

INSTITUTE OF MARINE ENGINEERS  
INCORPORATED.

SESSION



1917-18.

President: CAPT. R. H. GREEN, R.D.C.

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VOLUME XXIX.

Paper of Transactions No. CCXXIX.

Brass and other Copper Alloys used in  
Marine Engineering.

By MR. J. T. MILTON (Vice-President).

READ

*Tuesday, May 1, 1917, at 7 p.m.*

CHAIRMAN: MR. ALEX. BOYLE (Vice-President).

THE CHAIRMAN: To-night we have a paper by Mr. Milton on "Brass and other Copper Alloys used in Marine Engineering." The subject is a very wide and important one, and, as you will see in his paper, Mr. Milton deals with it in a very clear and attractive manner. So far as could be done within the limits of the paper, I think the subject is complete in itself. After reading the paper, I am of opinion that it is one well calculated to be instructive to marine engineers, and attractive and interesting as a study as well. I dare say most of you are aware that Mr. Milton has had an exceptionally long experience with the subject of this paper, and has made investigations and examinations of alloys which had failed for one cause or another, and which had been brought before him. Mr. Milton very kindly in his paper has presented us with the points of these investigations and examinations, and a study generally of the subject. You will also note that Mr. Milton must have spent a good deal of time, and has been at great pains to consult very

eminent authorities who have made extensive researches on the subject. That could be very much expanded. I will not detain you longer, but I will ask Mr. Milton to read his paper. I am sure you will listen with great attention, and I am sure it will repay a careful perusal and careful study. "All marine engineers would like to have a knowledge of the character of the materials they are dealing with, and they will be glad to have a copy of Mr. Milton's paper dealing with one side of the subject of materials used in marine engineering.

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MR. MILTON: This paper has been prepared, and is largely a compilation of information which is obtainable, but which is not at everybody's finger-ends. I do not put it forward as a bit of my own investigation. It is an accumulation of information given by others, and wherever I can I have always given reference as to where the information is to be found, so that those interested can refer to the original papers and original books. I need hardly say that the question of what we call "brass" is a very important one.

In this paper it is intended only to deal with brass and other copper alloys in their different forms as they are used by the marine engineer, and it will be found that even with this restriction the subject covers a great deal of ground.

The first point to be mentioned is that of nomenclature, and this is found to be a very difficult matter. Marine engineers, as well as many others who use brass, bronze and various alloys of copper with other metals, have very vague ideas as to names, calling all sorts of metals "brass" which are not true brass, and calling others "bronze" which are more nearly allied to brass than to bronze. In fact, we generally call parts of bearings "brasses" which are made of so called gun metal, phosphor bronze or anything but brass. Even when they are made of cast steel or cast iron and lined with white metal they are often still called "brasses." Some of the white metals are sometimes called "bronzes."

The subject of nomenclature of alloys has been dealt with comparatively recently by the Institute of Metals who, in conjunction with other Institutes, appointed a committee to report on the matter. Their first report was made in March, 1914, and will be found in Vol. XI. of the Transactions of the Institute (1).

Their recommendation was that the term "brass" should be restricted to alloys of copper and zinc only, but containing more



copper than zinc, *i.e.*, containing over 50 per cent. copper. An alloy containing a third metal is to be denoted with the name of the additional element used as a prefix. Thus the alloy containing 1 per cent. of tin, 29 per cent. of zinc, and 70 per cent. of copper used for Admiralty condenser tubes should be called "tin-brass." Similarly they recommended that the term "bronze" should be used to denote an alloy containing more than 50 per cent. of copper, the remainder being tin only. If other metals were present then their names should be used as prefixes, thus the ordinary Admiralty mixture usually called "gun-metal," containing 88 per cent. of copper, 10 per cent. of tin, and 2 per cent. of zinc, should be called "zinc-bronze." It may be stated that these names have not yet come into general use, and both the terms "brass" and "bronze" are being frequently used in most misleading ways.

Even the name gun-metal conveys no precise idea, either of the composition of the metal or of what a gun is made of, as when copper alloys were used for making guns they were generally composed of copper and tin only; that is to say, they were "bronzes," whereas the term "gun-metal" is now more often employed to denote an alloy containing zinc in addition to copper and tin. Moreover, these guns were generally spoken of by the soldiers who used them as "brass" guns.

In this paper the alloys will be spoken of by the names usually employed, although they are admittedly not precise, but it is hoped that no misconception will arise through the use of these common names, as it is intended in all cases to state the main elements of their composition.

Copper-tin alloys were known and used in the remote past, in the so-called "bronze" age before the use of iron. It is stated (2) that a rod of metal found by Dr. Flinders Petrie, at Meydum, was found to contain 89.8 per cent. of copper, and 9.1 per cent. of tin. It was estimated to date from 3700 B.C. Objects of bronze were found at Troy, supposed to date from 1200 B.C. The first artificer we read of in the Bible was Tubal-cain, who was an instructor of every artificer in brass and iron. In Hiorns' book on Alloys (3) there is a quotation from another work (4), in which it is stated that the word translated as "brass" in this and in other places in the Bible, probably refers to "bronze," an alloy of copper and tin. (5) From Percy's Metallurgy, however, it is evident that real brass, *i.e.*, an alloy of copper and zinc, was in use in Roman times. He gives the analyses of four ancient coins, all containing not less than 10 per cent. of zinc, of dates about 20 B.C., 60 A.D.,

79 A.D., and 120 A.D., and also analyses of other ancient brass coins of somewhat later period; one of these has a composition which would be suitable for making condenser tubes. Percy states that although zinc was used in these ancient alloys, it was not known as a separate metal. He implies that it was not until the 16th century that zinc was so known, and that from the Roman times until then the brass alloy was made by what is known as the "calamine" process, a method which was in use in this country so late as 1859.

(5) Calamine is a zinc ore consisting primarily of carbonate of zinc. In making brass 100 lbs. of calcined calamine was mixed with 40 lbs. of ground coal and a little water. This was then mixed with 66 lbs. of bean-shot copper and charged into crucibles which, in groups of nine, were placed in a furnace. The heat applied permitted the coal to combine with the oxygen of the ore. At a temperature somewhat below the melting point of copper the zinc which was reduced was vaporous and combined with the copper which, being in small pieces, presented a large surface to the action of the zinc vapour. The brass produced in this way has about the composition of 2 parts copper to 1 of zinc. "Calamine" brass was for a long time thought to be of superior quality to brass produced by the direct mixture of zinc and copper, which is the method of manufacture now always adopted.

Copper and zinc alloy in all proportions, and the alloys throughout their range have been scientifically studied perhaps more than any other series of alloys. Law (6) gives a table of no less than 144 records collated for the Committee on Alloys appointed by the United States Board (reported in 1881.) Mr. G. Charpy, an eminent French metallurgist, in a volume upon Alloys, published by the Societe Nationale d'Encouragement, Paris, has given a very complete account of the microstructure of these alloys. A. H. Hiorns in his book on "Metallic Alloys" (3) gives a table of 54 different alloys mainly of copper zinc, but a few containing small quantities of other metals. He also gives a table of the freezing points of the alloys throughout the range, which table agrees with the curve given in the Fourth Report of the Alloys Research Committee of the Institution of Mechanical Engineers, which report (8) deals with alloys of copper and zinc, and also those of copper and tin.

This report points out that the brass alloys which admit of industrial application are those containing from a minute proportion of zinc to 45 per cent. of that metal. When the proportion of zinc becomes as high as 50 per cent. the alloys become



fragile. The report states that it is found that generally the limit of elasticity, the resistance to penetration and the hardness increase with the proportion of zinc, the tenacity also increases until it attains a maximum at about 45 per cent of zinc. The extensibility, compressibility and reduction of sectional area also increase with increase of zinc, but attain their maxima at about 30 per cent.

In alloying copper and zinc there is no doubt whatever that true chemical union takes place between the metals, but this can only occur in atomic proportions. The atomic weights of the two metals are nearly equal, being 63.2 for copper, and 65 for zinc. Various experimenters have considered that the compounds  $\text{Cu Zn}$ ,  $\text{Cu}_2 \text{Zn}$ ,  $\text{Cu}_3 \text{Zn}_2$ ,  $\text{Cu}_3 \text{Zn}$ , all may exist. In the tables of brass alloys quoted both by Hiorns and Law (3 and 6), compositions are given ranging by units right up to  $\text{Cu}_{10} \text{Zn}$ , and down to  $\text{Cu Zn}_8$ . What might fairly be considered is that the alloys containing the least proportion of zinc are composed of a compound of copper and zinc existing as a solid solution in copper, and that those containing more zinc as solid solutions of one zinc copper compound in another compound of different proportion.

When copper zinc alloys are examined microscopically by suitably preparing and etching sections, it is found that all those containing from about 67 to 100 per cent. of copper have a uniform crystalline structure. Those of less copper content down to about 55 or 50 per cent. have a duplex structure; that is to say, they consist of two constituents, at about 50 per cent. one constituent only is present. The above refers to the metal, both in the annealed and also in the "hard worked" condition. If, however, the metal is raised to a very high temperature and quenched the duplex structure is found to have disappeared. Apparently the two constituents mutually dissolve into one another at a high temperature, and are retained as solid solutions by quenching. Slow cooling, however, permits them to again separate, and the slower the cooling the more complete is the separation which takes place. In the alloy named "muntz metal," containing approximately 60 per cent. copper and 40 per cent. zinc, the separation is well marked.

All the alloys containing 55 per cent. and above of copper have their useful properties considerably improved by working. Those below about 66 per cent. of copper may be forged or rolled hot, muntz metal being easily so worked; above 67 per cent. it is generally considered that the metals can only be worked cold. As the critical proportion, say 66 or 67 per cent.

is approached, more care is required in forging hot. Muntz metal and the other low zinc alloys can also be worked cold as well as hot. In all cases of cold working every deformation given to the metal hardens it and renders it less able to withstand further deformation, but this hardness may be removed by annealing.

A remarkable example of how cold work can alter the shape of a mass of metal without producing fracture was given by Sir William Anderson in the discussion on the Fourth Report of the Alloys Research Committee (8), in an explanation of the manufacture of brass cartridge cases for 6 inch quick-firing guns. These are made from an alloy of 70 per cent. copper and 30 per cent. zinc. This is rolled cold into a plate from which circular discs are cut. The discs are then pressed cold into a cup shape, then annealed and cleaned. The cups are then gradually drawn out into close ended tubes, thinner and thinner, each draw, except the last one, being followed by annealing and cleaning. In all there are eight annealings, the whole of the work being done cold.

The same alloy, 70 per cent. copper and 30 per cent. zinc, is also used for making condenser tubes, although sometimes a slightly higher percentage of zinc is used for this purpose, say up to 33 per cent., and similar metal is also sometimes used for cartridge cases. For the Admiralty, condenser tubes have a little tin added to the mixture, their standard proportions being 70 per cent. copper, 29 per cent. zinc, and 1 per cent. tin. In making condenser tubes the metal is first cast into tubes about  $3\frac{1}{2}$  inches external diameter,  $\frac{1}{2}$  inch thick. These tubes are then drawn down cold upon smooth mandrels by several stages until they become of the finished size, each draw, with the exception of the last, is followed by annealing. The last draw leaves the tube "hard." The amount of "draw" or "pinch," or reduction of cross sectional area at the last operation is such as to leave the tube sufficiently hard to withstand the tendency to crush, owing to its being tightly packed in the tube plates, but not so hard as to be brittle.

As a surface defect on the inside of the original cast tube would not be entirely removed by the drawing process, it is usual to bore out the cast tube before any drawing takes place, and so produce a clean and good surface to start from. This, however, is not always done.

The same alloy, viz., 70 per cent. copper and 30 per cent. zinc, is used for making turbine blades. The process of making them, so far as the author is aware, has not been made public.



Condenser ferrules are made of an alloy containing a little more zinc than the condenser tubes. They are machined from tubes "hard" drawn, as for them hardness is a desirable quality, enabling them to be screwed up tight upon the packing without deformation.

The brass tube plates of condensers are usually made of "muntz metal," *i.e.*, an alloy of 60 per cent. copper and 40 per cent. zinc. For Admiralty work the mixture specified is 62 per cent. copper, 37 per cent. zinc, and 1 per cent. tin, and this metal is called Naval brass. The tin is required, as it is thought that its presence assists in resisting corrosion. These plates are rolled hot.

It has been stated that with these brass alloys greater strength is obtained with those containing a larger proportion of zinc. Many figures are given in different books of test results of the various brasses, their diversity is due partly to variations in the quantity of work put upon the metal, partly to the greater or less amount of annealing to which it has been subjected, and partly to the effect of impurities in the metal. Quoting the report on Alloys Research previously referred to (8), the alloy "with 40 per cent. of zinc elongates 40 per cent., with a "strength of 23·8 tons per square inch. By adjusting the "softening effect due to annealing and the strength produced "by working, it is easy to increase the tenacity of bars and "sheets to 38·09 tons per square inch, and to attain even "greater strength in the case of wires."

In the same report (8) there is a statement by Dr. D. Watson, the Manager of the Broughton Copper Co., of Manchester, shewing the effect of small quantities of impurities upon the strength and ductility of brass. He gives the following:—

	Tenacity per square inch.	Elongation per cent.
Brass containing 70. per cent. of Copper and 30 per cent of Zinc . . . . .	20·2 tons	65½
Same Brass with the addition of 0·5 per cent. of Iron . . . . .	24·2 tons	31¼
Same Brass with the addition of 0·5 per cent. of Iron and 0·1 per cent. of Phosphorus	26·5 tons	28

The above samples were thoroughly worked, and afterwards annealed before testing.

Dr. Watson stated that the effect of iron was very marked, and that aluminium manganese and tin also had influence in increasing the tenacity and elastic limit, although they decreased the elongation.

It has been mentioned that when much cold work has to be put on brass, as, for instance, in the manufacture of cartridge cases, seamless tubes, etc., the brass has to be frequently annealed. The temperature at which this takes place is of great importance. Law (6) quotes some information obtained from Mons. G. Charpy, which shews that when brass of 70—30 composition has been worked to its maximum condition of strength of over 30 tons per square inch, the full effect of annealing is produced by a temperature of 600° C, which reduces the strength (cold) to 17.4 tons per square inch. Annealing below 280° C has practically no effect, at 420° C there is a marked softening effect, but the maximum is reached at the temperature stated above.

Some information as to the increase of tenacity due to cold work and also as to the effect of annealing at different temperatures was given by Captain C. Grard, of Paris, in a paper read at the Congress of the International Association for Testing Materials, held in 1912, at New York. He dealt with copper and also with brass containing 90 per cent. copper, 10 per cent. zinc, and brass containing 67 per cent. copper, 33 per cent. zinc, the latter being an alloy used for the manufacture of cartridge cases by the French War Department. He states that the brasses experimented upon were of good quality, very malleable when cold, but fragile and short when hot.

He states that the effect of cold working was the same, whether produced statically (drawing and rolling), or dynamically (under a drop hammer), and that the effect of cold work was completely removed by proper annealing. In making experiments with drastic amounts of cold rolling recourse had to be had to successive cold rollings without intermediate reheatings.

To denote the amount of cold work he employs numbers represented by  $\frac{S-s}{s} \times 100$ , where  $S$  = the original section of the specimen, and  $s$  = the reduced section after the cold work. Hence, if before annealing the section is reduced to one-half the original, the cold work number would be represented by 100. The effects of cold working upon the tensile strength, limit of elasticity and elongation, are shewn in Fig. 1 for the 67/33 brass, and in Fig. 3 for the 90/10 brass, and the effects of annealing at different temperatures are shown in Figs. 2 and 4.

It will be seen that with both alloys the effect of cold working, while increasing the strength, decreases the ductility very considerably, so that the danger of cracking the metal renders it



inadvisable to employ too large an amount of cold work without annealing.

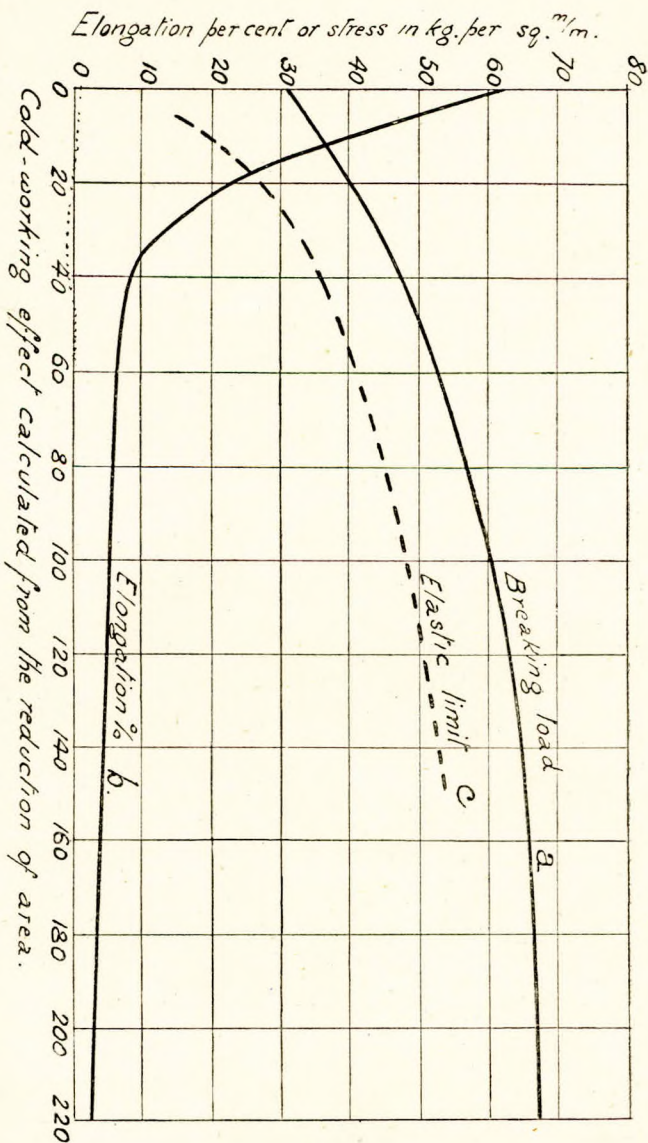


Fig. 1.

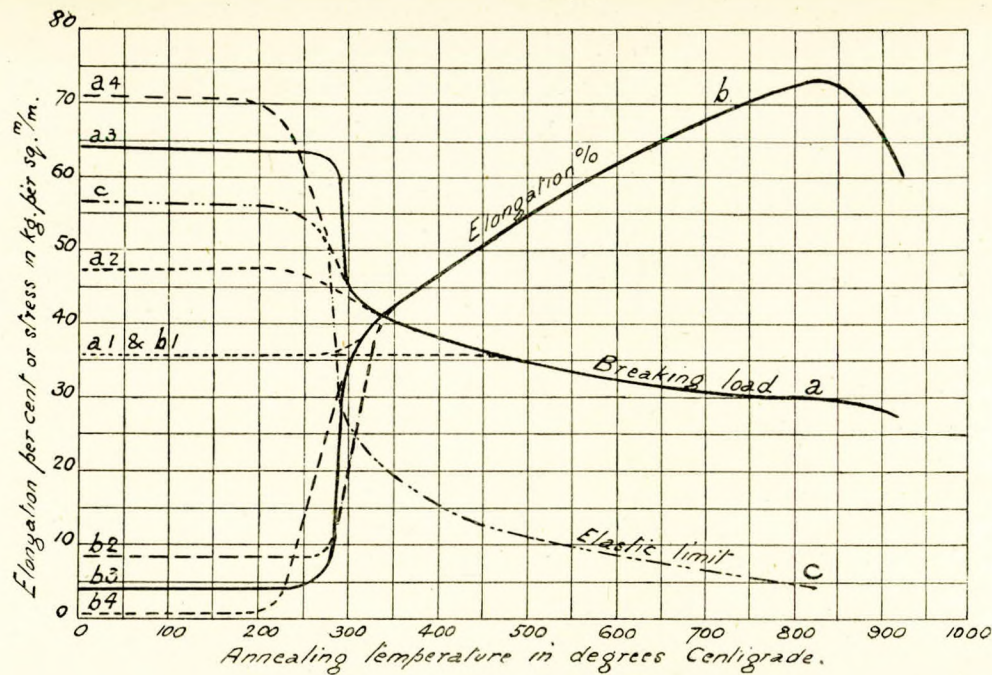


Fig. 2.

