INSTITUTE OF MARINE ENGINEERS,
INCORPORATED.

Patron: HIS MAJESTY THE KING.

SESSION 1926.

President: THE RIGHT HON. LORD KYLSANT, G.C.M.G.

VOLUME XXXVIII.

"Some Marine Researches and our Sea Fisheries."

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CHAIRMAN: THE HON. SECRETARY.

The subject of a Lantern Lecture given on March 30th, 1926, when ladies were invited.

The CHAIRMAN: We are greatly indebted to Mr. Ford for coming to give us a lecture to-night, illustrated by views, which will reveal to us much of what is generally unknown, and remind us of what we have seen washed up on the sea shore. We are glad to see that the subject is of interest to our lady friends and we welcome their presence.

Our sea fisheries present so many topics of general interest that in preparing a short non-technical lecture, one is tempted to pass over any subject which does not appear to be of obvious and direct practical application. But a great deal of valuable research work is being carried on at marine stations of this and other countries, which not only merits the closest attention of all those actively engaged in the commercial fisheries, but which could be made equally interesting to the layman.

Thus, a few years ago, our Ministry of Agriculture and Fisheries published a detailed and well-illustrated report* on a survey of the soils at the bottom of the southern part of the North Sea. Many samples had been taken, and each submitted to a careful process of sieving, settling, drying and weighing, until eventually it was separated into a number of distinct grades of texture. As a result of this tedious work it was possible to prepare charts showing the distributions of the various grades over the whole area, and also to give information concerning the water movements which had assisted in bringing about this distribution. I imagine that a reader would not find it difficult to sympathise with those practical men of the fishing industry who disapproved of the Ministry's policy in sanctioning this research as part of their programme of fisheries investigations. One critic bluntly suggested "that the Ministry's research trawler, instead of steaming thousands of miles collecting sand and mud, should be off looking for new fishing grounds." But was this collection of "sand and mud" entirely useless? We shall, I think, be able to answer this important question when we have considered a second line of research.

During the years 1872-76 when the *Challenger* was engaged on her great ocean expeditions, much use was made of the "naturalists' dredge" for collecting the smaller animals inhabiting the sea bottom. This instrument is, admittedly, not very efficient. Professor Jungerson has been credited with the amusing statement that "a dredging ship may be compared with an airship towing a dredge over Copenhagen, catching a policeman in one street and a perambulator in another; and from these drawing conclusions as to the whole population of the town!" More recently, Dr. Petersen of Copenhagen, devised an instrument which, on being let down open, automatically closed when it reached the sea bottom, taking an effective "bite" of known area, and enclosing the soil with its contained animal life. This bottom sampler or "grab" has been extensively used at Plymouth with most instructive results. In the first place, the work has shown that there is a marked association between the characters of the bottom soil and the animal population. For example, the animals which flourish in black mud are very different from those to be found in shelly gravel. This association is so clear at Plymouth that if we were shown a sample of soil from the bottom

*J. O. Borley. "The Marine Deposits of the Southern North Sea." Ministry of Agriculture and Fisheries. Fisheries Investigations, Series II., Vol. IV., No. 6, 1923.

somewhere within the district, we should be able to state with some confidence the general " make-up " of the animal population likely to be found in it. But many of these bottom animals form a vital part of the food supply of marketable fishes, so that we might be able to proceed one step farther, and express an opinion as to the fishes which would be likely to frequent or visit the ground from which the soil-sample had been taken.

If we now return to our consideration of the Southern North Sea bottom-survey we can understand that it is really a first step towards an evaluation of the productivity of fish food in that important area, for on the ground plan of soils there can ultimately be superimposed the distribution of the food animals; those regions where food is most abundant will obviously be profitable fishing grounds. In other words then, a sound method of prospecting for new fishing grounds is by " steaming to collect sand and mud."

Some two or three years ago Mr. Davis* of the scientific staff at the Ministry's Fisheries' Laboratory at Lowestoft, studied the animal population of the Dogger Bank in the Southern North Sea. His estimations by means of the " grab " revealed the fact that certain shell fish abounded there in amazing numbers. To deal with but one species, which is of especial value to plaice, as food, Davis located a single patch which covered an area of 700 square miles, and at one position within it there were over 8,000 individuals to the square metre (say 1 sq. yard). The total number of individuals in this patch was estimated to be about 4½ millions of millions. The occurrence of these shell fish in distinct " patches " forms another interesting and important study. To understand them we need to remember that the newly-born young of these molluscs are tiny free-swimming larvæ which are almost entirely at the mercy of the prevailing water currents at the time of their release. At a later stage the larvæ settle down as " spat " on the sea bottom to grow into the familiar adult form caught in the " grab." But, as we have already seen, the soil upon which they settle is of the utmost importance, for they can only survive and thrive under favourable soil conditions. Supposing then, that a brood of larvæ are produced from a patch "A" of adults, and that in one year the prevailing currents have carried the larvæ to a ground on which spat can successfully settle, a new patch "B"

*F. M. Davis. "Quantitative Studies on the Fauna of the Sea Bottom." Ministry of Agriculture and Fisheries. Fisheries Investigations, Series II., Vol. VI., No. 2, 1923, and Vol. VIII., No. 4, 1925.

from year to year may therefore occur, which may be reflected in the yield of the sea fisheries.

