled up, the ship takes its bearing on the following sections of the cradle.

Cradles are in use that can be telescoped from 30 to 36ft. The total weights of cradles, including the keel and bilge blocks vary with the type of construction, those constructed of timber weigh about 20lb. per sq. ft. of overall plan area, and steel cradles from 45 to 65lb. per sq. ft. The plummer blocks for the wheels are fixed to the longitudinal beams, which carry cross-beams about 5ft. apart, on which are mounted the timber keel and bilge blocks; the keel blocks are usually spaced 5ft. apart and the bilge blocks 10ft. Occasionally mud ploughs are fixed to the front and rear wheels of cradles, but are seldom necessary.

In some cases the bilge blocks are arranged to slide on the cross-beams by attaching angle iron cleats to them, the blocks being fixed to horizontal screwed rods having mitre wheels at the outer ends, connected to vertical rods passing up to the top gangways on each side of the cradle, and terminating in mitre wheels and hand wheels. In other cases they are pulled by ropes attached to them, and operated from the deck of the ship or from the gangways. The blocks should be low and of hard wood from 12 to 15in. wide.

Pawls.

The cast or wrought steel pawls are pivoted to cast iron or steel blocks fixed to the underside of the central longitudinal cradle beams, directly over the rack, and in cradles that do not require to be partially dismantled for blocking up ships on shore, each pawl is fixed to a shaft carried across the cradle to the outside where it terminates in a counterweighted lever, or in levers operated from the top gangway.

The number of pawls required depends upon the total friction of the loaded cradle, and may amount to from 5 to 7 tons per pawl, if placed 20ft. apart as usual. In some cases double pawls are used, placed side by side, but engaging with alternate teeth on the rack.

Wheels.

With regard to the wheels, which may be of cast iron or steel, with single flanges, the maximum safe load that may be put on them is given by the following empirical formulæ, viz.:—

For cast iron wheels—$W = 400\text{lb.} \times D \times T$.

For cast steel wheels—$W = 600\text{lb.} \times D \times T$.

Where D = diam. of wheel or tread, and T = width of tread, both in inches. Therefore for a cast iron wheel 12in. diam., and 2in. tread, the safe load will be 4·2 tons, and for a cast steel wheel 6·4 tons.

If the wheels are of cast steel, and the total weight of the ship and cradle amounts to 10 tons per lin. ft. 40 per cent. of this will come on the centre wheels = 4 tons per ft. and 30 per cent. on each of the side wheels = 3 tons per ft. Therefore the spacing of the centre wheels will be $\frac{6{\cdot}4}{4} = 1{\cdot}6$ft. for a single line of wheels, and that of the side wheels $\frac{6{\cdot}4}{3} = 2{\cdot}1$ft.

The cast iron rollers of swing bridges seldom carry more than 1·5 tons per inch width of tread, while cast steel rollers are not permitted to carry more than 2 tons per inch of tread, a higher factor of safety being used to avoid the risk of breakages The sketches, Figs. 9 to 16, illustrate cross-sections of various forms of cradles. Fig. 16 shows a suitable form of "relieving cradle", and Fig. 17 is a typical framework cradle plan.

The diameter of the drums or barrels of the winches for wire rope haulage should be 30 times the diameter of the rope, although some have been made only 20 times the diam., and pulleys on the cradle or on shore should be at least 12 times the rope diam. The ropes should always be black, that is, not galvanised, and should be kept well greased or oiled, when they will last for from 25 to 30 years.

To obtain uniformity of motion in a number of separate hauling drums, it is advisable to use continuous counter-shafting with gearing rather than to have synchronised electric motors to each drum.

For hauling by wire rope a ship and cradle weighing 1,000 tons, the weights of the machinery may be as much as 10 tons for the main drum, and 5 tons for the gear wheel, and also for the down haul drum, the gearing may weigh 13 tons, and the engine 4 tons, while the total weight of the machinery may amount to 50 tons.

Patents in Wartime.

Effects of New Legislation.

"Electrical Review", 22nd September, 1939.

The changes to be made in patent procedure, in order to meet the abnormal conditions of war, are set out in the new Patents, Designs, Copyright and Trade Marks (Emergency) Bill, which was presented to the House of Commons on September 7th by the Solicitor-General.

The first Clause of the Bill states that, notwithstanding the provisions of the Trading with the Enemy Act, any existing licence granted under a patent does not become invalid simply because the proprietor or owner of the patent (or any person otherwise interested in it) is an enemy. Nor does a contract made under that licence become *ipso facto* invalid, because a party to the contract happens to be an enemy. A proviso to this clause excludes any grant, assignment, or contract, made after the outbreak of war, that is in conflict with the Trading with the Enemy Act. Further, the clause does not authorise the performance of any contract made under the licence in a manner which is inconsistent with any law which prohibits trading or other intercourse with the enemy.