*a1 a* indicates the Breaking load for brass cold worked to 15 per cent.  
*a2 a* " " " " 50 " "  
*a3 a* " " " " 125 " "  
*a4 a* " " " " 300 " "  
*b1 b* Elongation for brass cold worked to 15 per cent.  
*b2 b* " " " " 50 " "  
*b3 b* " " " " 125 " "  
*b4 b* " " " " 300 " "  
*c* Elastic limit,



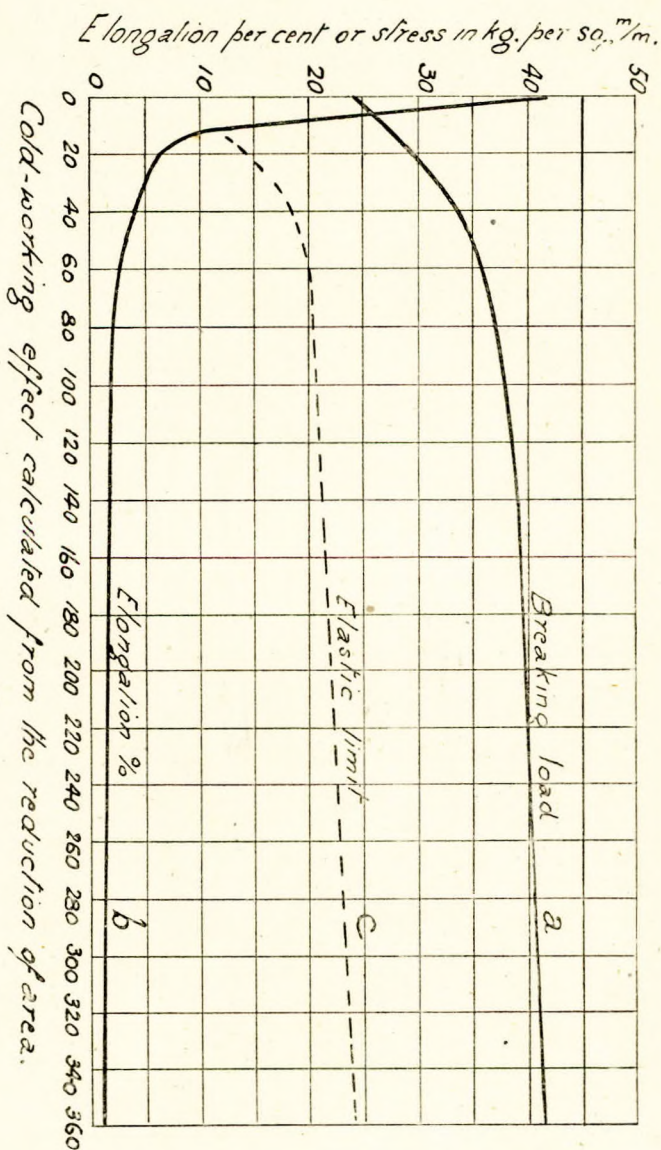
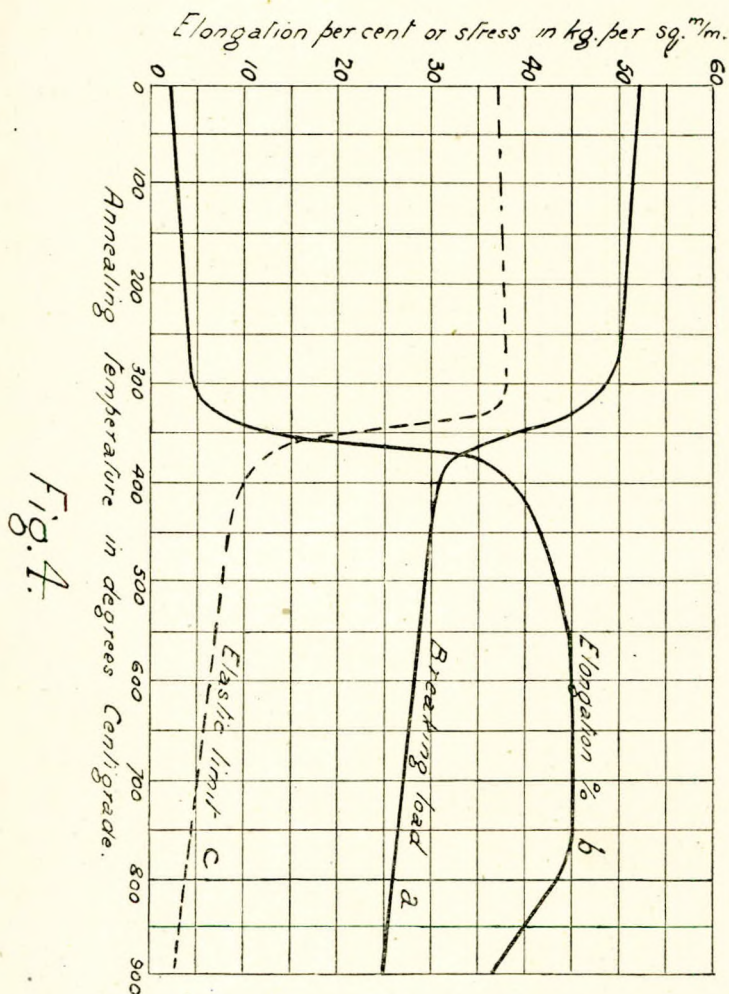


Fig. 3.



It is well worth noting in Fig. 2 that whether the alloy is much or little cold worked, the effect of annealing at between 250° C and 300° C is to bring it back to one standard condition of softness.

The shape of the annealing curves in Figs. 2 and 4 show that if the metal has been rendered too hard by cold rolling it is



The following illustrations are from blocks specially prepared to represent the specimens, showing defects, which were on view in the course of the evening, when paper was read. The blocks have been kindly lent by the Editor of *Engineering*, to whom we are indebted for the opportunity of reproducing them:—

SPONTANEOUS FRACTURE OF BRASS.

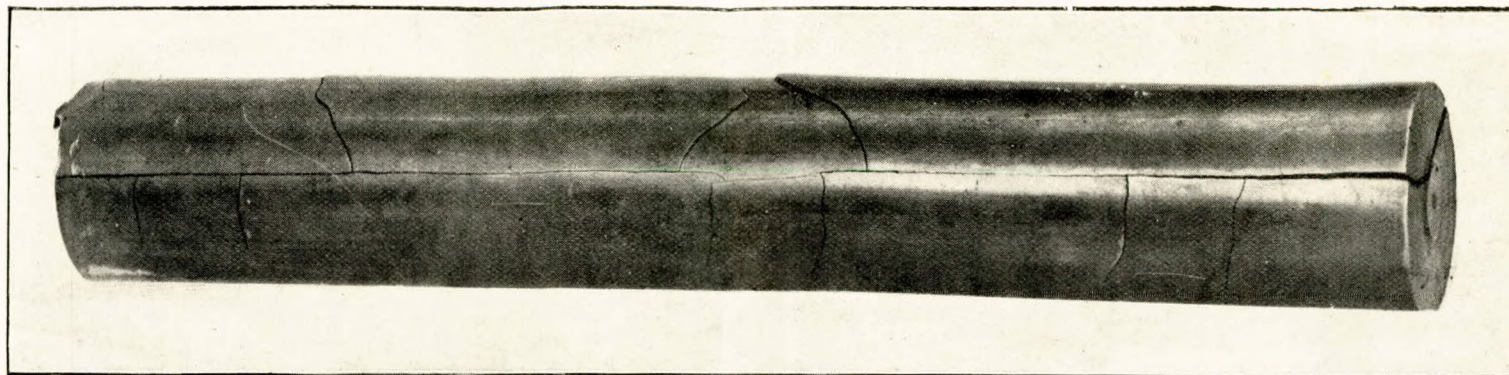


Fig. 5.  $2\frac{1}{8}$ " Brass Bar with cracks developed in transit over seas. Half size.

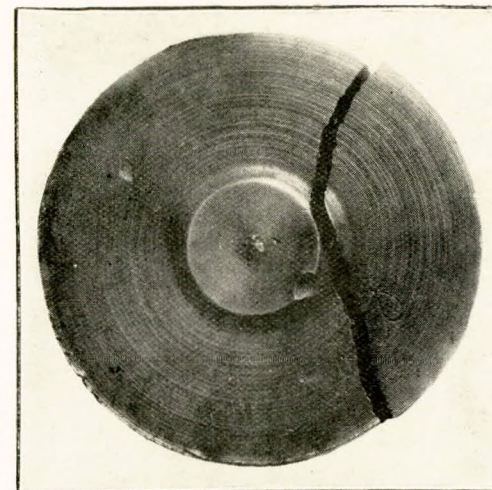


Fig. 5. End view of  $2\frac{1}{8}$ " bar. Full size.

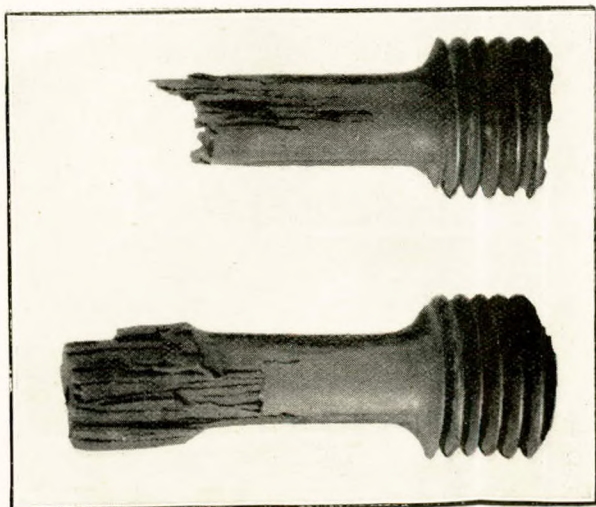
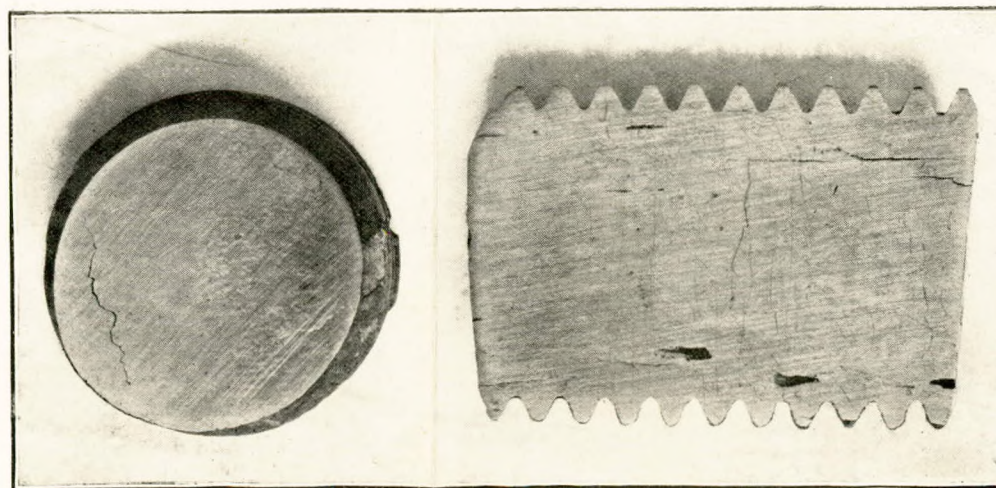


Fig. 6. Test pieces of fractured bolt. About full size.



Longitudinal and cross section of fractured bolt for ship's connections. Double size.







very difficult to adjust the temperature of annealing so as to only partially soften it in cases where complete annealing would render the metal too soft. If, therefore, only a slight hardness is required for any special purpose it is better to obtain it by adjusting the amount of cold work to give the necessary property rather than to attempt to first make it very hard, and then to soften it to the required degree.

Although valuable properties are given to these brass alloys by cold work, such as increase of strength and of elastic limit, it must not be forgotten that the ductility is much reduced at the same time. When brass is subjected to much cold work it is liable to spontaneous fracture. Cases are not unknown of condenser tubes spontaneously cracking longitudinally, and of cold-rolled brass rods being found split after being stored for some time. Such occurrences are sometimes called "season cracking." The cause is to some extent obscure, but the fact that it occurs shews how unwise it would be to rely upon what may be termed an artificial strength produced by cold rolling for articles in which a failure would cause disaster. This is sometimes not sufficiently realised by engineers who think they are securing a better article by specifying stringent conditions of high tensile strength and high elastic limit which can only be obtained by cold rolling.

Figure 5 shews a remarkable instance of this. It represents part of a round brass bar  $2\frac{1}{8}$  inch diameter, which was specified to have a tensile strength of 30, and an elastic limit of 20 tons per square inch. The cracks shewn appeared in the bars during transit between the manufactory and the works where they were intended to be used. Figure 6 shews the section of a part of a brass bolt used for fastening sea connections on a large steamer. It has been turned out of a cold rolled or cold drawn bar. As will be seen cracks have occurred in it both longitudinally and cross ways, and the metal is absolutely dangerous for use for such purposes, or, indeed, for any purpose.

Useful information on the effects of cold work upon metals is given in the May Lecture of 1914 by Professor E. Heyn, of Berlin, delivered at a meeting of the Institute of Metals, in which he shews that internal strains are set up by cold working affecting the metal near the surface differently to that nearer the centre of the piece. He mentions that cold rolling and cold hammering produce tension strains in the core of the worked pieces, whereas cold drawing has the contrary effect, bringing about tension strains on the superficial layers and compression in the core.

Brass such as has been considered above is mostly used by marine engineers in connection with condensers, or as bolts and nuts, and is never used in details exposed to high temperatures. At high temperatures its tenacity becomes considerably lowered. In the Alloys Research Committee's report already referred to (8) a table is given from which the following is extracted:—

Tenacity of brass of composition copper 61·2 per cent., zinc 38·8 per cent.

Temperature.	Tenacity Tons per sq. inch.
20° C = 68° F	20·7
100° C = 212° F	13·6
200° C = 392° F	12·6
250° C = 482° F	10·4
300° C = 572° F	7·3
350° C = 662° F	6·8
450° C = 842° F	3·6
500° C = 932° F	2·8

Another alloy of copper and zinc used in marine engineering is known by the names of "Spelter," and also "Hard Solder." It is used for brazing purposes. (Note the name Spelter is also used to denote ingot zinc, but brazing solder is generally termed "spelter" by copper-smiths and engineers). This alloy is composed of copper and zinc, varying from 60 per cent. copper, 40 per cent. zinc, to about equal proportions of each according to the purpose for which it is to be used; the higher proportion of zinc in any solder lowers the temperature at which it melts. During fusion, in brazing, some of the zinc evaporates, leaving the solder on the finished article richer in copper than the original alloy. Hard solder is always made in a granulated form, which is obtained by casting the alloy into flat ingots. These are heated to a high temperature, judged by the colour, and at this temperature it is very brittle. It is then pounded up into small pieces in an iron mortar. The broken pieces are sifted out to various degrees of fineness, the large pieces, if any should remain, are then reheated and repounded.

In making brass alloys it is important to use as pure metals as possible for the constituents. It has been stated that iron has a very marked effect upon the strength and ductility. Lead is often present in small quantities, being generally introduced along with the zinc, as much of the commercial zinc contains lead. It is, however, considered to be of great importance that



the metal should not contain either antimony or arsenic, both of which may be introduced along with the copper. There is a workshop test known as the Muntz Metal test, practiced in order to detect these impurities if their presence is suspected, either in copper or brass. A weighed portion of the copper or brass to be tested is melted in a small crucible and sufficient pure zinc is added to bring the proportion of copper and zinc to 60/40, the composition of muntz metal. The resulting metal is poured into an open cast iron mould, the quantity being sufficient to make a flat cake about 1 inch in thickness. This is allowed to cool. When cold it is nicked across with a chisel and broken. If the metal is good the fracture is fine and silky, but if even small traces of arsenic or antimony are present the fracture is different. The skilled workmen can in this way determine the proportion of either of these pernicious elements with almost the same precision as can be obtained in a chemical laboratory.

We will now consider the bronzes, *i.e.*, alloys of copper and tin.

Pure bronzes, *i.e.*, alloys of copper and tin only, are not much used by marine engineers, as almost invariably some zinc is added to the alloys, which in their various forms are usually misnamed either "brass" or "gun-metal." These alloys are used as castings, no forging work, either cold or hot, being put upon them. The reasons for their use for many purposes are the facility with which they can be cast to the shape required, their comparative resistance to corrosive influences, and their strength.

The alloy known as Admiralty gun-metal is composed of 88 per cent. copper, 10 per cent. tin, and 2 per cent. zinc, and this is without any doubt a very useful alloy. All kinds of boiler mountings, such as gauge cocks, feed, blow out and scum valves and chests, and the valves and seats of stop and safety valves requiring a strong and incorrodible metal, are made of this alloy. Sometimes where a little harder metal is required to resist wear, such as in some valves and valve seats, water gauge cocks, etc., the zinc is omitted and pure bronze is employed of a composition of 90 copper and 10 tin.

The addition of the zinc serves a very useful purpose in rendering the casting sound, besides the influence it has on the strength of the metal. When copper is melted and exposed to the air it rapidly oxidizes, and molten copper has the property of dissolving the copper oxide so formed. When a bronze is

melted both the copper and tin composing it are oxidized. The tin oxide is not soluble in the molten metal, but the copper oxide is; the tin oxide formed therefore remains on the molten metal as a scum, but the copper oxide disappears by going into solution in the molten metal. During the solidification of the metal at least part of the oxide becomes thrown out of solution and separated, and the result is a multitude of minute particles of copper oxide dispersed through the metal, which in consequence is more or less porous and unsound. If, however, there is a small proportion of zinc present, this metal has a greater affinity for oxygen than copper, and the copper oxide becomes reduced to metallic copper, giving up its oxygen to form zinc oxide, which, not being soluble in the fluid metal, rises to the surface in the scum. A small addition of zinc, therefore, permits a sounder casting to be produced.

A similar result may be obtained by the addition of a small proportion of phosphorus, which, as is well known, has a very great affinity for oxygen. When this is added to a copper-tin alloy the result is termed a "phosphor bronze." The phosphorus is added either in the form of phosphor-copper or phosphor-tin. Phosphor-copper is commercially obtainable in two forms, one containing 15 per cent. of phosphorus, the other 10 per cent., the latter melting at a lower temperature than the former.

If the precise proportion of phosphorus necessary to remove the oxygen is added to the bronze the metal remaining is still called "phosphor bronze," although it will contain no phosphorus, but its properties are considerably better than those of a bronze not deoxidized.

Zinc is often used in the so-called "gun-metals" employed in marine engineering in considerably greater proportions than the 2 per cent. specified in the Admiralty mixture. It is sometimes said that the greater proportions are used because zinc is cheaper than either copper or tin. Lead is also often added, but not always with the view of making a cheaper mixture, as a reference to Mr. Dewrance's research, to be presently referred to, will shew. The addition of lead renders the metal less tough, and therefore more easy to machine, and for this reason it is, to say the least, not objected to by the machinist. It is also claimed for certain admixtures of lead that they render the metal more suitable for bearing purposes, by reducing the friction under heavy loads, and, especially in America, alloys containing considerable quantities of lead are used for bearings in heavy machinery.



The microscopic structure of the so-called "gun-metal" used in marine engineering work is peculiar. When ordinary castings are being machined with a fairly rough cut the surface is seen to present a mosaic of ordinary yellow and of a rather lighter colour. Each portion shewing one colour is a crystal with different orientation to its neighbours, and the crystals so shewn are fairly large, their size depending upon the rate at which the casting cooled from its liquid condition. When a cut surface of the metal is carefully polished and suitably etched and examined under a microscope, it is seen that each of the above-mentioned crystals is really composed of a number of "dendrites," arranged in regular geometrical fashion like the divisions of a fern leaf. What happens in the cooling out of the metal is that the particles which first solidify are richer in copper than the average of the metal. They arrange themselves in a skeleton form of dendrites. Next to solidify are other particles not quite so rich in copper as the preceding, these arrange themselves outside those already formed, and the process goes on, the skeleton dendrites becoming more and more clothed with metal less and less rich in copper, and the portion of the metal which still remains fluid becomes relatively poorer in copper and richer in the tin or tin and zinc, until a point is reached at which it all becomes solid. The dendrites thus formed have been referred to by American metallographists as being of "onion" type, not because the shape is that of onions, but because it is formed of successive layers deposited on one another. Suitable etching of sections of the dendrites shews by the deeper colours of the centres that this difference of composition exists.

Where the copper is not more than about 91 per cent. of the composition the metal cannot well be worked either by hammer or by roll, either hot or cold.

With greater proportion of copper than 91, especially when the metal has been deoxidized by phosphorus, some amount of work can be put upon it, and we have made in this way the so-called "phosphor bronze" rolled sheets which are used for air pump valves, and which are hard and elastic. It is also drawn into wire for electrical purposes where high conductivity, combined with high strength and resistance to corrosion, are required.

In view of the peculiar onion-like, minute structure of gun-metal, it may be thought that it will be possible to modify its qualities by such heat treatment as will make the constituents

diffuse into one another and become a homogeneous whole instead of remaining of diverse composition. Experiments in this direction were made by Messrs. H. S. Primrose and J. S. G. Primrose, and were communicated to the Institute of Metals in 1914 (1). They experimented on metal cast in ordinary dry sand moulds, and also on samples cast in chill. Their tests included raising the metals to different high temperatures, keeping them at these temperatures for different lengths of time, and cooling some by quenching, and allowing others to cool out as in ordinary annealing. Their conclusions were:—

1. No improvement results from heating and quenching, which lowers the strength of the material.
2. Simple annealing of the metals for 30 minutes very considerably increases its strength and elongation, the maximum results being obtained after annealing at 700° C.
3. The homogeneity and other physical properties of the metal are correspondingly improved, but particularly the capability of the castings to withstand hydraulic pressure.

In the results quoted in the paper the unannealed dry sand casting had a tensile strength of 17·2 tons per square inch, and an extension of 24 per cent., whilst that which had been annealed for 30 minutes at 700° C had a tensile strength of 18 tons, and an extension of 37·5 per cent. With the "chilled" castings the improvement was still greater.