These results of Davis' work form an interesting sequel to some earlier experiments in transplanting small living plaice from the "nursery grounds" along the Dutch and Danish coasts, to the Dogger. The young fish were carried in sea-water tanks, and after being measured and carefully marked with numbered identity discs were liberated in the new surroundings. A reward, in addition to the current market value of the fish, was paid for those subsequently recaptured and returned to the Ministry. In describing the results of these experiments, Dr. Allen* tells us that fishes liberated in May which were small undersized fish of little market value, had become by the following autumn fine plaice of good size and in excellent condition. Taking the figures for say the following January: whereas the fish that remained on the Danish nursery ground had doubled their weight, those carried to and put out on the Dogger had become five times as heavy as they were originally. Now since well-grown plaice command a much higher price per 1 lb. than small ones, this increase of weight means that the value had increased to perhaps seven times the original value.

We have seen that, as the bottom-sampler always takes the same area of bite, we can use this instument to obtain estimates of the density of bottom population. If, then, we go to the same ground regularly over a period of time, we shall be able to discover what changes, if any, are in progress. We may learn that a process of reduction in the numbers of certain species is occurring, and make that our particular study. Thus, a Russian observer, Tchugunov, found that in one part of the Caspian Sea at a certain time in the year, the flood water from the Volga was largely responsible for a heavy mortality of a species of cockle living there. Or again, on one of the fishing grounds at Brixham (Devon), a ground richly stocked with flat fish food is periodically and suddenly invaded by starfishes, which prey heavily on the fish food. We may, however, elect to watch the increase in size and weight of the food animals during a lengthy period, and this aspect of the case is equally profitable. Thus we find that some shell fish grow very rapidly during their first year of life, and soon reach a size beyond which they are of little use to fishes as food, while others never attain a large size and remain "serviceable" food for fishes

*E. J. Allen. "The Age of Fishes and the rate at which they grow." Journal of the Marine Biological Association. Vol. XI., No. 3, 1917.