But in spite of the fact that enemy ownership of, or interest in a patent does not, in itself, invalidate a licence granted under it, the Comptroller of the Patent Office is now empowered, should the licensee apply to him, either (*a*) to revoke the licence or (*b*) to vary any conditions to which the licence is subject, or (*c*) to revoke or vary the provisions of any contract made under it.

The new Bill also makes it possible, wherever the Comptroller considers it to be in the public interest, to take away from the enemy owner of a patent, any or all of the monopoly powers which he would normally enjoy in time of peace. At the same time special provision is made to ensure the payment of royalties, and to control the destination of any money so paid. Clause 2 of the Bill, for instance, declares that any person who is not an enemy may apply to the Comptroller for a licence under a German-owned patent, and provided he can show that he is in a position to work the patent, the Comptroller may grant him a compulsory licence either for the whole or part of the remaining life of the patent on such terms as the Comptroller may consider expedient, and irrespective of any previously-existing licence.

Royalties must be paid in respect of a compulsory licence so granted, but the person to whom they are to be paid is to be nominated by the Comptroller. It is interesting to recall that during the Great War the benefit of existing enemy-owned patents was formally vested in the Public Trustee, and that royalties paid in respect of compulsory licences issued under them were paid to the Custodian. All such moneys were finally sequestrated at the end of the war, by the Board of Trade, as debts to the Crown.

If it is shown that the person to whom a compulsory licence is granted under the new Bill has obtained it by misrepresentation, or if he fails to work the patent so that the reasonable demands of the public for the patented article are not being satisfied at a reasonable price, the licence so granted may be revoked by the Comptroller.

Clause 4 of the Bill preserves the right of an enemy, even during the period of hostilities, and in spite of the statutory prohibition against trading with him, to apply for the grant of a British patent. Moreover, he is entitled to claim the priority date which would normally be accorded to him under the provisions of the International Convention. But he cannot demand delivery of the patent, and any rights which may arise under it are made subject to the various restrictions set out above. On the other hand, the Comptroller can refuse an enemy application for a patent, on the sole ground that it is against public interest to make the grant. These conditions also apply to cases where an application for a patent is made by an enemy jointly with any other person, or where the invention has been "communicated" by an enemy to the applicant for a patent.

The question of time limits is dealt with in Clause 6 of the Bill, which states that the Comptroller may extend the normal statutory periods whenever he is satisfied.

(*a*) that delay has been caused by absence on active service, or by any other circumstance arising from war conditions, or

(*b*) if, because of the existence of a state of war, the doing of the act required, within the statutory period, would have been injurious to the rights or interests of the person concerned.

The first reason for an extension of time is self-explanatory. The second concession will apply, for instance, to the case of an inventor who, because of circumstances arising from the war, has not been able to devote sufficient time to fully develop his invention within the period normally allowed between the filing of his provisional and complete specifications.

The length of the extension which may be allowed is left to the discretion of the Comptroller, and application for such an extension may be made at any time, even at a date subsequent to that at which, under normal conditions, the application would be held to have expired, or become void, or have been treated as abandoned. Provision is made for granting the same facilities even to an enemy applicant.

The Bill treats in broadly the same way all questions relating to proprietary rights, and extends the statutory time limits prescribed for making application for the registration of designs and trade marks and for acquiring copyright.

A special clause is devoted to cases where it may be difficult to describe or refer to an article, or goods, without using an enemy-owned trade mark or trade name. It is now made possible for any person who proposes to trade in such an article, or in a substitute for it, to apply to the Comptroller, asking for the rights of the enemy owner of the trade mark or name to be suspended in favour of the applicant.

BOARD OF TRADE EXAMINATIONS.

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

For week ended 14th September, 1939:—

Erskine, Jas. A. B.... ...	2.C.M.	Glasgow
Mills, George	2.C.	„
French, William Hanson ...	2.C.M.E.	Newcastle
Heatley, Thomas	2.C.	„

For week ended 21st September, 1939:—

Beattie, Alister Soutar ...	1.C.M.E.	Glasgow
Macdonald, Arthur James...	1.C.M.E.	„
Fisk, Harry	1.C.	Liverpool
Cook, John Foden	1.C.M.E.	„
Macintosh, James Levie ...	1.C.M.E.	„
Wilkinson, Randolph John	1.C.M.E.	„
Robertson, Arthur John ...	1.C.S.E.	London
Porter, Thomas	1.C.M.E.	„
Rankin, George Phillips ...	1.C.M.E.	„
Sinclair, George Henry ...	1.C.	Newcastle
Elliot, John Thomas ...	1.C.M.E.	„
Sunley, William	1.C.M.E.	„