It may be stated that the requirements of the Admiralty specification for gun-metal are a minimum tensile strength of 14 tons per square inch, and extension of at least  $7\frac{1}{2}$  per cent. in a length of 2 inches.

Although "gun-metal" is extensively used for boiler fittings, and therefore exposed to temperatures as high as that of high pressure steam, very little information is available upon the subject of the effect of high temperatures upon the strength and ductility of the metal. There has, however, long been an uneasy suspicion that high temperatures considerably depreciate its qualities.

Mr. John Dewrance (1) in a paper communicated to the Institute of Metals, gives some valuable information on this subject, which shews that the suspicion was well founded. Good Admiralty mixture with a tensile strength of over 16 tons per square inch, and extension of 11 per cent. when cold retains its



strength up to a temperature of 350° F (corresponding to a boiler pressure of 120 lbs. per square inch). At 375° F (corresponding to 170 lbs. pressure), its strength fell to 13.5 tons per square inch, whilst at 460° F (corresponding to 245 lbs.), its strength fell to 9.2 tons per square inch, and its extension fell to 1 per cent. At higher temperatures the deterioration was still worse. Mr. Dewrance, however, found that the admixture of a little lead to the metal considerably improved matters. If the tin and zinc were retained at 10 and 2 per cent. respectively, and the copper was reduced by  $\frac{1}{2}$  per cent. and  $\frac{1}{2}$  per cent. of lead added, the extension when cold was a little lowered, but the tensile strength was not affected. At high temperatures, however, a great difference was found. No reduction of strength took place until a temperature of 550° F was exceeded, and the extension was continuously improved right up to this temperature. Mr. Dewrance made similar experiments with still larger proportions of lead. His conclusions were that  $\frac{1}{2}$  per cent. lead gave the best results, but even more than this still left the metal better at high temperatures than that containing none.

Attention will now be directed to some of the alloys for which very special qualities of strength, etc., are claimed. They all are composed mainly of copper and zinc, and all or nearly all contain a proportion of iron, some of them contain one or more other components, such as tin, aluminium, manganese or nickel. They are mainly proprietary articles, and their exact composition and the methods of making them are supposed to be trade secrets, their composition, however, can easily be determined by analysis.

The fact that iron could be added to brass, and that its addition strengthened the alloy has been known for very many years, and such metals have long been known under the names of "Sterro metal" and "Aich's metal." Law (6) states that these two metals each contain 60 per cent. of copper, 38 per cent. of zinc, and 1.5 to 2 per cent. of iron, although the composition, so far as iron is concerned, varies within wide limits. This variation was due to the imperfect methods of introducing the iron. In 1883 Mr. Dick took out a patent for manufacturing an iron-brass, which he called "Delta" metal, by introducing the iron in the form of an alloy of iron and zinc, which could be obtained of reliable composition, other metals, however, were added. Law gives the average composition of Delta metal as copper 55 per cent., zinc 42 per cent., iron 1 to 2 per cent., with small quantities of manganese, aluminium, tin, and sometimes also lead.

Delta metal, like most of these iron-brasses, can be easily cast, and it is also capable of being rolled or drawn cold, and of being forged hot. It is also often "extruded." In this process, instead of being hot rolled from a billet, finished bars are made by forcing the highly heated metal through dies by applying a great pressure by means of an hydraulic press. By such means bars of almost any desired cross section may be made, but it is not generally considered that the quality of bar so made is equal to that of bars of the same composition made by the ordinary rolling process. Extrusion may be applied to most of the alloys containing from 55 to say 60 per cent. copper.

"Manganese bronze" is another of the alloys frequently used. It really ought not to be called bronze, but might, perhaps, claim to be called manganese-brass, although the amount of manganese in it is exceedingly small. This metal is used for castings, especially for propeller blades, and it is also forged when required and rolled into bars from which studs, bolts, valve spindles, etc., are made. It is made by several firms who all have their own ways of introducing the iron, the vital constituent into it. The basis of the iron in the case of this metal is Ferro-manganese.

It has been stated that copper when melted dissolves copper oxide, which is an undesirable constituent. The manganese has great affinity for oxygen, and hence acts as a deoxidizer. It, therefore, sometimes happens that the whole of the manganese added in the ferro-manganese leaves the metal as manganese oxide, as, however, the iron remains in the metal the desired strengthening quality is preserved. Ferro-manganese also contains carbon, which no doubt assists in the deoxidizing process. Some tin is usually added to the manganese bronze used for propeller blades, and often some aluminium as well.

Analysis shews that the iron is not always uniformly distributed through a large casting, the difference sometimes ranging to from 1.5 per cent. of iron to as much as 4 per cent., even when taken from contiguous parts of the casting. When a sample containing much iron is polished for microscopic examination minute hard spots are seen in it. These are thought by Mr. Dewrance and Mr. Arnold Philip, the Admiralty chemist at Portsmouth (1), to be particles of an iron tin alloy, due to the iron alloying with the tin, and a greater proportion being present than can be kept in solid solution.



Many analyses of manganese bronze have been published, Law gives the following (6).

	Copper.	Zinc.	Tin.	Lead.	Manganese.	Iron.	Alum.
Cast	57.20	40.14	1.18	0.02	0.03	1.33	0.10
Rolled	62.45	36.00	0.63	0.06	0.02	0.84	—

It will be seen how little manganese there is in either of these alloys.

Law states that nickel is sometimes added to manganese bronze used for propellers, in order to prevent erosion. It is, undoubtedly, present in one alloy used largely for forging purposes, which, however, is not called manganese bronze by its maker.

The tensile strength and elongation of good rolled manganese bronze are about the same as those of ordinary mild steel. Like mild steel when the bars are used for studs the material ought to be annealed in order to remove from it any possible effect of cold working. When bolts are made from it by forging the heating in the process effectually removes this particular trouble, but if bolts are machined out from the solid bar, as they sometimes are, then the bars should be annealed, as in the case of studs.

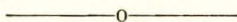
Aluminium brass, or, as it is usually called, aluminium bronze, has sometimes been used for propellers. This is very similar to the manganese bronzes, and like them contains a small quantity of iron. The aluminium is added to replace a small part of the zinc, the copper contents not being much varied.

Cast manganese bronzes of the special types as made by various makers can be relied upon to have a tensile strength of from about 30 to 35 tons per square inch. They are, therefore, about as strong as cast steel, but they do not corrode so much as steel, and can be made with good surfaces. The influence of a smooth surface in improving the efficiency of propellers is now fully appreciated, especially in fast ships, and with high speeds of rotation. It need not be mentioned how much greater efficiency is claimed by makers of special propeller bronzes over ordinary iron or steel screws.

When so-called "bronze" propellers were first used it was found that the iron of the ships suffered from corrosion in their vicinity, if by chance the paint became injured, this was put down to galvanic action. This led to a different composition being used for the propellers. Now,

more trouble appears to be met with in the corrosion of the propeller itself, and in some few cases very serious deterioration has occurred, especially in quick running propellers, such as are used with turbine engines. To meet this makers have in some cases again changed the mixtures, and "bronzes" are made which are claimed to be non-corrodible.

For yachts and small craft, which are built of wood and are copper sheathed, and in which iron or steel shafts are peculiarly liable to corrosion, forged "bronze" shafts of different sorts have been used, but it cannot be said with marked success, as all of the forgeable bronzes are copper-zinc alloys, and all seem to be peculiarly liable to a form of deterioration to which the term "dezincification" has been applied. Copper tin alloys would probably be more durable, but they do not possess the strength of the copper zinc alloys. It is with the view of preventing, or, at least, retarding this dezincification that the Admiralty require at least 1 per cent. of tin to be added to condenser tube metal, and to all brass exposed to the action of sea water. The question of the best metal for making screw shafts for wood vessels will soon be raised in view of the decision to build a large number of wood steamers in America.



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The HON. SECRETARY: The following has been received from Sir Gerard Muntz:—

French Walls, near Birmingham.

30th April, 1917.

DEAR SIR,—

I am very much obliged for the opportunity given me of attending the meeting of the Institute on the 1st proximo, but I much regret that owing to other engagements it will be impossible for me to avail myself of the opportunity. I should much have liked to have been present, as I always enjoy listening to Mr. Milton's remarks; they are always clear, practicable, and sound.

I have read the copy of the paper which you sent me, which is of much interest. It is too long, however, to deal with at length, and I should only like to make a remark on one point, that is with regard to the last paragraph of page 91, namely, the cracking or splitting of brass rods in store. Mr. Milton states that the reason of this cracking is rather obscure; it is not obscure to ourselves.

There are two reasons for the cracking of brass rods in this manner. Primarily: Irregularity of the mixture, that is to say, that the metal is made of an improper mixture, notably, for instance, Naval brass. The mixture specified and generally used, 62/37/1, is a bastard alloy, and contains far too much tin for the percentage of copper. Metal containing 1 per cent. of tin should in no case contain more than  $59\frac{1}{2}$  per cent. of copper, or, if it is to contain 62 per cent. of copper, it should not contain more than  $\frac{5}{8}$  per cent. of tin, otherwise it at once passes from the alpha beta phase to the alpha beta delta phase, which, as is well known to all makers of metals and to most engineers, is a brittle constituent, very hard and liable to cause disruption in the metal. Secondly, the amount of work put on brass rod in actually drawing or rolling is a very large element in this matter of flying. If too much work is put on, the outer surfaces are left, if drawn, in a state of high tension, and the inner side in a state of compression. Taking Mr. Milton's figures of strength—23·8 tons per square inch—it may be easily understood that the outer surface of the rods can be so compressed that the strain caused by the expansion of the interior may be sufficient to very nearly reach his figure





is not much left to say off-hand, and it requires a deal of study before you can criticise it. As to the rod shown to us, that is something I have never seen before. I have seen cracks longitudinally, and more often cross-ways. As to Muntz metal bolts—it is quite a common occurrence for them to go in the supposed strongest place, and not in the weak place. It is generally not in the heads or the body of them. I intend to study the paper, and if there is any further discussion, I hope to be able to take my part. I thank Mr. Milton very much indeed for the pains and study he has given to the subject.

Mr. MILTON: I want to make it all clear. You said you have found split tubes many times in the store?

Mr. BROWN: Yes.

Mr. MILTON: That is in direct opposition to what Sir Gerard Muntz says. He attributes it to too much tin. The tin is 1 per cent. That tin is in the Government condenser tubes, and therefore if his remarks apply, you ought to find split Government condenser tubes. As a matter of fact, split tubes in the Navy are extremely rare. The tubes you refer to are 70 and 30; and contain no tin?

Mr. BROWN: Yes.

Mr. MILTON: So the presence of tin is not the reason for splitting?

Mr. BROWN: No, not in my opinion.

The CHAIRMAN: We are very pleased to have your remarks at any time. Consider the matter when you can, for the paper, as you said, is well worthy of study, and thereafter, of discussion. You have practical dealing with these metals every day.

Mr. R. BALFOUR: I take this opportunity of emphasising a point in regard to sea-connection fastenings. I wish to emphasise the importance of that, as it is possible, with this excellent paper, before us. The importance of paying attention to sea-connection fastenings cannot be too much emphasised; after listening to, and hearing, these results, it makes it more so. I remember many years ago having occasion to see renewals from time to time in sea-connections, and I thought that it would have been much better to substitute mild steel bolts. I cannot understand why we continue to use yellow metal. But we seem never to get out of that. Then, again, what I wish to

remark specially about is the practice of covering up these important fastenings with cement. When fastening up the sea-connection, red lead with oil is used, thus you get cavities in the cement. I would advocate a thorough clean exposure of all these important parts to facilitate examination of bolts such as these, to guide us in maintaining efficiency. The practice of covering up is a bad one. This was doubtless introduced when sea connections were situated low in the bilges, but nowadays these are fitted at a higher level, and easily accessible for cleaning and examination purposes. I have often wondered why forged steel fastenings have not been employed, as they, in my opinion, would give the mechanic more confidence in making the joints; I refer particularly to cast-iron valve chests. The sea-connection fastenings handed to us for inspection prove the necessity of paying great attention to these vital parts.

Mr. BECKETT: I have here a small model of Greek bronze, and it was found in Roumania when building a railway. The end is drilled; it is a bit of ancient craftsmanship, and I am pleased to present it to the Institute. Reference is made in the paper to calamine, made of carbonate of zinc. According to Greek history it was mixed with copper and charcoal—not coal dust. The lid of the crucible was kept on. The sulphur was thus absolutely the mixing medium. I have a note about season cracking. It raises a fine point. The result appears to be like that in steel, even whilst new, due to fatigue in process of manufacture and bad workmanship. I have seen rails being made from ingot, and it started after the second or third roll, so that 2 ft., 3 ft., and even 4 ft., had to be sheared off laminated end of the ingot before again rolling, caused by the soaker furnace becoming cooled, on similar lines to the boring of the cast brass tube before drawing to make condenser tubes. Sterro, or firm metal, was first introduced to the Arts in Vienna, about fifty years ago, by Baron de Rosthorn, and was rapidly seized on by experimentalists in various parts of the world—it is of copper, zinc, tin, wrought or pure iron; tests to the ultimate tenacity vary from 43,000 to 85,000 lbs., or an average of 60,480 lbs. per square inch; it also requires a strain of 30,000 lbs. to produce a permanent elongation, or set, of  $\cdot 002$  of an inch per inch of length, whilst the ultimate elongation with the average strain of about 60,480 lbs. was  $\cdot 0675$  of an inch per inch of length, whereas bronze begins to yield at 15,000 lbs., and is fractured at 33,000 lbs., and shows an ultimate elongation of  $\cdot 290$  of an inch per inch of length.



Breaking Strain in Tons.	Treatment.	Mixtures.
28	After simple fusion .. .. .	Copper 57.63
32	Forged red hot .. .. .	Spelter 40.22
37	Drawn cold and reduced from 100 to 77 transverse sectional area .. .. . also	Iron 1.86
		Tin 0.15
31.61 and 32.52	} Cast in iron mould and forged red hot ..	Copper 60
		Zinc 34
		Iron 4
		Tin 2
38	" " " "	Copper 60
		Zinc 35
		Iron 3
		Tin 2

Torsional strain is wanted to complete these particulars, and I am unable to find this, or would quote same, but this is a specimen for propeller shafts when working in cool water.

*Bronze Mixtures for Heat:* Hopkinson has a good mixture for his check valves, both for hardness and closeness of grain, that suit temperatures of steam at 250 lbs.; and Ferranti has made a valve to suit superheat of 500 lbs., but if you are thinking of replacing boiler stays or making stays for boilers of bronze, I say do not do so, as we experienced one very sad experiment on a locomotive due to perishing at the fire-box sides a few years ago. According to Seaton's book, of all the bronzes he mentions, he leaves Delta Metal to the last, and states the invention of Mr. Dick as a high-class bronze, somewhat similar to manganese bronze, but rather harder and with a higher tensile strength—castings made from it have an ultimate strength of 34 tons, and resist torsion better than the other bronzes which are, as a rule, disappointing in this respect. Nature provides many metals in the Ural, in India and in Canada, for the metallurgist to experiment with, similar to the early days of electric light with the filament lamp. The chemist obtained tungsten, and now they use metallic wire to overcome the whole carbon difficulty, and I am of opinion that other metals could be used for bronze by adding to the copper—zinc or copper—tin alloys as an improvement, and also become a commercial success. As regards the annealing of cartridge cases and the fine measurements by pyrometer, what I have seen of the workmen handling these cases by thousands reminds one of the baker and his loaves in the oven, some overdone and some just cooked. So it is in the annealing of brass cases, though it is an interesting study.

Mr. A. E. SHARP: We are indebted to Mr. Milton for his pronouncement on the various metals. We have wanted such

a thing for some time. We have been calling all sorts of metals "brass," and attributing to them characteristics which they had no claim to. In connection with the season cracking, we have had two or three experiences recently with regard to the re-tipping of propeller blades which have shown the same symptoms. The blades seemed all right when put on board the ship. They were stowed in the after well-deck with straps across them, and after the ship had been away a few weeks the Chief Engineer reported that these blades had decided cracks where they had been re-tipped.

Mr. MILTON: How was the re-tipping done?

Mr. SHARP: In the usual way, by burning pieces on. The blades, so far as we could see, were all right when they left the makers' works to be put on board the ship. The peculiarity is, the cracking got worse. It evidently began in a very small way, and, of course, after it became a certain size it was noticed; and, as time went on, it further developed. When the ship came back we naturally thought that it might have been an imperfect job when done. But there is no reason for thinking that, as it was carefully examined along with other blades. And this re-tipping is not a new thing with us. Why this cracking should have started recently I do not know. I do not think the first occasion is more than a year ago. So it would evidently bear out what is given in the paper, viz., that there is something in connection with this metal that we have not got to the bottom of yet. I may mention a peculiar case in connection with a copper pipe, where the corrosion used to take place on the top side of a horizontal pipe used for salt water. The bad pieces were cut out of the pipe and sent to the office; the builders are in the foremost rank, and were consulted, but we never could get to the cause of the action. In order to get good material and workmanship expense is never spared. The only reason we can attribute to these pipes going that way is that the builders had some method of fixing up these pipes different from others. In connection with condenser tubes, I submitted a sample of some tubes, in which small holes had developed, to the manager of a copper works, who was a friend of mine. He had them analysed, and found these holes were due to small particles of iron in the tube. Where the copper is made, it evidently appears that the decomposition of all sorts of iron may enter into it, and one can understand it is possible for small particles to be present in the tubes which are attacked by the salt water. I think this experience might be of some



interest. In connection with manganese bronze, I had three or four different makes analysed, and I was woefully disappointed. In some of them there did not appear to be a trace of manganese. On that account one needs always to be very careful and cautious in talking of these alloys.

Mr. MILTON: Can you let us have a little more information *re* the re-tipping of blades? Surface cracking has been attributed to cold work being put on them. Were your blades simple castings with no cold work added?

Mr. SHARP: They had a certain amount of cold work put on.

Mr. MILTON: Hammering?

Mr. SHARP: Yes. After the tip is put on it is some distance away from the pitch, and it has to be set to the pitch to some extent by cold work; there is a certain amount of cold work put on the blade after the tip is on.

Mr. MILTON: Where do the cracks occur—near the junction of the new and the old, or in the middle of the mass of the new?

Mr. SHARP: At the junction of the metal; it was not so pronounced as where the blade has been at work. A certain amount of pitting took place between the old and the new. In these blades it was a little difficult to say exactly where the junction was. The accident was so long ago, and at the time we attributed it to the job having been imperfectly done in the first instance. But we have had two or three cases since then, and these we cannot attribute to what we did in the first case. There is cold work put on the blade to set the blades to the pitch.

Mr. WESLEY LAMBERT: I have to convey the best thanks of Messrs. J. Stone & Co. for your very kind invitation to send a representative to this meeting. I am fully conscious of being but a poor representative of such an old-established firm.

The last speaker has referred to ships' propellers, and as the metallurgical side of propeller founding falls particularly within my province, I am induced to come forward and contribute to the discussion.

In the early part of Mr. Milton's very concise and excellent paper, reference is made to the vagueness in the present-day nomenclature of the various alloys employed industrially. In this connection I would respectfully suggest that Mr. Milton is one of those gentlemen who, in virtue of an official appointment, is in the position to practically enforce the use of correct

descriptive names. Anyone holding an official appointment is in a much better position to do this than one connected with a private firm. There is, as some of us know only too well, an enormous number of specifications emanating from official sources. In the Royal Arsenal at Woolwich, for instance, you have the Royal Ordnance Factories, the Inspection Departments, the Army Ordnance Department, the Naval Ordnance Department, etc., each issuing separate and distinct specifications. Under the Admiralty, we find the Construction, Engineering, Torpedo, Aircraft, Electrical and Stores Departments, each of which issues separate specifications. The Crown Agents for the Colonies, the India Store Department, the Board of Trade and Lloyds' also issued official specifications.

A small committee of representative officials, working in conjunction with such institutions as the Civil Engineers, Mechanical Engineers, Electrical Engineers and Institute of Metals, could very well bring pressure to bear upon the respective departments named, and thus enforce a uniform nomenclature for the various alloys.

If Mr. Milton and his associates in the various Official Departments will only tackle the question wholeheartedly and with determination, the obscurity which the present-day nomenclature enwraps the identity of an alloy, will soon be dispelled. I am sure that both working engineers and metallurgists will welcome a standardisation of specifications and nomenclature of industrial alloys.

In regard to the method on page 86 of denoting the amount of cold work, where you have  $S$  and  $s$  representing the section, it is presumed that the cross sectional area is intended.

Mr. MILTON: Yes.

Mr. LAMBERT: Many years ago, before I entered the Government service at Woolwich, the late Sir Joseph Whitworth, I believe, introduced the "unit of forging work" in relation to the reduction of steel billets under the steam hammer or hydraulic press. The forgings more particularly under consideration were intended for Ordnance Construction.

The "unit of work" was defined as representing "the amount of work done in doubling the length of a forging." "The cross sectional area is thereby reduced one-half."

A definite number of units of forging work on the metal was insisted upon as being essential for the production of satisfactory forged material for Ordnance Construction.



It is very rare, indeed, in the ordinary run of engineering specifications, to find any mention of the amount of reduction by forging—that is to say, “work”—which is to be put upon the part under manufacture.