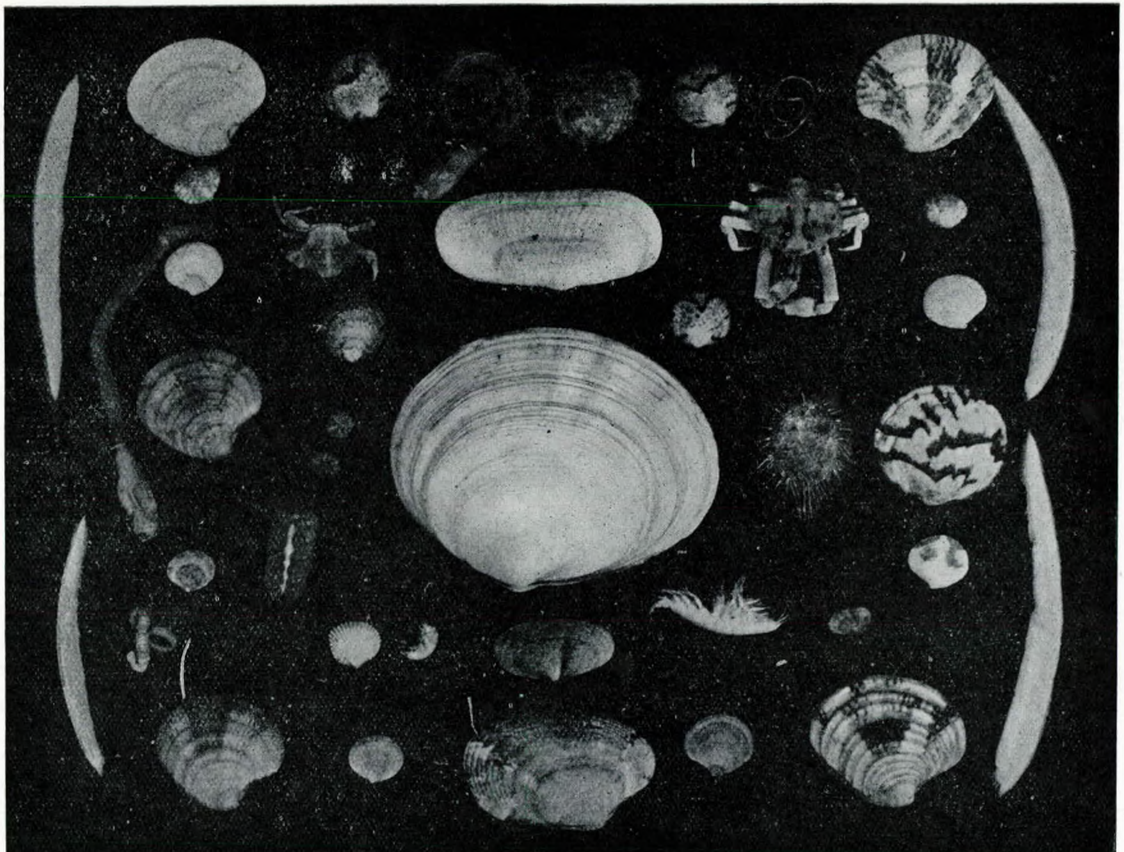

Fig. 3.—Photograph showing the number of animals per 1-10th sq. metre of ground near the Eddystone Lighthouse, on January 25th, 1923. The soil was clean shelly gravel.

all their days. We also find that many shell fish in common with numerous other marine animals, grow very rapidly during the summer months, but change very little during the winter; and as a result of this differential growth a clear mark or "winter-ring" is produced on the shell which is an index of age. (See Figs. 2 and 3*). It is only by combining all the data from these different observations that a really sound picture of the productivity of fish food for different grounds can be obtained. As an instance of this, we may survey the results of repeated visits to a small area in the Plymouth district. Here, during the spring of the year 1922, a large new brood of the small shell-fish *Syndosmya alba* (see fig. 2) was located. In the

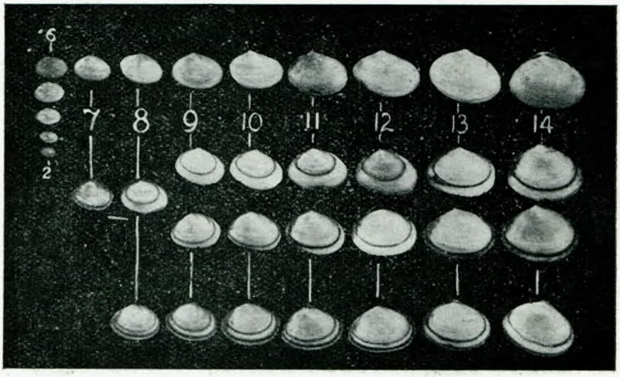

Fig. 4.—Photograph of shells of *Syndosmy a alba* from Bigbury Bay. Top row without winter ring, middle rows with one winter ring, and bottom row with two winter rings.

spring of 1923, the individuals of this brood showed one winter ring, and they still formed the bulk of the food on the ground, although there was a certain percentage of a new brood for the year 1923. In the spring of 1924 the same 1922 brood predominated, although now of course they exhibited two winter rings. The actual numbers, however, had been much reduced owing chiefly to a heavy death-rate during the two winters. In 1925 practically all the 1922 stock had gone, and unfortunately no new brood for either 1923, 1924 or early 1925 had arisen and thrived to keep up the supply. Here, then, is a case of a feeding ground which for two years depended for its richness on one brood, but which had, after that time, become

*The figures in the text were reproduced from blocks kindly lent by the Marine Biological Association.

practically barren of fish food because no new broods had been able to survive and take the place of the steadily diminishing original population.

The story might be continued almost indefinitely by discussing the many additional problems arising from the study of the fish food animals when they are still in the young free-swimming stage. These too, have their "enemies," and they are also susceptible to changes in such physical conditions as temperature and salinity. Perhaps one of the most interesting studies is that of determining their distribution from the surface to the bottom during the hours of daylight and dark. Moreover many young fishes eat them, including the young of the herring. It is hoped, however, that sufficient has now been said to convince the reader of the immense importance of detailed and continuous observation on such subjects as have been mentioned. It is not always wise to discourage work which at first sight appears to be "academic" rather than "practical."

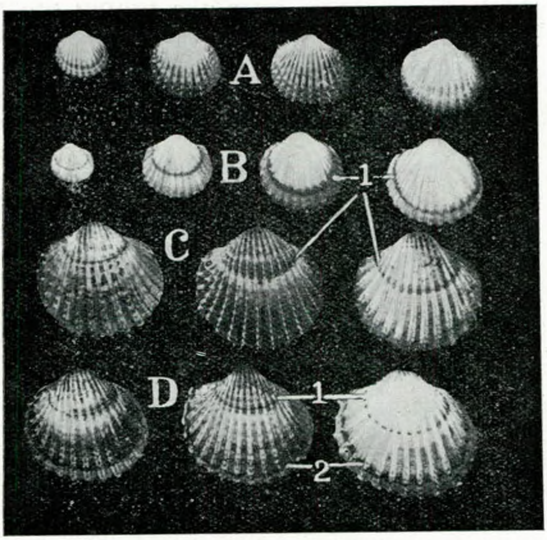

Fig. 5.—Photograph of shells of *Cardium echinatum* from Bigbury Bay.
A. Specimens without winter ring. Autumn 1922.
B. Specimens with one winter ring. May, 1923.
C. ,, ,, ,, January, 1924.
D. ,, two ,, May, 1924.