With the exception of the “unit of forging work” just spoken of, and which does not seem to have been adopted for other than gun forgings, the engineer does not appear to have, up to the present, any standard to define the amount of “work” put upon the materials he is constantly using.

Mr. MILTON: In one of the engineering standard specifications you will find that the section of the finished forging must be not less than one-fifth the section of the original bloom or billet. This is the only instance known to me.

Mr. LAMBERT: On page 97 Mr. Milton, writing of Delta metals, makes the following statement:—

“Delta metal, like most of these iron-brasses, can be easily cast, and it is also capable of being rolled or drawn cold, and of being forged hot. It is also often ‘extruded.’” In this process instead of being hot rolled from a billet, finished bars are made by forcing the highly heated metal through dies by applying a great pressure by means of an hydraulic press. By such means bars of almost any desired cross section may be made, but it is not generally considered that the quality of bars so made is equal to that of bars of the same composition made by the ordinary rolling process.”

The statement in the last sentence may be true, and perhaps there has been good reason for the assumption in the past. Today, however, there are hundreds of tons of extruded rodding being manufactured throughout the country and being accepted by Government Departments without any demur for distribution to the various munitions factories throughout the Kingdom. I am aware of one or two instances that Mr. Milton has had brought before his notice of the failure of parts said to have been made from bars manufactured by the extrusion process. He has stated that he is not at liberty to discuss this point or to enlarge upon it. It is known to me, however, that in some of the instances referred to by Mr. Milton a certain amount of hot work was subsequently put upon the material. Now, unless you educate the smith in the particular characteristics of the metal he is dealing with, serious damage to such material may result. For instance, large crystallisation may be developed by improper heat treatment. Such damage is

due to ignorance of the physical properties of the metal, and should not suffice to condemn the process by which the material itself is produced.

The further statement on page 98 in the paragraph commencing manganese bronze, to the effect that the basis of the iron is ferro-manganese, may be a trifle misleading. If one studies the published analyses of manganese bronze, I think it will be found that the larger number of analyses show a percentage content of iron in rather a larger proportion than would be introduced as a result of the addition of commercial ferro-manganese in such proportion as to carry into the metal the percentage of manganese shown in the analyses. An addition of iron in some form other than in combination with manganese must have been made. Regarding the quantity of manganese in so-called manganese bronze, a point to which a previous speaker has referred, I would point out that a manganese bronze containing only traces of manganese may be truthfully described as a manganese bronze, having regard to present-day nomenclature. Just as in the same way one may correctly speak of a phosphor bronze as being a phosphor bronze, even though a faint trace only of phosphorus may be detected by analysis. As Mr. Milton has pointed out, such an alloy as the last mentioned can be called a phosphor bronze in virtue of the fact that phosphorus has been used for a specific purpose during the manufacture of the bronze. Manganese is largely employed on account of its effect as a deoxidising element, and occasionally added only on account of this property. One must not expect to find necessarily a large percentage of manganese in the finished product. On the other hand, some manganese bronzes compounded for particular services contain a relatively considerable quantity of manganese. There are certainly manganese bronzes on the market supplied by reputable manufacturers in which one can find considerably higher manganese contents than those quoted in Mr. Milton's paper.

I heartily agree with Mr. Milton that certain parts machined out of the solid might be annealed with advantage. There is not the slightest doubt that both cast and worked metals are liable to internal stress, and if one desires to secure the most reliable results in the finished article, a suitable method of annealing will do much to ensure against subsequent failure. However, in the case of small articles turned from properly normalised bar, there is little or no necessity for subsequent annealing of the machined article, providing the machining



of the same is reasonably executed and the metal has not been rooted off at the highest speed and with the coarsest feed and cut.

With reference to the piece of rodding exhibited by Mr. Milton, I have been particularly interested in examining that specimen. Mr. Milton has told us that it represents a portion of a round brass rod  $2\frac{1}{8}$  in. diameter and supposed to comply with certain specified mechanical tests.

Now, with all due respect to Mr. Milton, the description given by him is somewhat vague. It is obviously a round, yellow metal bar, but whether rolled or extruded has not been stated. We do not know whether any cold work such as reeling or die-drawing has been put upon the metal, and whether, if so, the rod was subsequently annealed. It is very apparent that it is not a specimen of good yellow metal rodding. If the full history of the bar was obtainable, I venture to think that, in common with other Works Metallurgists, I might be in a position to offer an explanation as to the cause of the defect and to suggest a safeguard to future happenings of a like character during manufacture of yellow metal rodding.

Personally, I am not altogether in agreement with the prevalent assumption that the so-called "season cracking" phenomenon is responsible for many of the varieties of defects in manufactured metals and alloys commonly ascribed to this cause. Having had a somewhat long experience in some very large works, I have had my attention drawn from time to time to defects and happenings which, although bearing a close resemblance to season cracking effects, have been proved to have their origin from a totally different cause. It is not an unknown incident for billets of steel of very large diameter to fracture in halves from causes other than over work, and certainly not as a result of cold work. It is also within my knowledge that gun tubes have split in exactly similar manner—*e.g.*, longitudinally throughout the whole length—to the sample of condenser tubing which Mr. Milton has passed around for inspection this evening.

I hope Mr. Milton is in a position to give us a little more information as to the history, and also of the operations subsequent to the formation of the actual bar, from which his sample of defective rodding has been taken.

On page 99 Mr. Milton says:—"When so-called 'bronze' propellers were first used, it was found that the iron of the ships suffered from corrosion in their vicinity, if by chance

the paint became injured; this was put down to galvanic action. This led to a different composition being used for propellers. Now more trouble appears to be met with in the corrosion of the propeller itself."

May I suggest that Mr. Milton intended the word "erosion" for "corrosion" in the last sentence? I am not aware that there is much corrosion of manganese bronze propellers in service. I venture to think he will admit that the problem of overcoming erosion of propeller blades has been a serious one. The removal of metal by corrosion, over the surface as a whole, is practically of negligible moment. With reference to the cracking of propeller blades subsequent to the operation of "burning on" of new tips as mentioned by the previous speaker, I should like to comment on this, because during the last few years this operation of "burning on" of new tips to damaged propeller blades has formed a particular study on my part. I believe no secret is divulged by my pointing out that the practice in some yards of "burning on" of gunmetal tips to manganese bronze blades is one which can only be justified by expediency. Only little better is the practice of repairing by burning on a tip of manganese bronze of one composition on to a manganese bronze blade of a different composition, often without reference to the maker of the original blade. Occasionally disastrous results occur. Mr. Milton has referred to the copper-zinc alloys as being divided into one or more phases designated under letters of the Greek alphabet. No two metals, or for that matter no two phases of the same alloy, have precisely identical physical properties, and for this reason it is not good practice to burn on a gunmetal tip to a manganese bronze blade, or to burn together two manganese bronze parts of dissimilar character. If the operation of "burning on" of a new tip is performed with a full knowledge of the scientific limitations of the process, and with due regard to the relieving of the internal stresses in the metal unavoidably set up as a result of the very nature of the operation, there is little danger of cracking of the repaired blade, either before or during subsequent service.

Mr. SHARP: The last speaker has not explained why we should have been immune from these cracks so long, and why we should just have them within the last twelve months. It is not that re-tipping is a new thing, or that it is being done differently. But we have had this experience to contend with in the last twelve months.



The CHAIRMAN: Are the conditions identical?

Mr. SHARP: As far as we are aware, and as far as it is possible to tell, the conditions are exactly similar. The blade has not been set to work. It is standing on deck as a spare blade.

Mr. MILTON: I think the previous speaker means that the success for a long period has rendered the workman careless, and he has thought there was no necessity of taking sufficient precautions.

Mr. A. E. SHARP: We have kept such a careful record. The work is done by the same people.

Mr. LAMBERT: I think the speaker is particularly fortunate in only quite recently having experienced this class of failure. Other shipowners have certainly had a like experience, and for this very reason my study of the question was entered upon. There is little doubt that unless the operation is performed with a certain amount of scientific control, together with the best foundry practice, one is liable to have trouble often when least expected. If one has escaped trouble in the past it is a matter for self-congratulation. The mentioning of the fact that the blade was "out of pitch" after the repair was executed points to the conclusion that the "burning on" in this instance was not conducted in accord with the best practice. Had the damaged blade been brought to pitch before burning on the new tip, and the operation of re-tipping been successfully performed, it would be necessary only to remove the superfluous metal along the line of the burn, and no subsequent manipulation should be required to bring the blade to correct pitch.

Mr. MILTON: The gentleman representing Messrs. Stone & Co. has criticised some of my words. He says, where I put "corrosion," I should have put "erosion." I should like to know the exact difference between erosion and corrosion. Erosion, to my mind, means where we have wear by rubbing. I do not think any propellers erode in that sense, in the same way as you erode a piece of wood by sand-paper. There must be corrosion. I think corrosion is the proper word.

Mr. LAMBERT: Previous to joining the staff of Messrs. J. Stone & Co. I was for a number of years chief metallurgist of the Royal Gun Factory at Woolwich, and during that period it fell to my branch to examine a very large number of instances of erosion in gun liners. As a result of my investigations I am of opinion that there is a great similarity between

the erosion of a gun tube and the erosion of a propeller blade. I do not think in either case it is a question of corrosion as generally understood, but essentially one of mechanical erosion.

Mr. MILTON: I am not so sure, but it is not electrolytic corrosion. In the case of corrosion in a gun you have gases of great temperature, and at this temperature do they combine with the surface of the steel? That is erosion, and it is very different to that of a propeller blade. I have seen some propeller blades from very large liners corroded more than one inch, and it cannot have been by the rubbing of the water. It is by oxidation or chemical action.

Mr. LAMBERT: If when examining a badly eroded area of a propeller blade one removes the prominent nodules from the eroded metal, and subjects these nodules to chemical analysis, no difference between this metal and the uneroded metal of the propeller can be determined. If the action was one of corrosion, you would expect to find some difference of composition, as a result of the chemical or electrolytic action.

Mr. MILTON: To a certain extent. My point is—that it does not wear away the bare metal. That which has rubbed off is metal that has corroded. It has oxidised or combined with something. If the pure metal were rubbed away it would be left bright. But it is always dull. The metal disappears from positions where it cannot have severe rubbing. You must have noticed hundreds of times that wherever there is a roughness started on a propeller blade, there the corrosion or erosion takes place to a greater extent. These roughnesses, if they produced anything, produced a partial vacuum in the water, so that air in the water separates out. That, I believe, is the real cause of this corrosion taking place from behind roughness. A rough propeller soon gets much rougher from this cause. Ferro-manganese is spoken of as the basis of putting iron into manganese bronze. I do not know the various methods of those who put in iron. But I do know that with some firms the basis is ferro-manganese. The ferro-manganese contains 75 per cent. manganese, and it is combined with a certain amount of pure iron, and it is then put into the mixture. I imagine Messrs. Stone have the same plan; I doubt very much whether they buy metallic manganese, and probably buy ferro-manganese, which is a marketable article of a definite composition. I thank you very much for the attention you have paid to the paper and for giving me this attendance in



your time. I need not say that Messrs. Stone's are in the front rank of brass-making firms, and it would have been well had other firms been represented. We shall be very pleased to have communications in writing from any firms or members.

Mr. B. P. FIELDEN: I have great pleasure in proposing a hearty vote of thanks to Mr. Milton for the valuable paper he has added to the Institute's records; it is very gratifying to know he has put in so much time in writing the paper, under the strenuous condition now existing. As to the paper itself, there is one thing that has not been fully touched upon, and that is in regard to the condenser tube question, although a sample has been shown of a split tube. Most engineers would know what to do with that. But the corrosion of condenser tubes is the trouble of to-day, and it is one of the troubles which the marine engineer will have to get over in the future. If Mr. Milton could throw any light on that point for the adjourned discussion, most marine engineers would be very glad of it.

Mr. J. CLARK: I am very pleased to second the vote of thanks to Mr. Milton. The subject can be a very dry one, but Mr. Milton has so treated it that the paper has been supremely interesting to everybody.

Mr. MILTON: This paper has nothing whatever to do with the corrosion of condenser tubes, but that is a subject that a paper could deal with. It is a subject of great interest, and I hope some of our members will bring it before the Institute. It has been before the Institute of Metals, and a Research Committee has been at work on it for years. They have made voluminous reports, and have added much information to our knowledge. Recently it has been taken up on a larger scale than before. They have Government assistance for making investigations, and experimenting work is being done both in London and at the Electricity Works at Brighton. Most valuable reports are to be found in the transactions of the Institute of Metals. If any members have the leisure, they could get these reports from the Institute of Metals and study them. They will tell you where to get other information. In the Royal Navy they have had in the past a great deal of trouble with condenser tubes, but it has been said that within the last two or three years they have got over it. If so, they must know why and how they have got over it. No doubt they will communicate their experience in due time to the Institute of Metals. One way which has assisted in getting

over difficulties is, I think, the very great precision in which they have insisted in having condenser tubes made to very minute clearances in the tube holes. They have done that, I think, to ensure that the tubes shall be in metallic contact with the tube plate. I think the adoption of this rule has gone a good way towards keeping condenser tubes free from corrosion. I am not sure that is the way; but that is the only difference I see in Admiralty specifications now from what they were years ago. They always have required tubes to be made of a 70—29—1 composition, and are always very careful not to get other impurities in the tubes; also, they are always particular to get a certain amount of pinch in the last draw to make them stand the packing. Now they say they do not have the corrosion they used to have. Where vessels are fitted with water-tube boilers, unless the water is practically free from salt, the boilers prime badly, and there is serious trouble. I think it shows pretty well that the condensers are in excellent condition in our war-ships. And now I will move that a hearty vote of thanks be accorded to our Chairman of to-night. Mr. Boyle is our oldest, and one of our much-respected, Vice-Presidents. He will always turn up if he is asked to do anything for the Institute, and he is well worthy of your acclamation.

The CHAIRMAN: Thank you very much indeed.

The HON SECRETARY: The annual meeting is to be held on May 18, at 7 p.m., and Sir James Mills is expected to be here to take the chair.

The CHAIRMAN: We shall take up the resumed discussion on Mr. Milton's paper at the first meeting of the next session in September. Mr. Milton has so condensed his opinions into this paper that many of the headings and details afford fruit for further discussion after the paper has been issued to the members for study, in view of an adjourned discussion.

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The following paper is from the proceedings of the American Railway Association. It was also reprinted in *The Mechanical Engineer* of February 9th, 1917:—

## Bearing Metals.

BY GEO. H. TINKER.

A bearing metal should have a low coefficient of friction, high resistance to wear, and sufficient strength to resist distortion by crushing. In the case of gears and screws a certain tensile



strength and resilience are also required. The final criterion for the suitability of a metal for a specific purpose is its behaviour under actual use. To determine the probable behaviour of a metal submitted for such purpose the nearer the test applied duplicates the actual conditions of service the greater our confidence in the probable outcome. It is also necessary that the test should be easily, quickly, and cheaply applied, and last, but most important, it should give concordant results.

Friction tests are difficult to make. So also are wear tests. Resilience tests are unsatisfactory. There remain compression and tension tests, which fulfil all the requirements of a test except that it appears doubtful if they furnish sufficient evidence of the probable behaviour of bearing metals in service.

Our knowledge of the nature of the phenomenon of friction is theoretical. Latest theories lead to the corollary that the harder a substance the greater its anti-friction qualities. There is some evidence of a definite relation between hardness and tensile strength. The existence of a definite relation between hardness and compressive strength is not established. As to the relation between hardness and resilience, there is a point in the hardness scale where hardness is accompanied by brittleness and resilience decreases. It thus appears that hardness may or may not indicate the presence of the qualities desired in a bearing metal.

There is some evidence that the ability to resist wear is indicated by density rather than hardness. The suggestion of adding a small amount of lead to phosphor bronze has been made with the idea of increasing density. It is undoubtedly true that the addition of lead tends to raise the friction coefficient, but it does not follow that the metal having the most desirable qualities will have the lowest coefficient of friction. It is not shown that the several qualities desired follow the same law; they may be antagonistic, in which case the most suitable compromise must be chosen.

It is recognised that neither compression nor hardness tests on bronzes always give concordant results, owing to the effect of various conditions of manufacture. That is one very good reason for controlling the chemical composition within narrow limits.

Although the making of hardness tests has increased in the last few years, the data are not yet sufficient to enable a definite set of figures to be adopted for bearing metals. There is not

yet evidence to show that a bronze of a given hardness is the most suitable for a specified use. It should be kept in mind that the hardness test is an indirect test. A metal is suitable for a bearing not because it is hard, but because being hard it is likely to have a low frictional resistance, or is likely to wear well, or is likely to be able to sustain a certain pressure without distortion. In the case of steels the hardness values corresponding to certain specific qualities are better known.

The compression test is a direct test of one of the qualities desired, and should not be discarded until we are better and more definitely informed as to the proper hardness numbers. To this end the collection of data should be at once undertaken by all users of bearing metals. In a paper by A. Portevin and E. Nausbaumer the table herewith, headed ball-hardness, has been rearranged in the order of resistance to wear and the hardness numbers computed.

*Ball-hardness.*

Mark.	Diameter of impression.	Extreme deviations.	Hardness number.
D1 .....	4.325	±.175	65
D2 .....	3.9	±.1	80
D7 .....	3.45	±.05	103
D8 .....	2.9	±.05	148
D5 .....	4.1	±.1	77
D6 .....	3.9	±.1	80
D3 .....	3.65	±.15	92
D4 .....	2.920	±.075	146

Pressure = 1,000 kg.

Diameter of ball = 10 mm.

*Chemical Composition.*

Mark.	Cu	Sn	P	Pb	Fe	Zn
D1.....	91.12	5.73	0	0.12	0.15	2.68
D2.....	88.31	8.78	0	trace	0.31	2.40
D3.....	84.45	13.89	0	0.23	0.04	1.22
D4.....	80.22	19.16	0	trace	0.13	0.43
D5.....	94.80	5.08	0.011	0	0	0
D6.....	89.54	10.02	0.012	0	0.05	0.21
D7.....	85.45	14.42	0.015	0	0.05	trace
D8.....	80.11	19.79	0.020	0	0.08	trace

In the following specifications for phosphor-bronze bearing metals the customary tests are retained and provision made



for the accumulation of data as to hardness of bronzes which may be later compared with the record of service.

Phosphor bronze for bearings shall be a homogeneous alloy of copper and tin. It shall be made from new metals, except that scrap of known composition and produced by the foundry at which the bronze is cast may be used.

The phosphorus shall be introduced in the form of phosphor copper or phosphor tin. There shall be no sulphur in the metal. Unspecified elements shall not exceed 0.5 per cent.

The alloy shall be cast into ingots and allowed to cool, and the castings poured from the remelted ingots. Care shall be exercised that the metal is not overheated, and that the temperature at pouring and the conditions of cooling are such as will be most likely to secure dense castings.

Castings shall be sound and free from blowholes, sandholes, porous places, cracks, or other defects.

Grade "A" shall be used for contact with hardened-steel discs under pressure exceeding 1,500 lbs. per square inch, such as used in turntables and centre-bearing swing bridges.

Grade "B" shall be used for contact with soft steel at low speeds under pressures not exceeding 1,500 lbs. per square inch, such as trunnions and journals of bascule and lift bridges.

Grade "C" shall be used for ordinary machinery bearings.

Grade "D" shall be used for nuts, gears, worm wheels and similar parts which are subjected to other than compressive stresses.

The composition of Grade "A" bronze shall be approximately copper, 80 per cent.; tin, 20 per cent.; phosphorus, not more than 1.0 per cent.

Grade "B" bronze shall be approximately copper, 85 per cent.; tin, 15 per cent.; phosphorus, not more than 1.0 per cent.

Grade "C" bronze shall be approximately copper, 80 per cent.; tin, 10 per cent.; lead, 10 per cent.; phosphorus, not less than 0.7 per cent. nor more than 1.0 per cent.

Grade "D" bronze shall be approximately copper, 88 per cent.; tin, 10 per cent.; zinc, 2.0 per cent.; phosphorus, not more than 0.25 per cent.

For Grade "A" bronze the elastic limit in compression shall be 25,000 lbs. to 40,000 lbs. per square inch. The permanent set under a load of 100,000 lbs. per square inch shall be 0.6 in. to 0.10 in.

For Grade "B" bronze the elastic limit in compression shall be 19,000 lbs. to 23,000 lbs. per square inch. The permanent set under 100,000 lbs. per square inch shall be 0.12 in. to 0.25 in.

For Grade "C" bronze the elastic limit in compression shall be 15,000 lbs. to 20,000 lbs. per square inch.

For Grade "D" bronze the elastic limit in compression shall be not less than 14,000 lbs. per square inch. The ultimate strength in tension shall be not less than 33,000 lbs. per square inch, and the elongation in 2 in. not less than 14 per cent. The yield point in tension shall be recorded.

At least one compression test shall be made from each melt for Grades "A," "B," and "C," and one compression test and one tension test for Grade "D." If a test fails to show the specified properties a retest shall be permitted. If the second test fails, the melt shall be rejected.

The test specimen shall be turned from coupons or sinkheads attached to and a part of the casting, and poured and cooled under the same conditions. The specimens for compression tests shall be cylinders 1 in. high and 1 sq. in. area. The specimens for tension tests shall be turned to a diameter of  $\frac{1}{2}$  in. The coupon shall be not less than 1 in. in diameter, and shall be fed through a gate running the entire length of the coupon.