Mr. Thorburn expressed his appreciative thoughts regarding the lecture, which had been listened to with pleasure and had revealed many intricate and interesting problems connected with the depths of the sea, and he proposed a vote of thanks to the lecturer.

Mr. F. O. Beckett in seconding, agreed that pleasure and information had been imparted. It was good for the mind to be led below the surface of things and examine into the depths. It occurred to him that the sea and currents around the Dogger Bank might have influences upon the fishing grounds. The work of the research station was of great practical value to all.

The vote of thanks was carried with acclamation.

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Bearing Metals.

By W. T. GRIFFITHS, M.Sc., F.I.C., A.Inst.P.

READ

Tuesday, April 20, at 6.30 p.m.

CHAIRMAN: MR. W. E. FARENDEN (Member of Council).

THE subject of the so-called Bearing or Antifriction Metals is one which merits the attention of both the engineer and the metallurgist. These alloys are worthy of study by the former because of their influence upon the efficient and economical running of all mechanical plant and by the latter because of the interesting metallurgical problems involved in the production, in the bearing, of a material which is best suited to the engineer's needs. The object of this paper is to summarise the existing metallurgical information on the subject, hoping thus, if possible, to add to the interest of the members of the Institute in these useful alloys.

It now seems fairly well established that a desirable material for bearing purposes should be composed essentially of two constituents, one in the form of hard grains which make up the actual bearing surface, and the other of a softer, more plastic nature which, by reason of its deformation or rapid wear, enables a uniform distribution of the load to take place over the bearing. Experience shows that a single, homogeneous metal or alloy is not of general utility, for if hard enough to give a reasonable resistance to wear and a low coefficient of friction, it lacks sufficient plasticity to allow the self-adjustment of a shaft or journal when the alignment is imperfect. This results in the load being supported entirely by a few small areas with a consequence that the oil film may be broken continually, and intense local heating and possible seizing and scoring of the journal takes place.

Of recent years attention has also been drawn to the possibility that, even when the alignment is originally perfect the duplex structure of constituents of differing hardness may have an advantage over a homogeneous material in assisting in the efficient lubrication of the bearing. This is referred to later.

In addition to its ability to resist wear, to adapt itself to the journal and to keep down frictional losses there are a number of other properties which have to be considered in selecting a bearing metal for a particular purpose. Thus it is necessary that the alloy as a whole should have sufficient compressive strength at the temperature of running of the bearing to withstand the load put upon it. It must not be brittle and in certain cases must be able to stand up to considerable "pounding." It must not cause excessive wear of the journal, and must be capable of being "worked" with comparative ease. Its melting point is of importance because, if this is too low, accidental momentary heating of the bearing may cause serious trouble, while if it is high, casting difficulties tend to increase. High thermal conductivity is beneficial in assisting cool running while the capability of being remelted repeatedly without deterioration is convenient and economical. Excessive shrinkage during solidification is objectionable in a white bearing metal, as it tends to cause separation of the liner and shell with a consequent lack of rigidity and increase of resistance to heat conduction. Lastly the question of cost is naturally one of importance.

All these properties are mainly dependent on two factors. These are, firstly, the chemical composition, which determines the nature of the constituents present, and secondly, the microstructure or arrangement of these constituents. It must be pointed out that it is the microstructure of the alloy *in the bearing* that is important and this is determined to a very large extent by the casting practice when preparing the bearing. In considering these two factors the information afforded by microscopical examination is of the greatest assistance, as by this means the effect of these variables on the nature and arrangement of the constituents may be observed.

Tin, lead, copper, antimony, zinc, nickel and other metals are used in making the various bearing metals, but the most used alloys fall principally into three groups, the tin-base, the lead-base, and the copper-base alloys, the groups containing tin, lead and copper respectively as predominant metals. The first two belong to the wider class of alloys known as "white metals," while the third are for the most part among the so-called "bronzes."

Tin-Base Alloys.

If a little copper is added to tin, provided there is more than one per cent. present, the microscope shows that the resulting alloy is composed of two constituents. One of these, which is present in the form of needle-like crystals, is a compound of tin and copper * containing about 60 per cent. tin. The remainder of the alloy, which forms a matrix in which the needles are buried, is an intimate (eutectic) mixture of tin with a little of the copper-tin compound (See Fig. 1). The needles are sometimes arranged in a star-shaped formation and Fig. 2 shows a beautiful specimen of one of these crystals obtained under special conditions.