The elastic limit in compression shall be taken as the load, which produces a permanent set of 0.001 in.

The chemical analysis of each melt shall be determined.

The hardness of the finished castings shall be measured by the Brinell ball method, and a record of same furnished. The ball shall be of hardened steel, 10 mm. in diameter. A load of 500 kg. shall be applied for 30 seconds to a finished plane surface. At least two hardness determinations shall be made on each melt. Each disc and each trunnion bearing shall be tested. If it develops that the hardness number is a reliable criterion of suitability of a bronze for a specific use, the hardness test may later be made a requirement for acceptance.

Nino Pecoraro states that on the acceptance tests of white metals, the compression tests appear suitable for arriving at an estimate as to how far the respective metal will be able to satisfy the conditions of compression without undergoing any practically inadmissible deformation.



Abrasion tests appear always most desirable, since the resistance to abrasion is an important characteristic of anti-friction alloys. These tests are, however, neither easily conducted nor can they rapidly be carried out. It would, nevertheless, be advantageous to substitute for them some simple experiments, which would likewise enable us to make a comparison between different alloys as regards their resistance to abrasion. The hardness test by the Brinell method constitutes such an expedient. Further experiments to elucidate this matter more fully would be desirable.

The determination of the hardness number of anti-friction alloys of equal chemical compositions may perhaps supply us with the possibility of establishing a comparison in broad features between the different alloys as to their suitability for diminishing friction. If this should be confirmed, the exact determination of the average hardness numbers of anti-friction alloys would acquire an extraordinary importance, because it would, in many cases, enable us to arrive at a quick estimate in the place of the tedious, expensive, and difficult friction test, for which, moreover, suitable arrangements are not always available.

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The following Articles and Papers on Metals may be found useful by those who desire to study the subjects dealt with in this issue and in that of March, "Cast Iron":—

"Cast Iron, with Special Reference to Engine Cylinders," by Mr. S. E. Hurst (American Association of Engineers, December 9th, 1916).

"Case Hardening," by T. Baker, D.Sc. (Rotherham Technical Institute Engineering Society, February, 1917).

"Metal Melting in a Simple Crude-oil Furnace," by H. S. Primrose (Institute of Metals, March 22nd, 1917).

"Corrosion of Tinned Sheet Copper," by P. D. Mercia (United States Bureau of Standards, Paper No. 90).

"Machining Properties of Brass," by O. W. Ellis, B.Sc. (Institute of Metals, March 21st, 1917).

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## Correspondence.

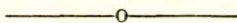
A Member writes as follows:—"In passing through Abney Park Cemetery, Stoke Newington, recently, I was interested to read a memorial stone of much interest to our profession. It ran as follows: 'Henry Wimshurst, the builder of the first screw steamer *Archimedes*. Died 26th August, 1884. In the 81st year of his age.' I had read a good deal of the history of steam navigation, but I had not heard of the *Archimedes* and its builder, and he is not mentioned in any of the standard works. To those who wish for more information about Mr. Wimshurst and his self-denying work, the writer recommends a short and interesting obituary notice in *Engineering*, Vol. XXXVIII., 1884."

How many of our members know that Symington lies buried in the Churchyard of St. Botolph's, Aldgate, so near the Institute, and how strange it should be that the home of his profession should be near his grave? That he died in the parish is assured by a memorial tablet in the church, which runs as follows: "To the memory of William Symington, born October, 1763. He constructed the *Charlotte Dundas*, the first steamboat fitted for practical use. Dying in want, he was buried in the adjacent churchyard, March 22nd, 1831. This tablet is placed here by the Rt. Hon. Sir Marcus Samuel, Lord Mayor, 1903."

The *Archimedes* is referred to in several books on the History of Steam Navigation, especially under the heading of the introduction of the screw propeller to displace the paddle wheel. The *Archimedes* was built about the same time as the *Great Britain* in 1838-9.

A reference to William Symington will be found in pp. 150-154 of Volume XXIV. of our Transactions (1912-13), and an illustration of the *Charlotte Dundas* (built in 1801) on page 145 of the same volume, under the heading "The Comet Centenary Celebrations.

J.A.





## Election of Members.

Members elected at a meeting of the Council held on Tuesday, May 22nd, 1917:—

### *As Members.*

- James Aitken, 107, Bellevue Road, Edinburgh.  
Stanley Harris Bowden, 83, Corinne Road, Tufnell Park, W. 19.  
Robert Stanley Campbell, 58, Station Road, Wallsend.  
John Allan Craig, Marine Engineers' Institute, Shanghai.  
Montague Downing, 149, Brereton Avenue, Cleethorpes, Lincolnshire.  
Robert J. M. Gibbs, Glengall Iron Works, London, E. 14.  
Robert Houston, 3, Budge Budge Road, Kidderparis, Calcutta.  
James Jones, 3, Caithness Drive, Liscard, Cheshire.  
Thomas Ernest Legg, "Grasmere," Hulse Avenue, New Barking, Essex.  
John Walter Robertson, "Bellarina," Castle Hill Road, Ayr, Scotland.  
William Livingstone Roxburgh, 2, Eaton Road, Cressington, Liverpool.  
John Hamilton Smith, 8, Woodchurch Road, Prenton, Birker head.  
Robert Craig Smith, 23, Wentworth Avenue, Wallasey, Cheshire.

### *Companion.*

- Andrew H. Paterson, 53A, Oswald Street, Glasgow.

### *Associate-Members.*

- James A. Greig, "Kincorth," 42, Wanstead Park Avenue, South Wanstead, E. 12.  
Albert Ward, 15, Kelvin Grove, Cheetham, Manchester.

### *Transfer from Associate-Member to Member.*

- J. Bowie, *c/o* Messrs. Parry & Co., Light Railway Engineers, Calcutta.





# INSTITUTE OF MARINE ENGINEERS INCORPORATED.

SESSION



1917-18.

President : CAPT. R. H. GREEN, R.D.C.

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## VOLUME XXIX.

Paper of Transactions No. CCXXVII.

### Cast Iron.

READ

*Tuesday, March 6, 1917, at 7 p.m.*

DISCUSSION ON MARCH 6th, 1917.

CHAIRMAN : MR. J. T. MILTON (Vice-President).

Mr. TIMPSON : In introducing a discussion on this subject, the difficulties experienced with the internal combustion engine are suggested and the reliability of cast iron for various parts to withstand the heat and pressure, I can only say that there seems no finite mixture for certain purposes, one item being the tops of hot bulb engines. Some will stand 12 months, and work quite well; others will not stand more than a fortnight. This does not seem to be the case only in this country, but also in engines of Continental make, they may have more tests for cast iron but are evidently up against the same trouble. In fact, bulbs of foreign origin have been replaced by British productions, and these have stood better. But there does not seem to be definite knowledge of the mixture required of this very important detail. As regards hot bulb type engines, the same applies very much, as the Chairman mentioned, in regard to cast iron bodies under superheated steam, in some cases the casting will stand for a long period, often this is not the case; therefore, generally speaking, it all points to more knowledge being required of a metal—which is so useful to engineers.

We are very much indebted to the author for bringing the matter before the Institute, and I trust the discussion, with

other comments as may come in from our members, will be a useful augmentation to this valuable addition to our Transactions.

The CHAIRMAN: You were referring to hot bulb engines. It gets to a dull red heat.

Mr. TIMPSON: It is a most drastic heat for any metal to stand, and cast iron stands it best. Cast steel seems to burn out more rapidly. In regard to the cast iron bulb, some engine makers seem to have been fortunate in obtaining a good mixture which stands a long period, while others have not done so well; that, I suppose, is purely a question of a lucky hit, and not of research, for which it is evident there is considerable scope to the general good.

Mr. A. H. MATHER: Can the same foundry be relied upon to cast exactly the same material regularly and without that slight variation which brings about trouble.

Mr. TIMPSON: So far as I have been able to gather information on the subject, the foundry referred to has supplied regularly a reliable mixture to produce satisfactory castings.

Mr. W. P. DURTNALL: I have much pleasure in adding to the discussion on this most interesting subject which the author has kindly put before us. As he rightly says, the question of Cast Iron is of the highest importance to this country, and the industries therein have in the past reaped great benefit from its use in many directions. The use of cast iron in connection with internal combustion motors has been found very satisfactory, and is still being used in a great many cases of heavy land, marine and automobile type engines, but, with the exception of cylinders and pistons, its use is not desired in connection with the frames and other main parts, whilst in connection with operating gear and other essential features the use of steel has been more favoured, and the use of "cast steel" is now predominating in modern designs, because of its greater strength and lightness for given strength. In connection with the latest practice in aeronautical engine construction, the use of pistons and cylinders constructed of alloys is coming into favour, especially in connection with very high revolutions for these modern prime-movers, in the place of cast iron; this is because of the much higher mechanical efficiency that can be secured at high revolution speed, owing to the lighter weight per given volume of metal; indeed, it is this fact which makes possible the aeronautical engine of to-day running at 3,000 R.P.M. and up to 500



brake horse power, and this is an English made engine. As a designer of prime-movers, especially those of the internal-combustion or high-temperature type, and for high revolution speed, I would say that when it comes to system of construction, and the materials used for same, there can be no laying down of fixed hard and fast rules, for sufficient reason that the suitability of any given material is governed by circumstances of application and operating conditions, and weight per unit power developed, and which demands are ever varying.

For stationary engine design and construction cast iron offers a cheap and easy method of construction and machining, but when it comes to the design and construction of prime-movers for all kinds of transport work, including marine engineering, cast iron does not present such a satisfactory solution to the problem, owing to its high weight per unit strength, and it is quite noticeable that the most advanced designers and constructors of high-power marine internal combustion engines are embodying the use of steel wherever possible, on account of weight, which has to be carried, and every ton of extra weight means a ton of extra displacement to be dealt with in connection with the propulsion of the vessel, which again reflects on the fuel consumption per unit live ton-mile, or given voyage. A tribute must, however, be paid to the metallurgists and manufacturers on account of the great improvements that they have introduced in the cast iron available for cylinders and pistons of recent years, with the high tensile and good ductility, and these qualities being very noticeable, but I am of opinion that cast iron will experience a great competitor in the immediate future from the superiority of good aluminium alloys for much constructional work, especially bearing in mind that this material can be cast in so many designs and with such great ease, and clean drawing, etc. Cast iron suffers also from loss of tensile strength, which begins to decrease as the temperature rises; beginning at say 200 degrees Fahr., at a temperature of, say dull red, about 1,000 degrees Fahr., its strength is reduced to about one-third, falling to Zero strength at about 1,240 degrees. This at least indicates the importance of water cooling the exhaust pipes and working cylinders and pistons of high-power gas and oil engines, etc. It also indicates the difficulty of using cast iron for operating conditions where these temperatures are attained, and where internal pressure may be excessive, and on permanent work, or in connection with superheated steam, even with steel, the strength is reduced considerably with a rise in temperature.

Cast iron derives its characteristic qualities from the impurities present; to a certain extent these impurities are the same as those in steel except for graphite, which is one form of carbon. The carbon is always present in two forms, namely: (1) combined carbon in the form of cementite; (2) uncombined carbon, or graphite. The total carbon seldom exceeds 4.5 per cent., or falls below 3.25 per cent. The larger the proportion of carbon in the combined state, the harder and more brittle will be the metal. Silicon is a desirable impurity, because it tends to precipitate carbon in graphite form; about 3 per cent. of silicon gives the best results. Sulphur has the opposite effect of silicon, and is undesirable. Manganese increases the total carbon and also the proportion of combined carbon, but tends to neutralise the similar effect of sulphur. Phosphorus, if present in sufficient proportions to be chemically active, tends to hold the carbon in combined form, and also tends to weaken the metal.

The author refers to the castings of steam turbines; by this I take it he means the slow-speed marine direct-coupled type of turbine; I may say that in connection with the "Paragon" Thermo-Electrical Ship Propulsion system, that for anything over 50 lbs. pressure the turbine cases are of steel, especially when superheat is to be used; this also applies to all steam valves and pipes, and this feature also saves valuable weight, the extreme short length of main supply pipe facilitates the use of steel with, if anything, a reduction in steam pipe costs, and at the same time increases the safety factor. In the case of gas engines being used as the prime-movers, the engines are of the vertical open stanchion type of design of steel construction on girder frames, and also in all cases where high strains are dealt with, only the cylinders and water-cooled pistons are of the finest cast iron. These same design of "Paragon" cycle internal combustion engines are used in connection with the "Paragon" internal-combustion railway locomotives up to 1,500 horse-power; in the case of the 500 horse-power they run at a revolution speed of 450 R.P.M., and, being of "double-acting" design, they do not have or require any flywheel, the six double-acting cylinders give all the necessary turning movement for silent and sound operation, whilst the temperature of the circulating water is kept at about boiling point, and the maximum pressure on the working pistons is about 300 lbs. per square inch, and by the special expansion obtained in the "Paragon" cycle of internal combustion allows the exhaust temperature not to exceed about 400 degrees Fahr., the



nickel steel exhaust valves not giving the slightest trouble at this very low exhaust temperature.

The electrical generators and the electric motors have cast steel stators and rotors, this being lighter and, from the magnetic point of view, much more efficient than the use of cast iron as is used on land work. The same applies to the "Paragon" automatic electrical steering gear, and all other auxiliary plant, the quadrants and side frames are all of cast steel, and a goodly use of drop steel forgings is to be made use of in this modern method of building marine engineering and other machinery, built to my specifications.

Although the author is to be congratulated for the very complete information which he so kindly provides us with in connection with his paper, I am of opinion that, as progressive marine engineering proceeds along the time, that a general application of steel construction is essential to the well-being of the British shipping industry. I think that the pig iron should be made into steel, and not cast iron, as this is the metal which must be used for the construction of all kinds of machinery in the future, if Britain is to hold her own, against the Continent of Europe and America in the great field of engineering, and marine engineering especially. It is not so many years ago when marine boilers were actually made of cast iron, yet who would think of making a cast iron marine boiler to-day? Steel is the coming metal, and after this great struggle of military activity is over, then will be the period when Britain may be forced to see that it will be in her converters that her Might will be maintained, and may I propose that the members of our splendid Institution may not be the last to give full appreciation to the fact? When the great coming war of commercial enterprise is opened, may British marine engineers rise to the occasion, and still retain the principal carrying business of the world.

Mr. JAS. WELLS: It is a very good thing to have one's attention called to the common things of engineering practice, and so be able to realise the value of the advances that are being constantly made in every field of work. Cast iron is one of these very common things used every day by engineers for the widest possible variety of work, and the Author has done well to recall the attention of the members of this Institute to the subject. In the past (if not at the present time) reliance has been solely placed upon the skill of the founder to obtain the particular result required. This method of trial and error is, of course,

a very costly one both of labour, of time involved, as well as the uncertainty of any given result being attained. The modern method has been first a search into the connection between cause and effect by means of careful experiment, and this search has given excellent results so far. The refined and improved means of measuring high temperatures has contributed very largely to this result. The chemist has long known that most substances behave differently if the heat treatment that they receive be varied. Prolonged heat treatment will spoil bread, cakes, &c.; then why not Metal Alloys? Chemists have used the method of fractional distillation with most useful results; then what is the difference between a salt solution and a molten mass of metals? The Author has detailed the progress made when definite experiments, carefully devised and as carefully carried out, were made along these lines, but I do not think that he has laid enough stress upon the causes that have resulted in the great variety of results recorded, with regard to cast iron. In great measure this has been due to the great first cost of any investigation into engineering problems, together with the lack of training in exact experiment. The skill required to make a correct measurement, to record exactly what happens during an experiment, to determine exactly a weight, or a temperature, are not the easy matters that the uninitiated so often think. Most of the experiments were made formerly in the works, where some new difficulties were encountered in the course of fulfilling some order. In such cases, from a lack of experience in the art of experimenting, someone who carried the most influence would suggest a certain mixture of metals, and this would be tried; if it did not give the result wanted another shot would be made at the required mixture and the work done over again, and so on until the result required was approximated to, as closely as time and money would allow. If the result obtained was satisfactory, then there was an end to the matter, and no record would be kept except that of memory, but if the end was not quite as satisfactory as desired, well, then, any similar order in the future would be allowed to go to some other fellow to "burn his fingers" with, &c. Data obtained in such experiments are in no way reliable upon which to base any inferences for future use. The actual method of making tests is often the source of many of the difficulties mentioned by the Author; for example, recently the speaker had occasion to examine into the reason for some very widely divergent results obtained at a test house upon the same class of material, for which there was not any



apparent reason. Some specimens, upon being tested by the speaker, yielded results quite consistent with each other, and to clear up the difficulty he made a visit to the test house to see how the tests were made, and at once found the cause for the discrepant results obtained there. The tests were tensile, and the method adopted was in turn to put on some load and then take up the extension alternately until fracture took place. The amount of load put before the extension was taken up appeared to be quite dependent upon the grinder, who changed from one handle to the other when he wanted a change! As this was an Official test house, it is easy to understand how future workers examining such test sheets stamped with the imprimus of authority of an uninterested authority would be compelled to charge the material under test with irregularities that were, in fact, due to the operator's ignorance of what he was doing. Another very common failure on the part of experimenters when devising a series of experiments is to overlook the necessity of arranging for the change of one variable only at a time, so that the influence exerted upon the results obtained by each can be immediately traced to the source without any doubt, otherwise it is extremely easy to attribute the result to any but the correct source or sources. Much time has been wasted over the so-called paradox that different values of the Modulus of Elasticity may be obtained experimentally according to the way the tests are made—that is, by a tensile test or bending test, but if the basis of the formulæ were understood such discussions would be impossible. The assumption made is that the stress does not exceed the limit of proportionality of stress to strain, for no formula is possible when the rate of stretch ceases to be proportional to the stress. In the case of cast iron it is exceedingly difficult to establish the yield point, but before failure takes place usually it is quite possible to determine E. In the case of bending tests it is the practice to use the bars as they come from the foundry, and then their section is not uniform unless they are machined, so that it is not possible to calculate the value of the moment of inertia exactly because of the varying section, but if the difference between the average value and that at any section is small, then if the deflections are measured per increment of load a very satisfactory value of E may be obtained, and results that are concordant with the tensile tests upon the same sample. With some of these points in mind the results of the hardness tests will be more intelligible. The Brinell test imposes a *steady* load, whilst the Shore

is an *impulsive* load, and this suggests the difference between a press for forging and a steam hammer. This latter test, being the result of a hammer blow, leads at once to inertia effects, and it is evident that its indications cannot be at once directly comparable with the Brinell. The height of the rebound will depend upon the character of the particular crystal struck as well as the nature of its backing, which immediately supports it. Very wisely, the Author dwells upon the wear-resisting qualities that are frequently required of structures having cast iron rubbing surfaces. The best way to deal with this is probably to limit the maximum pressure imposed to something between 20 and 60 pounds per square inch, also to provide abundance of a suitable lubricant. Under these circumstances the speaker does not recall any trouble in his experience; the temperature range must be limited, and the designer should bear in mind the necessity for the provision of channels for the ready distribution of heat so soon as it is produced. It is not at once evident that the progress made in our knowledge of cast iron has been relatively so small as the remarks of the Author would seem to imply; of course, the demand for higher grades of steels has been much more insistent, and in consequence the efforts made to meet the demand proportionally greater, but great advances have been made in the field of cast iron, and still greater will be made.

Mr. NEWTON: As high a temperature as 600° has been mentioned. What would become of the lubrication at such a temperature? I know of one engine running with red hot piston head, and we were using a mineral oil. The cylinder liner was not hot. There is no lubrication that will stand such a temperature.

Mr. A. H. MATHER: And some of the lighter oils stand it also, it is not necessarily the heavier oils only. There is one point which struck me in connection with this paper, and that is the high and sustained interest of the subject matter from start to finish. One result of this is that everyone here, in his own special line, can find something of interest to himself. Mr. Timpson found a point in relation to internal combustion engine cylinders, and Mr. Wells has also been able to give us something of value from his own experience of the testing of cast iron. There is one paragraph of great interest to me, where reference is made to the action of heat on cylinder liners either in internal combustion engines or when using superheated steam, and the theory of the growth of cast iron under



these conditions provides food for thought as to how far this may prove to be a cause of cylinder troubles. Usually when cylinder trouble occurs, the first attitude adopted is "blame the oil," and should the growth theory prove to have some foundation in fact, it would provide a good alternative reason for a scored liner when such a mishap has to be accounted for.

Mr. TIMPSON: You will find some piston rings wearing for years, and the next disappearing very quickly. Some get very drastic treatment in springing them over larger piston bodies to get into place, and stand it—others fail, all showing differences in the characteristics of the metal.

The CHAIRMAN: What is the spring in the ring when the temperature is  $700^{\circ}$ . It is not in contact with water, and is probably hotter than the cylinder liner.

Mr. TIMPSON: You will find in some two-cycle engines that the rings will run from 12 to 15 months, and be quite good.

Mr. NEWTON: I know of some cast iron tank plates where you could put a penknife through in places. River Plate water has some peculiarities, causing corrosion in both iron and brass valves. There are various chemicals in the waters of the Tyne also. The tank plates mentioned are no doubt of a very open grain cast iron. I have seen similar decay in cast iron well cylinders, and it would appear that the iron used for such purposes is high in silicon necessary to increase the fluidity in running large thin castings of this kind. The silicon induces coarse grain, on account of the graphitic carbon developed; this causes decay to occur more readily, as explained in a paper read by Mr. Milton before this Institution in 1908.

Very high silicon alloy cast irons, with no free carbon, are quite immune from corrosion or action of any acids whatever. Such special cast irons are only useful for chemical plant, as they are extremely brittle, have very large shrinkage, and cannot be machined.

In castings for engine work each part should have the right mixture of iron for its particular purpose—liners should be of a different grade to pistons and cylinder heads, but it is not possible always to arrange this, and the engine maker is more favourable to a mixture which will machine well.

I should like the author's opinion on the now general use of from 15 per cent. to 25 per cent. of steel scrap added to

the cupola charge, in order to get close grain castings and additional strength; or is a casting made only from selected brands of pig preferable. Titanium, vanadium and other alloys are also favoured by some founders.

The following notes on iron castings, furnished by an expert metallurgist, may be a useful guide:—

*Combined Carbon.*—The actual amount of total carbon varies very little, but its condition varies very much. Maximum general strength is obtained with 0·6 per cent. combined carbon present. Low silicon and quick cooling increases the combined carbon, high silicon and slow cooling decreases it. The thinner the casting the higher the silicon necessary.

*Graphitic Carbon.*—A casting is soft, according to the percentage of graphitic carbon present; this percentage is conditioned by the silicon, sulphur and manganese present, also by the rate of cooling. Graphite in large flakes makes the casting weak; low silicon and quick cooling lessens the size of the graphite.

Total carbon should be low for the best tests, but an iron with low total carbon has increased shrinkage. Castings left a long time in the sand after casting will be softer than those stripped immediately after casting.

*Phosphorous.*—If over 1 per cent., rarely gives good tests, and is a probable cause of failure; 0·6 per cent. will give fair results; 0·4 per cent. is very much better.

*Sulphur* should not exceed 0·25 per cent in the casting; tends to increase hardness but to decrease strength.

*Manganese* should not exceed 0·75 per cent.; it stiffens the test bars and gives low deflection in the transverse tests.

*Silicon*, the most important element to watch, may vary from 1·25 per cent. in heavy castings to 2 per cent. in medium. In test bars 1·75 per cent. to 2 per cent. gives about the maximum strength.

Mr. DURTNALL: I have pleasure in proposing that a hearty vote of thanks be accorded to the author for his excellent paper, and to Mr. Adamson for reading it to the meeting.



## Notes on the Growth of, and the Effect of Super-heat on, Cast Iron.

Mr. G. W. BUCKWELL: In Volume XXVI., pages 39 to 52, is given a copy of the report on the explosion from a boiler stop valve chest at Pinkston Power Station, Glasgow, the cause of which was attributed to the effect of super-heat. The following notes were taken at the time, but were not included in the report, as they were only of general interest, and had no connection with the particular case. They may, however, be of service in connection with the paper on Cast Iron recently contributed to the Institute.

With cast iron, if the heating is sufficiently prolonged, a growth takes place at comparatively low temperatures, *e.g.*, cast iron valves subjected to super-heated steam increase in size permanently, a length of time being, however, required for this. The ultimate growth is proportional to the quantity of the silicon present, holding good up to 6 per cent. of silicon. The growth is accompanied by a loss of the metallic nature. Graphite is one of the essential factors in the growth of cast irons under heat treatment. The presence of silicon causes deposition of carbon in the form of graphite. Iron in its cast state is to some extent in a condition of unstable equilibrium, and when the material is heated the substances tend to crystallise and separate out. The presence of manganese modifies the action of silicon for the reason that graphite formation is hindered, 5 per cent. of manganese restraining about .7 per cent. of silicon. As the amount of sulphur is usually small, this element, combined with its tendency to keep carbon in the combined state, does not contribute to growth, neither does phosphorous contribute to growth. Phosphorous produces a white close-grained iron.

If the iron is imagined to be in a very soft state, and to be surrounded by a hard skin, it is quite conceivable that the particles of iron, when heated, might expand at the moment of heating, and when they wanted to shrink back they could not get back. Every time the iron is expanded, whether by oxidation of the silicon, or by slight oxidation of the iron, the presence of those bodies again prevent it from contracting to its old size when it is cooled, and this goes on when it is again stretched by heating. The combined heating of white irons oxidises the carbon present in the outer zone, eventually leaving it entirely free of carbon for depths varying from  $\frac{1}{8}$  in. to  $\frac{3}{16}$  in., and, given a sufficiently long period of heating, it may

be assumed that the entire mass may be changed. From research experiments it has been found that grey irons lose approximately 75 per cent. of their original strengths.

Dissolved gases have no influence on the growth of an iron containing more than 3 per cent. of silicon. Below that percentage they may cause a growth. Below 1 per cent. their influence is very potent, causing a large growth.

Dr. Stead's experiments have shown that silicon and phosphorous are both oxidised.

In discussing the effect of super-heated steam on cast iron and steel, Cary states that there is little reason to believe that steam has any material chemical effect upon metal parts, and therefore physical effects must be considered in order to arrive at any useful conclusion regarding the action of super-heated steam. Comparatively few tests are available in the investigation of cast iron under temperature below 1500° F., but certain tests were carried out at an arsenal, where samples of cast gun iron were tested at various temperatures up to 1500° F. The average of these tests showed the normal strength of the iron to be about 30,000 lbs., which was maintained until a temperature of 900° F. was reached. The strength then gradually dropped, until at 1100° F. it was only 20,000 lbs., while at 1500° F. it had decreased to 10,000 lbs. Without doubt a change in molecular structure occurred in this iron at a temperature of about 900° F., and probably with other grades of cast iron such a change would occur at a still lower temperature. This will doubtless account for many of the troubles reported as occurring in the cast iron parts of pipe lines using super-heated steam.

Dr. Carpenter has stated that silicon is the chief cause of the swelling of grey irons on heating, whether at high or low temperatures, in air or furnace gases or super-heated steam, and is present as dissolved iron silicide. But this silicide exerts no influence unless graphite is present, as on heating, the graphite allows the oxidising gases to penetrate into and gradually attack the metal chemically, owing to the graphite and iron having different co-efficients of expansion. On heating at low temperatures, oxides are formed on each side of the graphite plates, and on raising the temperature the graphite acts upon and reduces the oxide, producing metallic iron, a substance more dense than the original metal. If silicon be present, the oxides formed at low temperatures are highly charged with iron silicates, proportional to the quantity of



silicon. These silicates cannot be reduced by the graphite at higher temperatures, hence the cast iron remains porous, and gases continually enter, which eventually opens the under layers of metal, and makes them porous also. The growth of cast iron is due to the pressure caused by this increase of volume due to formation of silica and iron oxide.

When cast iron cools from the liquid condition, the first portion to solidify is some of the carbon, which separates out in plates or shells of graphite; the last portion to solidify is the phosphide eutectic, which fills up the intercrystalline spaces that are left. There are thus at least three distinct constituents, the joints of which form planes of weakness, and each of which has a different co-efficient of expansion. This is quite independent of the oxidation of the carbon, which will constitute a further source of weakness. It is conjectured that, owing to the slight breaking away of the graphite from the other constituents, from one or both of the above causes, the super-heated steam penetrates the cast iron along the graphite planes. This is a very plausible explanation of the fact that prolonged heating at a high temperature causes eventual disintegration of cast iron; and the reasoning will hold good whether a reasonable pressure accompanied by super-heat, or a very high pressure with saturated steam only, be employed, the super-heat having, however, under present conditions the more disastrous effect. It is even suggested by some authorities that if the temperature were high enough, the low fusing phosphide areas would be attacked and eventually destroyed. It is also quite possible that if saturated steam, of a temperature equal to that of the super-heated steam now used, were to be employed, the effect on the graphite would be worse than that of super-heated steam, on account of the greater supply of oxygen that would be at hand, due to the saturation.

Theoretical considerations, founded on recent experimental research work, suggest that cast iron, not to be subject to growth, and consequent disintegration, should contain, in addition to combined carbon, only a low proportion of phosphorus, say 5 per cent., and about double this amount of each of silicon and manganese, in the proportion of 7 of the former to 5 of the latter, other elements being present only in minute quantities, but even this material would require to be heat treated before use.

Recent experiments convince me that what is popularly called the burning of cast iron is really an abnormal growth checked

by some means, such as want of room to expand, which causes the metal to disintegrate and fall to pieces; this applied particularly to low grade irons.

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### Influence of Gases in Cast Iron.

The following is from *The Mechanical Engineer* of May 25, 1917:—

In a recent issue of *The Iron Trade Review* Mr. Edgar A. Custer discusses the influence of gases in cast metal. He states that during the process of pouring, a large amount of air is carried into the casting and becomes dissociated by the molten metal, and that if the trapped air and impurities are prevented from entering the mould there will be an amazing change in the microstructure of the metal, and the apparent lines of gas flow will become exceedingly difficult to trace. If, in addition, an iron mould is constructed so that it will not yield to the influence of the hot metal there will be no spongy spots, gas cavities, or large masses of segregates. In order to prove that these assertions are correct, it is only necessary to make an iron mould that will have sufficient metal around the casting and pouring gates to give not only an abnormal strength, but also to provide a very large heat-absorbing bulk. There should be provided swirling or trap gates with sufficient capacity to materially reduce the velocity of the molten iron as it flows toward the matrix. Mechanical means for opening and closing the mould swiftly and with precision must be attached so that there can be no question as to the effect of long exposure of the casting to the influence of the mould.

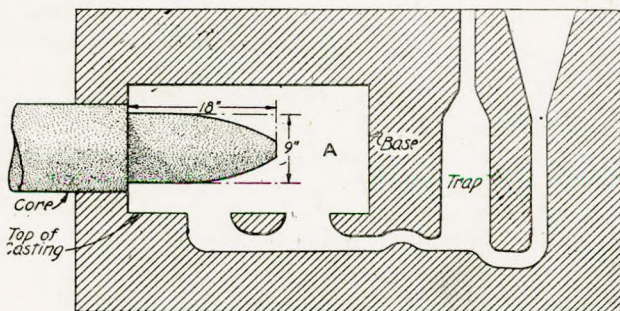
If these directions are correctly followed, it will be absolutely impossible to make a casting that has spongy spots, gas holes, or any material amount of segregation. Moreover, there will be no shrinkage. The casting, when cold, will have the same dimensions as the matrix in which it was cast. Shrinkage will take place only when the amount of molten metal is in excess of the mould capacity for absorbing heat and resisting the strains that occur when the molten metal expands in the initial cooling.

The prevention of segregation by the use of large iron moulds has long been recognised by the steel makers. Much has been



written on the subject, and there is no reason to doubt the testimony of ingot makers not only in Europe, but also in the United States. A large steel concern has cast recently a number of ingots, each weighing almost 300,000 lbs., in an enormous iron mould, with the result that they reduced the carbon segregation to a difference of but six points between the top and bottom of the ingot, whereas in a sand mould there was at times a difference of forty points.

Returning to the subject of shrinkage. The writer had constructed a mould, as shown in the accompanying illustration. It will be observed that the casting had comparatively thin upper walls and a very heavy base. There were no risers on



We are indebted to *The Mechanical Engineer* for the loan of the block to reproduce this illustration.—J.A.

the casting, and the only means provided for the escape of air from the matrix were a few shallow channels cut into the mould at the top of the casting. It weighed about 1,100lbs. A large cast iron core, operated by a hydraulic cylinder, formed the interior cavity. The mould was opened and closed by a similar cylinder. Into this mould irons of the following analyses were poured, all being melted in an ordinary cupola :—

	No. 1	No. 2	No. 3	No. 4
Silicon ...	1.05	1.75	2.25	1.05
Manganese ...	1.50	0.50	0.80	1.50
Sulphur ...	0.03	0.05	0.06	0.03
Phosphorous ...	0.05	0.06	0.06	0.05
Steel scrap ...	...	...	...	16.00

From 10 to 12 castings were poured from each iron, and when these castings were broken and examined not one showed the

least sign of sponginess. There were no risers, or any means of feeding the casting. The mould was poured full, and the first portions to freeze were the entrance gates, so that there was no possibility of feeding. Only enough iron was poured to fill the cavity. When the castings were taken from the mould before chilling set it, and, consequently, before the formation of white crystals, there was no arrangement of the structure that would indicate in the remotest degree any direction of the primary crystals. The crystals at the point A were somewhat larger than those at the outer portion, but showed no definite lines of direction or any signs of gas streams. The line of setting was measured by the time the core remained in the casting before it was withdrawn.

No. 1 iron required one minute and 20 seconds before it was safe to draw the core. When the core was allowed to remain in the casting one minute and 30 seconds it was gripped by the iron and had to be cooled to the room temperature before removal was possible. No. 2 required one minute and No. 3 30 seconds. In the case of No. 4 a new condition was set up, when 16 per cent. of steel scrap was melted with the charge in the cupola. In this case it was two minutes and 20 seconds before the core could be drawn without the casting bleeding or sweating.

The results show that a low silicon iron cools or sets much slower than one of the higher silicon content. The range of from 1.05 per cent. silicon in No. 4 to 2.25 per cent. silicon in No. 3 made a difference in time of setting from 30 seconds to two minutes and 20 seconds. The time of setting was not affected by the temperature of the core, as the tenth successive casting had to be given the same time as the first.

The diameter of the plug or core was 9.0475in. when cold. When the cavity of the cold casting was micrometred the dimensions varied from 9.0425in. to 9.05in. The length of the core was 18.175in. The depth of the cavity when cold never varied more than four one-thousandths of an inch from that figure. These variations are all within the range of human error. It can hardly be asserted that there was any definite shrinkage when these irons were cast in a chill.



## On the Erosion of Bronze Propellers.

The following article, which bears upon a recent discussion on Brass and other Alloys, appeared in *The Marine Engineer and Naval Architect* of February, 1910, and is reproduced by permission:—

Since the introduction of high-speed turbine engines the phenomenon of erosion in propellers of high-tension bronze, which was, until recently, practically unknown, has forced itself upon the notice of those interested in shipbuilding.

Hitherto the bronze manufacturer has been chiefly occupied in overcoming corrosion, both chemical and galvanic. The improvements in engines and the demand for high-speed ships, both for the purpose of war and peace, have led to conditions never before dreamed of. On the one hand, we have to consider the high-speed propellers of our torpedo boat destroyers, some of which are capable of making 700 to 800 revolutions per minute; and on the other the great four-bladed solids which propel our gigantic liners.

As generally happens when a material, which has hitherto proved perfectly satisfactory for a given purpose, is subjected to new conditions, something suffers, and so has it proved in the case of these propellers.

Perhaps the most remarkable instance has been that of the propellers of the Cunard liner, *Mauretania*. Some three months after her maiden voyage she was dry docked, and it was found that all the propellers were very badly eaten away. Of the four, those at the stern were least affected. In all cases the area that had suffered most damage was situated about 2 feet from the root and towards the after edge of the blade. In extent it amounted to 3 or 4 square feet, and in depth varied from a quarter of an inch to as much as  $2\frac{1}{2}$  inches in places. The damaged surfaces presented somewhat the appearance of galvanic action.

The edges of the blades also showed eroded areas. Many of these could apparently be traced to a chip or damage at the edges. In shape they were curved, in most cases on an arc described from the centre of the propeller shaft. On the back, with two exceptions, the blades showed the same curious comet-shaped marks, in some cases, commencing at the shackle holes. These holes do not appear to have started similar areas of damage on the driving face, and in two cases no such mark was

apparent. The extent of this part of the damage would appear to depend upon the length of time during which the plug remained out of the shackle hole.

The condition of the bronze on the driving face was excellent, showing a smooth, crystalline surface (probably due to the etching effect of the water), but no signs of corrosion.

As will be readily understood, the weakening effect of this deterioration is remarkable. Thus a portion of a damaged propeller from the SS. *Lusitania* was broken off across the line of maximum deterioration, and on examining the fracture it was found that the line of compression was situated right against the un-eroded side.

These details may, broadly speaking, be regarded as typical of an extreme case, so having briefly touched upon the nature of this deterioration let us now deal with a few possible causes.

Since the material withstood the old conditions it is obvious that the primary cause of the deterioration described must be sought in the modified conditions. The problem thus arises as to what these modified conditions are, and in what way they affect the question at issue.

In the first place, we have to consider the terrific surface friction of the water. To illustrate this let us take a few figures, and for this purpose we cannot have a better example than the above mentioned liner, viz., the SS. *Mauretania*. As is well known, this ship was originally fitted with four three-bladed, built-up propellers, of the usual standard high-tension bronze that has been employed for many years for the propellers of Atlantic liners and war vessels of all descriptions. These propellers were somewhat under 17 feet in diameter. Upon the outward journey the average revolutions of the engines were 174, the horse-power developed, being about 68,000, and the speed of the vessel nearly 26 knots. It is evident, therefore, that the perimeter of each propeller travelled through the water in a helical path of approximately 154 feet per second, or 105 miles per hour, and transmitted to the water no less than 1,700 h.p. the whole time. A consideration of these figures at once enables us to realise that under such conditions the water becomes a very rough file for any alloy to withstand, and when the standard bronze, which has proved so serviceable in the past, was subjected to these conditions we can scarcely be surprised that it failed.



So far so good, but now we come up against the extraordinary discrepancies between the various propellers examined. While of the propellers examined nearly all showed more or less deterioration of a similar nature, yet in degree and position there were wide and marked divergencies. Thus in the case of the *Mauretania's* sister ship, the SS. *Lusitania*, where the conditions are at first sight identical, the backs of the propellers were quite as much affected as the faces. Still more remarkable is the case of certain destroyers the propellers of which show a maximum damage at the base, where the helical velocity is at a minimum.

This led to a search for secondary causes, a few of which may well be briefly touched upon.

(1) Dirt in Castings. This may be dismissed at once. Not only did the propellers examined include some of the cleanest castings the author has ever inspected, but seldom did the maximum concentration of oxide or dirt coincide with the area of maximum damage.

(2) Galvanic Action. In the case of the SS. *Lusitania* the stern propellers were much less affected than the wing propellers, whilst the conditions, in so far as they affected the zinc plates, were exactly reversed, those at the stern being far more eaten away. From this it was at first thought that galvanic action played a part in the deterioration. The appearance of the damaged area was strongly in favour of this theory, the metal having been eaten and pitted in a most remarkable manner, sponge-like masses as much as  $1\frac{1}{4}$  inches in diameter being left attached by a base of less than a quarter of an inch across, whilst all the surrounding metal had been eaten out.

Analysis, however, rendered it evident that no large concentration of copper had occurred on the eroded surface, so that if galvanic action enters into the problem and tends to cause a concentration of a softer alloy much richer in copper, this effect appears to be more than counterbalanced by the erosive action of the water as it sweeps over the surface. At the same time, the areas of maximum deterioration do not coincide with the view that erosion is alone the primary cause, for in no case do these areas occur at the extreme tips of the blades where the helical velocity is greatest.

With facts of so conflicting a nature it appeared obviously unsafe to hazard an opinion as to the nature of the action in all cases. A large number of instances were accordingly submitted to the most minute examination, every cause possible and im-

possible being taken into account. The details of these prolonged researches would prove far too tedious to recapitulate. It will suffice to say that the specific nature of the trouble ultimately proved to be primarily erosion, though the degree to which secondary causes entered in varied far more widely than could have been anticipated.

We need not delay to point out the many useful conclusions that may be drawn from the results, but only to remark in passing that our knowledge of the nature of eddies and the amount of energy absorbed thereby has been greatly enriched.

The problem thus resolved itself into (a) the production of an alloy better calculated to withstand the new conditions, and (b) the minimisation of the various causes.

This latter investigation obviously varies with each particular case, and need not, therefore, delay us further.

In order to deal with the first problem, conditions for the artificial production of this phenomenon in the laboratory were worked out and a very large number of alloys made, thoroughly examined, and then submitted to this test.

The following table gives the figures obtained in a few instances:—

TABLE SHOWING RELATIVE RESISTANCE TO EROSION OF A FEW OF THE ALLOYS EXAMINED.

Designation of Alloy.	Time taken to Produce Standard Deterioration under Standard Conditions. Hours.	PHYSICAL PROPERTIES OF ALLOYS.			
		Ultimate Strength. Tons per sq. inch.	Elastic Limit. Tons per sq. inch.	Elongation per cent.	Hardness, Brinell's Figure.
Standard High Tension Bronze (various makers) .. ..	24,700	32—34	16—18	12—20	—
Alloy No. 188 .. ..	30,900				—
Alloy No. 190 .. ..	39,700				—
Alloy No. 287 .. ..	33,600				—
Alloy No. 298 .. ..	43,200				1 0
Alloy No. 351 .. ..	32,300				166
Alloy No. 528 .. ..	46,650				173
Alloy No. 660 .. ..	50,900				99
Alloy No. 955 .. ..	57,000				131
Alloy No. 1003 .. ..	64,800				132
Parsons' New Turbine Alloy ..	117,200	33—34	18	12—15	131

From the above the following conclusions may be drawn:—

- (a) That the capacity to withstand this deterioration is not, strictly speaking, dependent on any one physical



property, but must rather be regarded as a property peculiar to itself; in short, it would appear to constitute a new physical constant for alloys.