If, alternatively, we add antimony to tin, while the antimony content is below seven per cent., only one constituent, a solid solution is obtained. When more than seven per cent. antimony is present, cubic crystals of a compound of antimony and tin (Sb Sn) appear, and the alloys consist of a mixture of these and the solid solution.

Now, since the compounds in both the above cases are harder than the surrounding matrix, these alloys might conceivably be used as bearing metals. There are, however, certain disadvantages in doing this, and what is actually done in practice is to add both copper and antimony to the tin. It is found that the metals act very similarly when the three are present together, as they do above in pairs. When the antimony is below about seven per cent. the alloy consists of the comparatively hard needle-like crystals of the copper-tin compound embedded in a softer matrix, which is a mixture of this compound with the antimony-tin solid solution and some tin. Where considerable toughness is required, an alloy of this type is often used. One such has a composition:—

Tin, 93%; Antimony, 3·5%; Copper, 3·5%.

*It is not yet certain whether this so-called ϵ constituent is correctly termed a compound, but this designation is used here for convenience.

Fig. 1.
Copper-tin Alloy.
Copper 10 per cent. Tin 90 per cent.

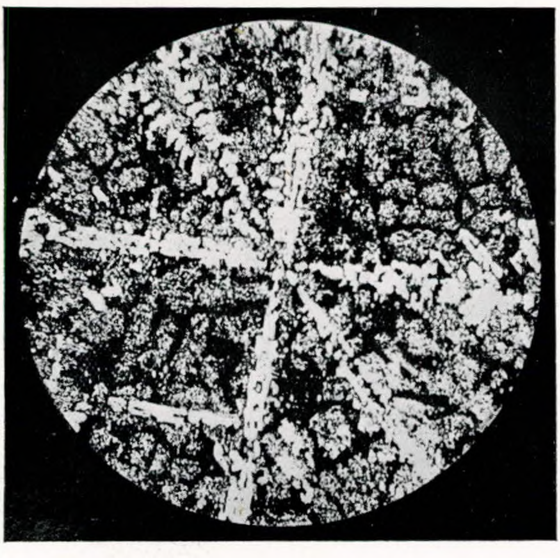
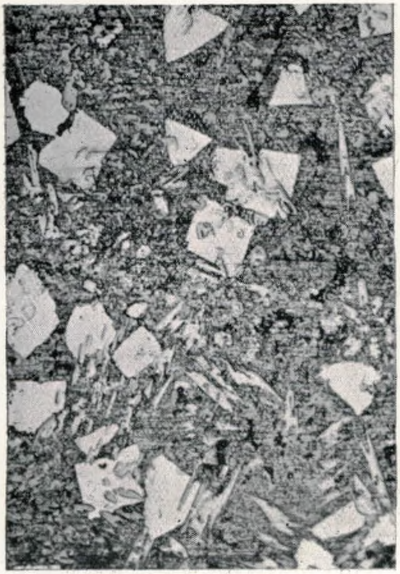


Fig. 2.

The magnification in all the illustrations is 100.

Fig. 3.



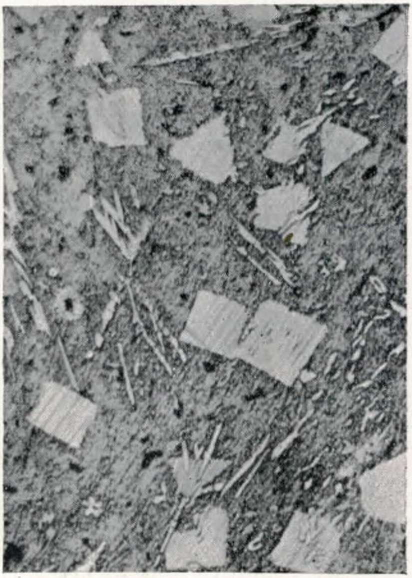


Fig. 4.

Fig. 5.

The magnification in all the illustrations is 100.

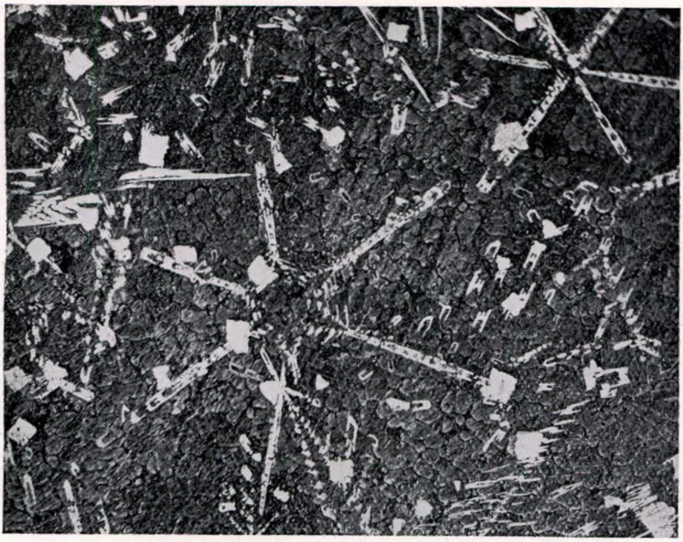


Fig. 6.
Tin-Base Bearing Metal.
Containing 14-15 per cent. lead.