- (b) That in the new alloy ("Turbine Alloy") this property has been brought to a remarkable pitch, its resistance to the action under standard conditions being nearly five times as great as that of the old alloy, from which it will be seen that the new alloy is likely to resist all reasonable conditions of wear indefinitely.

The elementary difference between these two alloys is remarkable. Its efficiency depends upon certain treatment of the alloy, and the addition of certain new elements which we may unhesitatingly state have not hitherto been brought under consideration as a possible solution of a problem of this nature.

Interesting instances, illustrative of the superiority of the new alloy, have been afforded by certain destroyers. In one case the ship was first fitted with propellers of ordinary high tension bronze; these, after running at full speed for sixteen hours, showed such marked and serious erosion that the speed could not be maintained. They were then replaced by a new set cast in Turbine Alloy, which have proved fully equal to the demands put upon them.

Indeed, the efficiency of the new alloy has now become a matter of history. The first propellers made of it were the new solids for the SS. *Mauretania*. To those who inspected the old propellers after running for three months the superiority is scarcely to be believed. After running for twice as long the present solids are still like new; indeed, they bid fair to outlast the ship.

In this connection the following report of Mr. Wm. J. Norris, Surveyor for Germanischer Lloyd, may be quoted as being of great interest.

Certified copy of Report received from Mr. W. J. Norris  
 "On some propellers of Parsons' special Turbine Alloy supplied by the Manganese Bronze and Brass Company, Limited, to the Cunard Steamship Company for the R.M.S. *Mauretania*.

"To the Manganese Bronze & Brass Co., Limited,

"116, Fenchurch Street, E.C., 1st July, 1909.

"Dear Sirs,—In accordance with your request, I proceeded to the R.M.S. *Mauretania* in the Canada Dry Dock, Liverpool,

on Tuesday last, to inspect the new wing propellers lately supplied by you of your special 'Parsons' Turbine Alloy.'

"I understand that these propellers were specially made by you to take the place of other propellers of the ordinary standard high-tension bronze, as used for the propellers of the principal Atlantic liners, which had proved subject to erosion, apparently resulting from the high revolutions of the engines, combined with the action of broken water under high pressure upon the surface of the blades.

"I learnt from the Cunard Steamship Company that the new wing propellers referred to were fitted in January last, and have, therefore, been running for nearly six months. After a thorough examination of these propellers I found them in perfect condition; there was no sign of wasting or erosion, the surface, in fact, appeared to be as good in every way as when the castings were first made.

"While in Liverpool I also examined the blades of the built-up propellers previously fitted to this vessel, and noted with great interest the very extensive erosion which had taken place over a great part of the surface of the same.

"These blades, I was informed, had only made three round trips, so that it was obvious such a severe and rapid erosion would very soon have worn out these blades.

"I consider it, therefore, a matter of great scientific interest, and one upon which you can be congratulated, in having been successful in producing an alloy which, from the inspection carried out by me, appears to withstand the erosion so satisfactorily."

"Yours faithfully,

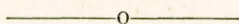
"(Signed) WM. J. NORRIS,

When the SS. *Mauretania* was first fitted with solid wing propellers of this material (each weighing nearly 20 tons) she, as is well known, beat all previous Transatlantic records. Now that the SS. *Mauretania* has been similarly equipped we see that there will be keen competition between the two ships. It is rumoured that the Cunard Company propose shortly to replace the *Mauretania's* stern propellers also, so that the duration of the journey to New York is likely to be still further reduced in the near future.

In conclusion, I should like to thank the directors of the Manganese Bronze and Brass Company, Limited, and those of



the Cunard Steamship Line Company, and Messrs. John Brown & Co., for the hearty assistance and facilities they have given me for carrying out this work, and I may add that the success of this investigation has been largely due to the great knowledge of bronzes and allied alloys possessed by the managing director of the first-named Company.



## Cast Iron: With Special Reference to Engine Cylinders.

By J. EDGAR HURST.

The following is an abstract of a paper read before the Manchester Association of Engineers on December 9th, 1916; it was printed in *The Mechanical Engineer* of December 15th, 1916:—

The trend of advance in connection with modern prime movers, particularly internal-combustion engines, would seem to be in the direction of the improvement of existing types rather than in the introduction of new types of engines. In this connection the materials of construction of the engines occupy no mean share of attention, and cast iron, of which the vitals, the cylinders and pistons of engines, are composed, is by no means of the least importance. The subject, "Cast Iron," has been dealt with many times before, by this and other institutions, and no doubt its importance in this connection is fully realised. It is an undoubted fact that grey cast iron possesses unique and invaluable properties when in use as rubbing parts, and, this being the case, one is surprised to find that much is still lacking in the way of actual scientific enquiry into the mechanism of the behaviour of cast iron in this respect.

One or two aspects of the application of cast iron to engine cylinder construction are of great importance, both from a metallurgical and engineering standpoint, and the study of these has engaged the author's attention for some time past. It must be borne in mind, however, that the subjects dealt with are by no means fully exhausted, and an enormous amount of work still remains to be done before these points are thoroughly elucidated and entirely understood.

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*The Wearing of Cast Iron.*—The wearing and antifrictional properties of cast iron are very intimately related and undoubtedly interdependent; but for the sake of clearness and simplicity it will be advisable to consider them under separate headings. Wear for our purposes may be defined as the mutual loss in weight of two substances when rubbed together over a given period of time. Obviously when the number of substances with which, and the number of modes in which cast iron can be rubbed, and so bring about wear, is considered, the subject becomes one of exceedingly wide dimensions. Therefore, for the purposes of this paper, it is proposed to consider only the case of wear such as occurs in engine cylinders—that is, wear brought about by the mutual rubbing or abrasion of cast iron by cast iron.

The supreme difficulty experienced in all cases of wear study is the lack of any satisfactory means of reducing industrial conditions to an experimental scale. And doubtless it is to this cause that research in this direction has been so long delayed. Of necessity, therefore, we have to rely for our knowledge of the subject on that chiefly derived from investigations of actual industrial cases—a very slow and prolonged method.

The characteristic feature observed on the visual examination of worn gas engine liner surface is that the whole of the worn surface is covered to a more or less extent with small pits or holes. These holes or pits are commonly put down by many engineers to the coarseness of the grain of the cast iron, and are often considered to be the holes from which the coarse plates of free graphite existing in the original iron have been detached. This is not strictly correct, for as a matter of fact on microscopical examination of etched specimens these holes prove to be the result of the detachment of whole grains of any constituent from that particular portion of the surface of the liner. On subjecting worn liner surfaces to a microscopic examination one invariably finds the harder constituents standing in relief exactly as though the liner had been subjected to relief polishing.

Cast iron as a whole is a conglomerate of a number of constituents, ferrite, pearlite, cementite, and phosphide eutectic, of widely different mechanical and physical properties, the soft and ductile ferrite and pearlite on the one hand, and the extremely hard and brittle phosphide eutectic and cementite on the other hand. The whole of the grains constituting the mass



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are more or less separated by numerous graphite plates, resulting in the mass having a very low intercrystalline cohesion.

In the engine cylinder, under the influence of the abrading action of the piston rings, together with the slight initial surface disintegration, brought about by the stresses resulting from the reaction of the connecting rod, a certain amount of detached material is produced which becomes powdered and suspended in the film of oil. This suspended material, under the influence of the reciprocating motion of the piston, is undoubtedly responsible for the relief polishing of the surface of the cylinder, resulting in the harder constituents, usually the phosphide eutectic or the cementite, projecting above the surrounding material.

Eventually, these projections, together with the other grains composing the surface of the cylinder, under the influence of the abrading action of the piston rings and the vibratory stresses produced by the motion of the piston and the reaction of the connecting rod, are loosened and subsequently detached, a procedure which is no doubt facilitated by the increased temperatures and gas pressures inside the cylinder. Such is, in all probability, the mechanism of surface disintegration in engine-cylinders.

*Surface Flow Phenomena.*—It has been well known to engineers for a long period that with cast iron parts which are subjected to the influence of rubbing actions, such as, for example, engine cylinders, slides, &c., immediately such parts have been in use for a sufficient length of time to have acquired a peculiarly glazed surface or glazed appearance, then satisfactory working of those parts is obtained.

The cylinder walls of high-speed engines, after having been in running for a considerable period, are harder, and become increasingly difficult to file, and the raised markings left on the cylinder walls after a "seizure" has taken place, are often hard and incapable of being filed.

The glazy appearance produced on cast iron liner surfaces after a period of running is undoubtedly very important, and plays a large part in the reduction of the extent of wear and in the efficiency of its antifrictional properties. Our Continental neighbours would appear to have realised this, and it is believed that some of the large Continental gas engine manufacturers subject their gas engine liners and pistons to a period

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of running in the engine previous to putting the engine in work, The object of this procedure is undoubtedly to bring about the production of this glazy appearance.

It is very probable that this glazy appearance is the product of a number of different causes. The most important one appears to be that under the influence of alternating stresses brought about by the motion of the piston, the surface grains are deformed by being broken down along the slip planes, ultimately producing a surface of very fine crystal structure. Micro-examination of such surfaces reveals in many instances very finely granular structures even at high magnifications. Such surfaces are harder, and will be obviously far less sensitive to the effects of surface disintegration than the original coarser grained structure. In addition, owing to the increase in the number of crystal boundaries, the total effect of intercrystalline cohesion is enormously increased, and whether this enhanced strength noted at the crystal boundaries is due to the influence of the presence of amorphous cement or surface tension, or both, such superficial layers on liners must be enormously strong. The presence of the elements manganese and chromium in notable quantity undoubtedly increases the resistance of cast iron to wear. This is due to the production of these deformed surface layers, which are readily produced in such irons. Micrographs taken of a gas engine liner surface after a seizure showed a layer of hard matter. The author considers that these layers consist of detached material which has been bodily deposited on the surface of the liner, either from the piston or displaced from some other portion of the liner. In all probability they consist of, in this instance, large ferrite areas which have been detached, and owing to their comparatively large size, and under the influence of the intense pressure, have "flowed" over the surface of the liner. It is very probable that the intense heat developed in this layer, owing to friction (which can actually be observed as a white heat), causes the rapid absorption of carbon either from the graphite or from the lubricant, or from both, resulting in the production, at this high temperature, of the hardenite solid solution. The cooling of this highly heated layer, in actual contact with the solid walls of the liner, is more or less rapid, and according to the degree of rapidity of the cooling, the type of structure and the degree of hardness presented by the layer is determined. On examination of these layers under the microscope, when etched, structures are revealed which are undoubtedly intermediate



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between hardenite and pearlite. Similar effects are sometimes obtained during grinding operations on cast iron. Under certain conditions when the wheel is said to glaze, in the case of cast iron this peculiar hard surface is produced. This is probably the result of surface flow in a like manner to that above.

*Antifrictional Properties.*—It is a well-known fact that, apart from the wear of metals and alloys under actual rubbing contact, that certain metals and alloys exhibit a special property of undergoing this rubbing treatment in a more satisfactory manner than others. The extent to which a metal or alloy will undergo this treatment without overheating or seizing is to a large extent a property of the individual metal or alloy concerned, and this property for the purposes of this paper we designate its antifrictional property. It must be understood that the load, and possibly also the speed under which the mutual rubbing action takes place, also have an influence on this property. For our purposes these influences are at present ignored and considered as constant.

Reference to the so-called antifriction alloys affords an interesting analogy. These alloys are for the most part constituted of such metals as tin, lead, copper, and antimony, the proportions of which are so designed as to produce an alloy of such a character as to give the most satisfactory results from the point of view of overheating and seizure when in use as engine or line shaft bearings.

Experience has shown that such an alloy should as a general rule consist of at least two constituents of widely different physical properties embedded in each other. When in actual use the surface of such a metal becomes polished in relief, and the harder constituents project above the surrounding matrix, producing a surface of an irregular contour. It is considered that these hard projecting points serve as direct supports for the greater part of the load, whilst the minute hollows serve as minute reservoirs evenly distributing the oil over the whole surface.

In the high-speed engine cylinder the running properties of the material of which the piston and cylinder are constructed are subjects of great importance and demand wide recognition. Primarily it is owing to its special properties in this respect that engine cylinders are constructed of cast iron, and it is very significant that as yet we have no other material that will successfully replace cast iron in this capacity. In addition, the limitations of cast iron, both in respect of these properties and

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also the general mechanical strength properties, are a drawback to advance in high-speed engine design.

The general excellence of the antifrictional properties of cast iron is commonly ascribed to the lubricating qualities of the free carbon content. In a large measure this is quite true, though not *strictly* correct, and, indeed, when it is remembered that cylinder liners and pistons are in successful use for a number of years the influence of the superficial graphite content is not sufficient explanation.

Exactly as is the case with antifriction alloys previously mentioned, under the influence of the reciprocating motion of the piston, and the abrading action of the fine particles suspended in the oil, a surface of irregular contour is developed on the cast iron, the harder constituents standing in relief as illustrated in the section on wear. These minute hollows, together with the holes developed as a result of surface disintegration, serve as distributing reservoirs of the lubricant, ensuring efficacious and excellent distribution of the lubricant over the whole surface. It might also be mentioned at this point that the "glazy" surfaces presented by cast irons after subjection to continuous motion, are also an important consideration in this connection, although at present their influence is somewhat obscure.

*Micro-Structure: Influence and Considerations.*—It will readily be seen in this connection that the micro-structure of cast iron is of prime importance. In the first place, it will be evident that up to a certain point, as a result of the wearing action on cast iron, a surface possessing good antifrictional properties is produced. Even in cast irons containing no well-defined hard constituents, such as, say, for example, phosphide eutectic, the effect of the surface disintegration will result in the production of surfaces having good antifrictional properties. Obviously, however, excessive wear as a means of obtaining efficient liner surfaces is highly undesirable from the point of view of engine power development, and in addition the excessive production of debris resulting from surface disintegration, more particularly in the initial stages of the running of liners, is a contributory cause to "galling or seizure."

The cast iron having the highest intercrystalline cohesion, otherwise the highest tensile strength, will possess the greatest resistance to surface disintegration, and, consequently, to wear. Under a given load and speed, therefore, it would appear that wear in engine cylinders is proportional to the tensile strength



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of the iron. This conclusion was arrived at by Messrs. Ludwig Loewe & Co., Ltd., from a series of experiments in which the wear was determined as the loss in weight after rubbing cast iron cylinders for a given length of time, under a given load and speed, on a hardened steel die.

Cast iron of the highest tensile strength at normal temperatures is that having the closest grained structure and a free carbon constituent existing in a very finely divided, or, alternatively, in a rosette form.\* Generally speaking, in so far as the tensile strength of cast iron is concerned, the identity of micro-constituents is of little importance providing the above conditions obtain. Consequently, it would appear that the corollary of this statement is true, and that the identity of the constituents is of little moment in the case of wear.

In so far as pure surface disintegration is concerned, and under ideal conditions, this would appear to be perfectly true. The effect, however, of the action of alternating stresses on the character of the surface grains, and the effects of the differential polishing of these grains largely modify this conclusion, and in this respect the identity of the constituents is of importance.

It is yet too early to state definitely the influence of different constituents on the production of "glazy" surfaces. The greater portion of our knowledge and experimenting in this direction is confined to the behaviour of pure metals only, and its extension to, perhaps, the most complex of all alloys, cast iron, involves an enormous amount of work.

The extent of the differential polishing of the surface grains in a large measure depends upon the individual characteristics of the grains. It will be obvious that this effect in excess will rapidly lead to the inauguration of surface disintegration. Cast irons constituted of large grains, varying widely in physical hardness, are an example of this type of occurrence, and the comparatively rapid wearing of coarse-grained irons, consisting largely of ferrite and phosphide eutectic, is in a large measure due to this cause.

The influence of wear in the production surfaces of good antifrictional properties on cast iron has to a large extent been fully dealt with. The influence of the general micro-structural arrangement on one or two points is of importance. Photomicrographs obtained from polished and etched specimens of two samples of cast iron showed in one case a beautiful network arrangement of the phosphide eutectic and cementite,

\* Foster, Manchester Association of Engineers. January, 1904.

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and in the other a blotched appearance, which, in this case, consisted of large ferrite areas, around which the hard constituent was indiscriminately distributed. A micro-structure of fairly large grain size is typical of a comparatively fast wearing liner, although at the same time possessing good antifrictional properties.

It must not be assumed that the presence of the hard constituent, structurally free, however, is absolutely indispensable for the production of a good wearing and running liner, and, in fact, cast irons of very low phosphorous content and containing practically no structurally free hard constituent, give excellent results in this respect. The study of the influence of pearlite in this respect is still under investigation in greater detail, and undoubtedly its influence is very important. Qualitatively it may be explained in part somewhat on the following lines. Pearlite consists of numerous very fine lamellæ of the two micro-constituents ferrite and cementite, which in individual properties represents the two extremes. The result of the polishing action on such a structure is the production of a surface containing very fine microscopic channels. Such channels behave in exactly a similar manner as fine capillary threads, distributing the lubricant undoubtedly by means of surface tension.

*Hardness and Wear.*—The lack of any means whereby the wearing properties of any material can be tested and readily adjudged is sorely felt by both engineers and metallurgists alike. It is customary to use the hardness number which is, as a general rule, obtained by the Brinell method as a means of indicating the wearing properties of metals. As applied to cast iron for the purposes of engine cylinders, this method is far from satisfactory. Cast irons giving the same hardness numeral often wear at widely different rates, and, furthermore, the influence of the presence of such elements as manganese and chromium, which, in normal percentages, are not detected by the hardness numeral is most important.

The unsatisfactory nature of the Brinell hardness numeral in this capacity is undoubtedly due to a multiplicity of causes. In the first place, an enormous amount of uncertainty surrounds the definition of hardness, and it is very doubtful whether the methods of determining hardness actually do determine this property in its entirety. The hardness of a body, as defined by the nomenclature committee appointed by the Iron and Steel Institute, is "the resistance offered by a body to the 'mechanical' separation of its particles." It



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would appear from this definition that hardness and wear are very intimately associated. Indeed, it is the author's opinion that in a homogeneous material the true hardness property is its resistance to wear. From this, therefore, the resistance to wear is a function of the cohesion of the particles, or rather, in the light of more recent knowledge concerning the architecture of crystalline bodies, is the resistance to deformation, and it is therefore tentatively suggested that the yield point gives the more correct indication of the true hardness. The high resistance to wear of some of the non-ferrous alloys, *e.g.*, antifriction alloys, is in all probability due to their liability to produce under the influence of stresses during working overstrained superficial layers. The investigation of the yield point in this connection will doubtless throw much more light on this hitherto somewhat neglected subject.

To return to cast iron. It is extremely probable that wear due to surface disintegration is not exactly wear in the above sense, but is really a function of the brittleness of cast iron. The abrasion or relief polishing previously outlined is the true wear in that it depends upon the resistance to deformation of the individual component grains. The whole subject, particularly in reference to the material cast iron, it will be plainly evident, is extremely complex and involved, and an enormous amount of work still remains to be done.

The Brinell hardness test as applied to cast iron is most unsatisfactory, and it is practically impossible to correlate the figures obtained in this test with the chemical constitution of the cast iron. Broadly speaking, the hardness numeral varies with the combined carbon content. The presence of such hard constituents as phosphide eutectic increase the numeral. This can only be truly said of cast irons obtained under exactly identical conditions. In such a complex alloy as cast iron this is not at all surprising, and is in all probability to be explained by the numerous subsidiary influences, chiefly the casting temperature and the rate of cooling, which largely affect the structural arrangement and distribution and the grain size.

The impossibility of correlating the hardness numeral with other mechanical tests or the chemical constitution is doubtless largely due to the permanent bodily slip of the crystals under compression, owing to the presence of the free carbon constituent, and as a result it can only be considered that Brinell figures on cast iron are at all comparative when the conditions under which the specimens are obtained are strictly identical.

## Ferro-Manganese in the Iron and Steel Industry.

By ROBERT J. ANDERSON, B.S.

A paper was contributed to the journal of the Franklin Institute on Ferro-Manganese in the Iron and Steel Industry by Robert J. Anderson, B.S. The following abstract is from *The Mechanical Engineer* of June 8, 1917:—

The main sources of manganese ores are the producing mines of Russia, India and Brazil. Briefly, the ores of Russia have come in the main from the Tchiatouri deposits in the central part of the Caucasus, and some ore has been produced in the Nikopol district. The mode of mining was, until about ten years ago, exceedingly primitive, being conducted by peasants, but of late years foreign capital has become interested, and modern methods of extraction have been installed.

The manganese ores of India occur at a large number of localities, but the only deposits of known economic importance are those of the Jhabua district of Central India; the Panch Maháls district of Bombay; the Chindwára, Balaghât, Bhandára, and Nágpur districts of the Central Provinces; the Sandur and Vizagapatam districts of Madras; the Shimoga district in Mysore; and the Gangpur district in Bengal. There are a number of operating mines producing high-grade ores in which the manganese shows 50 per cent. and more on analysis. Ore blocked out and in reserve indicates that these mines will be in a position to be constant producers for many years to come.

Manganese ore is known in Brazil in the states of Bahia, Minas Geraes and Matto Grosso. The mining of the ores dates back to 1894, the main bulk of the output having come from Minas Geraes. In late years the Queluz or Lafayette district of Minas Geraes has outstripped the Miguel Burnier district near by with the development of the phenomenal Morro da Mina mine, so that the Lafayette district has assumed foremost importance in Brazil. Development work has disclosed an ore reserve of about 10,000,000 tons, and the mine is producing at the rate of over 200,000 tons per annum.

Manganese ores have been mined in Chile; the industry was carried on quite extensively prior to 1900, or about the time when the extensive Indian deposits began to be exploited. Since 1905 practically no manganese ore has been mined in Chile, and the mines have been abandoned. Manganese ores



occur in the Huasco and Carrizal districts of Atacama; the Los Chorros, Los Cañas, La Liga, Arrayan, and Corral Quemada districts of Coquimbo, and the Aculeo district of Santiago. Most of the exported Chilian ore came from the Carrizal and Corral Quemada districts, and a considerable tonnage from Los Cañas and La Liga.

Manganese mining has never been an important industry in the United States on account of the scattered and discontinuous nature of the deposits. Deposits are found in many localities, but in only a few places do they occur in sufficient quantity to be of high commercial value. Ores have been mined in the New England, Appalachian and Piedmont regions in the eastern United States, in northern Arkansas, and to a small extent in California in the central western part. The main mines as to production have been those in the Blue Ridge and the James River-Staunton River region of Virginia, the Cartersville and Cave Spring districts of Georgia, the Batesville district of Arkansas, and the Livermore Telsa district of California.

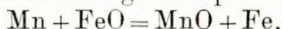
In every process of steel metallurgy it is common to employ one, and often more, of the ferro-alloys, according to the kind of steel being made and the use for which it is destined. By reason of total tonnage consumed, ferro-manganese is the most important of the ferro-alloys. Its importance may be realised when it is said that its use is virtually indispensable. In a recent paper, F. H. Willcox, of the U.S. Bureau of Mines, pointed out the great importance of manganese in the metallurgy of steel. The scientific press has not generally recognised the significance of manganese; the trade journals have urged the matter of research to develop substitutes for both ferro-manganese and spiegeleisen. In view of the well-known action of both alloys in the metallurgy of steel, it is needless to recall their effects here. However, it may not be out of place to sketch the possibilities of substitute deoxidisers and the means of securing data thereon. In any event, the scientific method of attack is the practical one.

Ferro-manganese and spiegeleisen, aside from their recarburisation effects, are added to steel for the purpose of deoxidising the metal and for the purpose of removing gases and oxides therefrom. In general, the following substances mainly have been used as deoxidisers and purifiers: ferro-manganese and spiegeleisen; aluminium, ferro-silicon, and ferro-titanium, either carbon-free or not. To a much less extent, the

following substances have found application for the same purpose: ferro-aluminium, ferro-manganese-silicon, or, as it is more commonly called, silico-manganese; ferro-silico-manganese-aluminium; ferro-silico-aluminium; silico-calcium-aluminium; ferro-vanadium; calcium-silicide; ferro-calcium-silicide; ferro-titanium-aluminium-silicide, and some others.

*Ferro-manganese.*—Manganese, in the form of one of its iron alloys, is the most important deoxidiser known. As commonly recognised, ferro-manganese is an alloy of about 80 per cent. Mn, 15 per cent. Fe, and 5 per cent. C. Strictly speaking, it is rather more of a manganese alloy than one of iron, although it is classed with the ferro-alloys. Spiegeleisen is a low-grade iron-manganese alloy of about 10 per cent. to 25 per cent. Mn, and occasionally up to 35 per cent. Mn, and about 5 per cent. C. The higher percentage alloy hastens the chemical reactions in the steel more rapidly than does the lower percentage alloy, and accordingly absorbs less heat in so doing. Certain advantages are found in using the higher alloy; among other things, a smaller quantity of the former will be required to produce the same results, and consequently the loss through volatilisation and for other reasons, when added in the solid state, will be minimised.

Ferro-manganese is used in cases where it is undesirable to materially increase the carbon content of the metal, as happens when spiegeleisen is added. The former is therefore of great importance in the manufacture of manganese steels. Typical 80 per cent. English ferro-manganese may analyse as follows: 80·00 per cent. Mn, 7·20 per cent. C, 0·80 per cent. Si, 0·18 per cent. P, 0·004 per cent. S, and 11·20 per cent. Fe. Spiegeleisen has found, and still does find, extensive application in the manufacture of Bessemer steel, although at present ferro-manganese is used in conjunction with it in this practice. A typical English spiegeleisen analyses 20·11 per cent. Mn, 4·99 per cent. C, 0·42 per cent. Si, 0·074 per cent. P, and S nil. Irrespective of which alloy is added, and whether in the steel-making appliance or in the ladle or both, certain chemical reactions occur. The manganese, by reason of its greater chemical affinity for oxygen, robs the iron or steel bath of the dissolved iron oxides with the formation of manganese oxide (MnO), which is insoluble in the metal. The MnO joins the slag, and the reduced iron is given up to the bath according to



The deoxidising effect of manganese is very potent, but it will

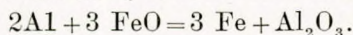


not remove the last traces of oxides from the metal, nor will it remove dissolved gases, *e.g.*, nitrogen. The last traces of oxides may be scavenged out by the use of aluminium or titanium alloys, after the addition of the manganese. In addition to its action upon oxides, manganese is valuable because of its chemical reaction with sulphur. In a frozen steel, sulphur, unless sufficient manganese be present, is in the form of ferrous sulphide (FeS), which is thrown out to the crystal boundaries in such a manner as to give rise to extreme weakness and brittleness of the metal when hot. Manganese has a greater chemical affinity for sulphur than has iron, so that, when added to steel, manganese sulphide (MnS) is formed in whole or in part, dependent upon the percentage of manganese added, according to



Some of the MnS may go to the slag, and some of it remains in the metal as rounded inclusions.

*Aluminium.*—This metal will remove traces of oxygen from steel when added in small amounts. Aluminium is a more efficient deoxidiser than either manganese or silicon, but its use is not entirely without certain disadvantages. The element, when added to molten steel, reduces ferrous oxide according to



As the equation shows, the reaction produces the very highly infusible  $\text{Al}_2\text{O}_3$ . As the temperature of the bath is usually below the melting point of this oxide, the tendency then is for the aluminium oxide to remain occluded in the frozen metal instead of entering the slag as desired. The use of too much aluminium tends towards the production of large pipe, and for this reason some railroad engineers specify that it must not be used as a deoxidiser for rail steel. Further, it has no effect upon sulphur. The benefits gained from the use of aluminium arise from the exothermic reaction induced on combining with oxygen, and since, on its addition, the metal is killed and thereby quieted, segregation is decreased. However, it cannot be used as a substitute for manganese because of its limitations.

*Ferro-silicon.*—This alloy, formerly made in the blastfurnace as a highly silicated pig iron containing from 10 per cent. to 12 per cent. Si, is now made in the electric furnace and may contain up to 95 per cent. Si. Typical English ferro-silicon made in the blastfurnace analyses 13.45 per cent. Si, 1.21 per cent. C, 1.71 per cent. Mn, 0.058 per cent. P, and 0.02 per cent.

S. Ferro-silicon made in the electric furnace may contain 25 to 35, 45 to 50, 75 to 80, or 90 to 95 per cent. Si. A typical English electric furnace ferro-silicon analyses 94.8 per cent. Si, 0.08 per cent. Mn, 0.01 per cent. P, 0.02 per cent. S, and C nil. The 25 per cent. to 30 per cent. ferro-silicon may be used to advantage in large pieces in both the open-hearth and Bessemer processes. Ferro-silicon is, as a rule, added to steel in the furnace, but occasionally in the ladle before the steel is tapped. Ferro-silicon is very effective in steel metallurgy because of the high chemical affinity of silicon for oxygen. Added in small percentages, as low as 0.1 per cent. by weight, it is said that it reduces segregation and increases the solvent power of the steel for gases. When added in excessive amount it produces pipe. Ferro-silicon owes its value to its ability to remove the oxygen by forming readily fusible silicates with Ca and Fe, but in some cases  $\text{SiO}_2$  remains in the steel because of its infusibility. In any event, ferro-silicon cannot be regarded as a substitute for ferro-manganese.

*Ferro-titanium Alloys.*—Both ferro-carbon titanium and carbon-free ferro-titanium have found quite extensive application in steel works metallurgy in late years for the purpose of deoxidising and denitrogenising metal, but their warmest adherents or the companies manufacturing them do not suggest that they be used as substitute deoxidisers for ferro-manganese. They are regarded as so-called super-purifiers, and leading authorities seem agreed as to their beneficial effects. That the alloys have found favour in practice is recognised, because a large industry has been reared upon the production and sale of ferro-carbon titanium, and in another works ferro-titanium is one of the principal products. It appears difficult to incorporate titanium in steel as an alloying element, but the metal combines with nitrogen with very great avidity, and is practically the only one which removes dissolved nitrogen in present-day work.

*Other Deoxidisers.*—Some of the other deoxidisers already mentioned have found a limited use; where they contain three or more elements in the alloy, these elements apparently augment one another's effects, but whether some of them are suitable or not is difficult to say. Whether they are or not, they have not enjoyed much use in modern practice.

*Liquid Ferro-manganese.*—In view of the utter dependability of steel makers upon foreign sources for their manganese supplies, it is little short of surprising that more time has not



been spent upon the subject of substitute deoxidisers or even on the matter of conserving the available manganese supply. When spiegeleisen, the low-percentage manganese alloy, is melted in cupolas, the large clouds of red smoke constantly issuing from the cupola tops indicate the utter extravagance of such a method. For melting the high-percentage alloy, the cupola is totally out of consideration. Various furnaces, fired by coke, coal, gas, or oil, have been tried for melting manganese alloys for liquid addition without satisfactory results. The standard method of adding ferro-manganese (*i.e.*, the high-percentage alloy) has been to break the alloy up into lumps and shovel it in in the solid state; in many European works the alloy is pre-heated red hot before adding. However, the experience of practice has shown the extravagance of this method also, because the loss in manganese totals from 20 per cent. to 35 per cent. from volatilisation. If this could be recovered it would represent a yearly saving, in a plant making 300,000 tons of steel per annum, of about £5,200, figuring ferro-manganese at £11 a ton. At the price paid for ferro-manganese in the past two years, the saving would be a great deal more. Naturally, whether it would pay to make this saving would depend upon the cost of so doing.

Among others, Alex. Sahlin, of Brussels, has prominently pointed out how melting ferro-manganese in the electric furnace is both practical and economical. No practical method for melting was available until the advent of the electric furnace, but now a number of plants in Europe have installed ferro-manganese melting furnaces. Heroult, Girod, Nathusius and Keller arc furnaces, as well as the Roechling-Rodenhäuser induction furnace, are used. The cost of electric current for operating constitutes the principal expense item. Irrespective of the working of the method, it is stated on good authority that worth-while savings can be effected, and those interested can refer to the account by Sahlin. The Rennerfelt furnace, brought out in 1913 by Ivar Rennerfelt, has proved particularly applicable for ferro-manganese melting. Where high grade or special steel is being made, and cost is a minor consideration, as in the manufacture of manganese steel castings, the ferro-manganese is melted in crucibles or in small, specially designed reverberatory furnaces. This method of procedure would not do for general work.

It appears, in the light of the facts presented in the foregoing, that the manganese situation is one of serious importance—one

that warrants thoughtful consideration on the part of those interested in the subject. The possibility of metallurgical science discovering a substitute deoxidiser which will take the place of manganese, either in whole or in part, appears to be an alluring one. Naturally, any attempt at such an endeavour will call for a large amount of labour on the part of many men, and it is not to be supposed that the final solution of the problem will be effected in any short time. The matter of obtaining suitable co-operation with steel makers for the use of their plants so that experiments may be carried out on a scale commensurate with that of practice is one that will have to be taken care of by research men who hope to contribute in large measure to any progress along this line. Steel works laboratories have an opportunity before them, if they have not already grasped it—and they apparently have not, if published data can be any criterion.

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### \*Engineering Training: Some Notes on Existing Facilities.

#### 5—SCHEMES OF CO-OPERATION BETWEEN EDUCATION AUTHORITIES AND ENGINEERING FIRMS.

Among the many useful examples of schemes of co-operation the following may be mentioned:—

(a) Many firms encourage their apprentices to attend evening classes by the payment of fees, award of prizes, increase of wages for successes at examinations, or by giving them permission to come to work at a later hour on the mornings following the classes.

(b) Other firms arrange for their apprentices to attend classes at a technical school on certain afternoons each week, or for a whole day once a week.

(c) A number of firms on the North-East Coast have had in force for some years a very complete scheme, whereby apprentices are selected as a result of satisfactory conduct and good reports from the works and the managers of the evening classes which they attend. The selected

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\* Extract from the Board of Education Leaflet on the subject of "Education and the steps being taken to effect improvements."—J.A.



apprentices attend during the six winter months of three or four years at the local technical college as full-time day students.

(d) In one northern town scholarships are offered at the technical college to apprentices who have served at least one year of their apprenticeship. The apprentices are allowed to attend at the college for two years, after which they return to the works to complete their apprenticeship. The scholarships are awarded partly on the results of an examination and partly on the recommendation of the firm.

(e) The scheme, which has worked with valuable results for many years in connection with H.M. Dockyards, is briefly as follows:—

Boys become apprentices in the dockyard as a result of a competitive examination at the age of fifteen. The apprenticeship covers a period of six years; attendance at the dockyard school is compulsory, and occupies one or two afternoons and two or three evenings each week. One of the most important features of the scheme is the system of progressive selection of the best apprentices for more advanced training to prepare them for positions of responsibility. A competitive examination takes place each year and decides which boys are to obtain promotion to a higher grade in the school, which brings with it increased opportunities for study. Further, at the end of the school course those apprentices who have reached the upper classes may compete for Admiralty scholarships, which give admission to one of the colleges conducted by the Admiralty in preparation for responsible positions in the Dockyards. The principle of selection by a continuous system of weeding out from the earliest stages, combined with careful co-ordination of the theoretical and practical work, forms a very admirable example of systematic training, and the scheme has enabled many men to rise to the highest positions.

#### 6.—EDUCATION AUTHORITIES AND OFFICIALS.

It is to be feared that opportunities of giving or obtaining information in regard to the educational needs of an industry are often lost by employers and industrial associations because they do not know who are the right officers to be approached

for advice and information, or to whom they should make suggestions or express their views as to the special requirements of their particular branch or industry.

It may therefore be worth while to set down briefly some particulars about the officers who are concerned with technical instruction.

In the first place, it must be remembered that in any area there are two categories of officers, one representing the Local Education Authority, and the other representing the Board of Education.

In a County or County Borough the Local Education Authority is responsible for the technical and other forms of education within its area. (Universities and a few technical colleges and schools are conducted independently of the Local Education Authority.) The executive officer of the Authority for educational purposes is usually the Secretary to the Education Committee or the Director of Education. In the case of large Authorities there may be an officer specially charged with the supervision of technical instruction, in addition to the officers already named.

Practically all forms of technical instruction, except when carried on for private profit, are aided by grants from the National Exchequer, administered through the Board of Education. The Board of Education maintains direct contact with all the schools aided from national funds by means of its staff of inspectors. For the purposes of the inspection of technical instruction, the whole country is divided into districts, and one of H.M. Inspectors is appointed to each district and charged with the special duty of keeping in touch with all forms of technical instruction within this area, as well as with the characteristics of the local industries. He is also instructed to give information and advice on matters pertaining to technical education within his district, and may be communicated with by name, or as "H.M. Inspector of Technical Schools," c/o the Secretary, Board of Education, Whitehall, London, S.W.1.

Further, a number of inspectors who have had practical engineering experience have been appointed in order to give advice on educational matters specially connected with the engineering industry; they are available for consultation if application for their assistance is made to H.M. Inspector for the district.



## The Chemist and the Engineer.

The following report from *The Practical Engineer* of July 26, 1917, is of interest, associating the Chemist and the Engineer:—

Speaking at the annual meeting of the Society of Chemical Industry in Birmingham last week, Dr. Charles Carpenter again discussed a favourite subject of his on the interdependence of the engineer and the chemist. If we sought the basis upon which the structure of modern industry has been erected we should find it largely in the sciences of mechanics and of chemistry; they might, indeed, be regarded as the first parents of technical industry as it exists to-day. The mechanical engineer would not be likely to dispute the influence of Watt, nor could the analytical chemist be likely to deny indebtedness to Priestley. But the steam engine the one designed was just as essential an adjunct of the modern power plant as was the chemistry practised by the other to the modern synthesizer of new substances. With the future of our Empire was closely bound up progress in applied science, and of a certainty chemical science, and this progress would be impossible of achievement without the complete and sympathetic collaboration of both chemist and engineer. With one or two notable exceptions that was not recognised to the full by many manufacturers in this country, certainly until recently. The progress of the chemical industry required the inspiration of the chemist in all and every direction; but the greatest possible advantage should also be taken of the engineer's particular gifts to bring about its achievement, once he was made to understand the conditions to be aimed at. The task might not be an easy one, for the temperaments of the chemist and the engineer are dissimilar, and the best examples of both were rarely met with in the same individual. The sorting-out process should begin at school. It should not be left to chance for the lad whose natural bent was along either of the paths to make his choice of one. If the teaching authority properly guided and took pains it should be an easy task to sift the pupil's leanings and direct his course in accordance with them.

As a preliminary step towards this, the first principles of experimental science should be compulsorily taught in all primary schools, as, for instance, is drawing. The ignorance of even the language of science among not only what are called the working classes, but the governing ones also, was appalling,

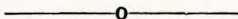
and the only remedy was its universal teaching. How were we to take full advantage of the latent capacity of our youth unless we teach one and all that the pursuit of chemical knowledge is a calling as honourable and praiseworthy as that of any other of the professions? Our educational system needed alteration at its foundations. A boy was old enough to learn science when he was old enough to learn history and geography.

When he reached the age of sixteen he should commence work, either at the desk or in the factory, with compulsory attendance at continuation schools. After two or three years he would, if showing himself to possess the necessary ability, be fit for entrance to the University to follow a further course of study along paths adapted to his temperament and qualities. In the past the nation's youth had been developed as unscientifically as its fuel resources. We have seen enough during these last three years to realise that our future depends upon the highest development of our industries, and in which the whole populace must be trained to take its share as a pleasure, no less than as a necessity. The taunt that we were a nation of shopkeepers was fast becoming a fact when our rude awakening came a century later; if we ever deserved another such rousing our sleep would prove eternal. There were, doubtless, many contributory causes, but the plight of chemical industry in this country was principally due to the fact that so small a part of the nation was taught its language. The nation cannot be expected to appreciate science at its true value unless that appreciation is inculcated as thoroughly as patriotism, for instance. The next point to be remembered is that the industrial chemistry of to-day is not largely a matter of pots and pans, but a highly complex combination in which temperatures and pressures of fine gradations and extended limits play important parts. The more one sees of this position the more imperative does it appear that the chemist and the engineer should get into double harness as quickly as possible; the very faults of each make him indispensable to the other.

The importance of the chemical industries in the scheme of national defence and national progress was at last becoming understood, and must be taken into account in the refashioning of our educational system. Another essential change was in our knowledge of the raw material resources of the Empire. It must be a State matter to map out all our mineral resources that they may be placed at the disposal of industry by, and, he had come to the conclusion, under the control of the State.



He could picture a future in which it was possible to work our mines, for instance, with regard only to the present, or in which anything but a surplus output went abroad before home requirements were satisfied. It should be an offence to supply coking coals for ships' bunkers even though the price paid was a good one. The State must consider whether it was better to export coal for steel making by our competitors, or to send them the finished article. And if we send our raw materials abroad their sale should be made a matter of inter-State exchange and barter. It ought to be possible to make a beginning by exporting coke instead of coal, and thus increase our control of by-products, the need for which was rapidly increasing. We should thus work up the nitrogen content of our own coal and export this instead of the mineral, which should be recognised as the property, as it was the heritage, of the nation.



## ELECTION OF MEMBERS.

Members elected at a meeting of the Council held on Tuesday, June 19th, 1917:—

### *As Members.*

Wilfrid N. Blevin, Resident Engineer, P. and O. Co., Aden.  
Crawford Allan Gilmour, 92, Sudbourne Road, Brixton Hill, S.W.

Robert James McLeod, Waltaire, Yiewsley, Middlesex.

David McNeil, 55, De Vere Gardens, Ilford, Essex.

David M. Murray, Craigmin East, 160, The Peak, Hongkong.

James Maitland Thomson, Post Office House, Bridge of Don, Aberdeen.

### *Associate Member.*

John McCrate, 14, Levenford Place, Dumbarton.

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Members elected at a meeting of the Council held on Tuesday, July 17th, 1917:—

### *As Members.*

Addison Stanley Burdis, 6, South Avenue, Horton, South Shields.

William Frederick Eggington, 115, Manor Road, Wallasey, Cheshire.

Percy William Harley, Grove House, Woodlands, Hither Green, S.E.

William Charles Oliver, 1, Pennycomequick Villas, Plymouth.

Kemp A. Saunders, 58, Wanstead Park Avenue, Manor Park, E.

### *Associate-Member.*

Frederick Leslie Suter, 22, Devonshire Road, Bexhill-on-Sea.

## TRANSFERS.

### *From Associate-Member to Member.*

James B. Crossley, 6, Ifley Road, Hammersmith, W.

### *From Associate to Associate-Member.*

Ernest H. Jones, Hongham Lodge, Hongham, Dover.