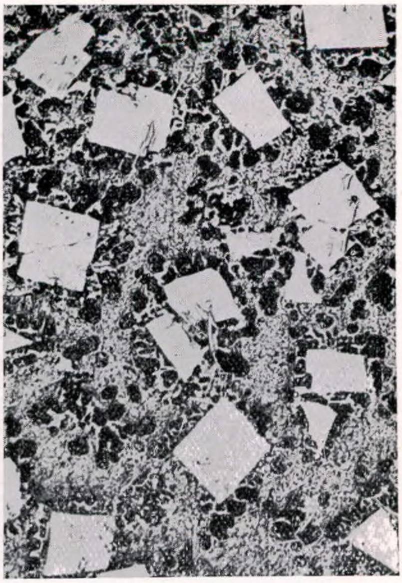


Fig. 7.

Fig. 8

The magnification in all the illustrations is 100.

TABLE 1.

Physical Properties of Some White Metal Bearing Alloys [1]

(Mundey, Bissett & Cartland—J. Inst. Metals, 1922, XXIII, p. 141.)

Alloy No.	Composition.				Tensile Test[2]		Brinell Hardness Number 10 m.m. Ball. 500 k.g. load.	Compression Test[3]	
	Sn.	Sb.	Cu.	Pb.	Ultimate Strength. Tons per sq. in.	Elongation per cent. on 2 cm. Tons per sq. in.		Yield Point. Tons per sq. in.	Compressed to Half Length. Tons per sq. in.
1	93·0	3·5	3·5	—	5·12	11·6	24·9	3·569	14·732
2	86·0	10·5	3·5	—	6·65	7·1	33·3	4·372	17·232
3	78·0	11·0	11·0	—	6·36	None	37·0	4·550	17·856
4	83·0	10·5	2·5	4·0	5·60	None	34·5	4·284	17·640
5	80·0	11·0	3·0	6·0	5·70	None	32·1	4·640	17·500
6	60·0	10·0	1·5	28·5	5·04	None	27·1	3·696	12·856
7	40·0	10·0	1·5	48·5	4·58	None	21·8	3·660	11·284
8	20·0	15·0	1·5	63·5	5·48	None	31·3	4·016	12·212
9	5·0	15·0	—	80·0	4·69	2·8	24·9	3·59	13·356

[1] Test pieces cast into cast iron stick moulds. Casting temperature 350° C. Mould temperature 100° C. approx.

[2] Acting portion of test piece 0·564 in. in diameter and length 2 ins.

[3] Compression test pieces were cylinders 0·564 in. diam. × 0·5 in. high. Yield Point taken as load producing permanent deformation of 0·001 in.

used for repair work. Fig. 5 shows the microstructure of a similar alloy containing a little less copper. The effect of the high copper content is to extend the temperature range between the first separation of crystals and complete solidification. During this period the alloy, being a mixture of solid and liquid, is in a " pasty " condition and can be moulded to any required shape.

The white bearing metals of high tin content which have been referred to above, are much used where a combination of hardness and toughness is needed and where the bronzes mentioned below are not suitable, as, for example, in certain thrust and step bearings. Owing, however, to the high price of tin these alloys are subject to the disability of high initial cost. For this reason early efforts were made to replace some of the tin with much cheaper metal lead.

Lead forms no compounds or solid solutions with the tin, antimony or copper of these alloys, and so exists in the cast metal either as globules of lead or as part of the intimate eutectic mixture forming the matrix (Figs. 6 and 8). With the addition of lead the hardness falls, though the effect is not marked until a considerable percentage of the tin is replaced.

Table 3, taken from a paper by Smith and Humphries*, shows the effect of adding increasing amounts of lead to an alloy of composition:—

Tin, 83%; Antimony, 11%; Copper, 6·0%.

The percentages of lead are not stated, but increase progressively from alloy F.D.S. to alloy M.B. though " even in the alloy poorest in tin a very substantial percentage of that metal is present." Mundey and his collaborators* point out that the addition of lead, even in small quantities, results in an entire loss of elongation, but this does not appear to be detrimental. Results of tests on alloys of this type, taken from their paper are shown in Table 1, Nos. 4, 5 and 6. Babbitt metals containing between 10 and 20 per cent. lead are much used in marine engineering work. (See Fig. 6).

Lead is said to add to the antifrictional qualities of a bearing metal, presumably owing to the increased difference in hardness, which its addition entails, between the hard bearing grains

* C. A. M. Smith and H. J. Humphries, " Some Tests on White Anti-friction Bearing Metals," J. Inst. Met. 1911, V, p. 194.

* A. H. Mundey, C. C. Bissett and J. Cartland, " White Metals," J. Inst. Metals, 1922, xxviii., p. 141.

TABLE 2.

Composition and Physical Properties of A.S.T.M. Tentative Standard White Metal Bearing Alloys.[1]
(Am. Soc. Test Mat. Tentative Standards 1924, p 94).

Alloy No.	Composition[2]				Yield Pt.[3] tons/sq. in.		Ultimate strength[4] tons/sq. in.		Brinell Hardness[5]		Melting Point		Temperature of complete liquefaction.		Proper Pouring Temperature	
	Sn.	Sb.	Cu.	Pb.	At 20°C.	At 100°C	At 20°C	At 100°C	At 20°C	At 100°C	°F	°C	°F	°C	°F	°C
1	90·9	4·52	4·56	—	1·97	1·18	5.74	3·13	17·0	8·0	433	233	—	—	825	441
2	890	7·4	3·1	0·03	2·73	1·34	6·65	3·89	24·5	12·0	466	241	669	354	795	424
3	83·4	8·2	8·3	0·03	2·95	1·41	7·86	4·42	27·0	14·5	464	240	792	422	915	491
4	75·0	11·6	3·0	10·2	2·48	0·96	7·20	3·08	24·5	12·0	363	184	583	306	710	377
5	65·5	14·1	2·0	18·2	2·24	0·96	6·72	3·01	22·5	10·0	358	181	565	296	690	366
6	19·8	14·6	1·5	63·7	1·70	0·93	6·50	2·70	21·0	10·5	358	181	531	277	655	346
7	10·0	14·5	0·11	75·0	1·59	0·72	7·00	2·75	22·5	10·5	464	240	514	268	640	338
8	5·2	14·9	0·14	79·4	1·52	0·78	6·98	2·75	20·0	9·5	459	237	522	272	645	341
9	5·0	9·9	0·06	84·6	1·52	0·69	6·53	2·61	19·0	8·5	459	237	493	256	620	327
10	2·05	15·7	0·12	82·0	1·50	0·82	6·90	2·57	17·5	9·0	468	242	507	264	630	332
11	0·09	14·8	0·19	84·7	1·36	0·63	5·73	2·28	15·0	7·0	471	244	504	262	630	332
12	0·11	2·9	0·12	89·4	1·25	0·56	5·75	2·28	14.5	6·5	473	245	498	259	625	329

[1] The Compression Test pieces were cylinders 1½in. in length, ½in. diameter, machined from chill castings 2in. in length and ¾in. diameter. The Brinell Test was made on bottom face of parallel machined specimen cast in a 2in. diameter x ⅝in. deep steel mould at room temperature.

[2] The Compositions given are those of the actual alloys used. They approximate very closely to the A.S.T.M. Tentative Standard Specification.

[3] The values for the Yield Point were taken from stress-strain curves at a deformation of 0'125 per cent. reduction of Gauge length.

[4] The Ultimate Strength values were taken as the unit load necessary to produce a deformation of 25 per cent. of length of specimen.

[5] Values are average Brinell number of three impressions on each alloy using 10m.m. ball and 500 kg. load applied for 30 seconds.

and the matrix. The principal difficulty which arises from its use is in the increased care which is necessary in the preparation of the bearing, as shown below.

Zinc is occasionally added to tin-base alloys, sometimes in considerable amounts. It is said to be advantageous where resistance to corrosion is needed and one alloy recommended for such positions as stern tube bearings has a composition of: Tin, 70 per cent.; Zinc, 27 per cent.; Antimony, 2 per cent.; Copper, 1 per cent.

Nickel is also present sometimes, but the advantage of its addition is doubtful. In fact, some tests by Mundey and Bissett† appeared to show that its effect was distinctly deleterious.

TABLE 3.

(Smith and Humphries—J.Inst.Met. 1911, v, p. 194.)

Material.	Compression.		Tension. Stress in Tons per Sq. In. at Fracture.	Brinell Hardness-Number. Load 508 Kgs.	Bending.		Impact. Energy used per Sq. In. Foot-lbs
	Stress. Tons per Sq. In.	Strain Per Cent.			Stress. Tons per Sq. In.	Distortion. In.	
F.D.S.	5·978	1·45	5·00	30·8	8·60	0·33	2·99
A.M.A.	5·943	0·66	5·86	30·1	8·48	0·29	3·48
T.X.S., A.1 ...	5·878	3·12	5·64	22·3	7·93	0·50	2·42
T.X.S.	5·982	4·07	5·32	20·5	7·13	0·57	1·89
M.B.	5·839	30·63	4·34	17·2	6·34	0·68	1·94

Lead-Base Alloys.

The replacement of tin by lead in the tin-base bearing metals finally resulted in a series of alloys in which lead was the principal metal.

The lead-base alloys usually contain between 10 and 15 per cent. of antimony either without or with varying amounts of tin. Copper is, in the majority of cases, kept below 0·5 per cent., but sometimes up to 1·5 per cent. is allowable when the tin content is high. In the absence of tin these bearing metals consist of cubic crystals of antimony in a matrix of antimony-lead eutectic. When tin is present the cubes of antimony are replaced by the less brittle cubic crystals of a solid solution of the antimony-tin compound (SbSn) in tin. Fig. 7 shows the structure of a lead-base alloy containing about 80 per cent. lead.

† A. H. Mundey and C. C. Bissett, "The Effect of Small Quantities of Nickel upon High Grade Bearing Metal," J. Inst. Metals, 1923, xxx., p. 115.

Alloys No. 6—12, Table 2, are typical lead-base bearing metals and some of the physical properties which might be expected from these are given.

Fig. 8 shows the microstructure of an alloy similar to No. 7, Table 1, which contains just a little more lead than tin. Alloys of this type are sometimes used for submerged bearings.

Opinions are very varied as to the relative advantages of tin-base and lead-base antifriction alloys. The lead-base are certainly softer and more easily deformed, while considerably more care is necessary in casting them owing to their higher viscosity in the molten state and the heaviness of the lead (see below). The higher fluidity of the tin-base alloys allows of a thinner liner being poured and thus greater support is given to the lining by the shell. In addition, alloys containing lead are more liable to pitting should the lubricant be at all alkaline. On the other hand lead-base bearing metals are said to have preferably antifriction properties and to wear better. It has also been widely stated, sometimes with experimental evidence*, that lead-base alloys retain their properties better at raised temperatures, but laboratory tests in the United States Bureau of Standards† have given an opposite result.

Taking everything into account, it may be stated that where high pressures and high speeds are co-existent or where any pounding action on the bearing surface is possible, tin-base bearing metals are preferably employed, but in many other cases the cheaper lead-base alloys may be equally well used, always providing the appropriate care is taken in making the bearing.

Mention must here be made of a type of lead-base bearing metal which was developed, under different names, in several countries during the late war, principally in order to avoid entirely the use of the then exceptionally scarce and expensive tin. In this case small quantities (usually less than 3 per cent.) of the alkaline earth metals, barium and calcium, are added alone or accompanied by antimony. It is claimed that this material gives better results than a high grade tin-base alloy. It has, however, to be prepared electrolytically and is liable to give considerable trouble in remelting owing to

* J. L. Jones "Babbitt and Babbitted Bearings," Trans. Amm. Inst. of Mining and Metallurgical Engs., 1919, Vol. IX., p. 458.

† F. R. Freeman and R. W. Woodward, "Some Properties of White Metal Bearing Alloys at Elevated Temperatures." Tech. Paper of U.S. Bureau of Standards, No. 188, 1921.

losses of the hardening constituents by oxidation, while the usual casting difficulties of lead-base alloys are pronounced.

Copper-Base Alloys.

Where the bearing metal has to stand up to very high pressures and heavy blows and especially where the normal temperature of running of the bearing is high, the white metals referred to above cannot always be used and in these circumstances alloys are employed in which copper is the principal metal. These are produced by adding tin, lead or zinc separately or together to the copper, while additions of phosphorus are often made.

Under ordinary conditions of casting, that is, without too slow a rate of cooling, a copper-tin alloy containing above 8 or 9 per cent. tin will show two constituents under the microscope (Figs. 9 and 10). One, forming the greater part of the material, is a solid solution (α constituent) and the other is an intimate (eutectoid) mixture of this α solution with a very hard, brittle, bluish grey compound (δ constituent). The increase of the tin content, which sometimes reaches 15·0 per cent., results in an increase in the amount of the δ constituent with a consequent rise in hardness and brittleness. The further addition of phosphorus, besides assisting in the production of a sounder casting, gives rise to the presence of another hard compound of phosphorous and copper.

The Admiralty specification for phosphor bronze for high-speed bearings stipulates 0·3—0·5 per cent. phosphorus, 90 per cent. copper and the rest tin. This should have an ultimate strength of 15 tons per square inch with 10 per cent. elongation. Similar compositions are used in the merchant service. Where specially hard bearing surfaces are needed the phosphorus is occasionally raised to 0·75 per. cent.

Although the copper-tin and copper-tin-phosphorus alloys make extremely useful bearing metals in certain circumstances, they suffer from a lack of plasticity and moreover, the harder constituents necessitate corresponding hardness in the journal in order to avoid scoring. With a view to increasing plasticity, additions of lead are made. In these lead bronzes the lead remains free just as in the white metals and is distributed more or less uniformly throughout the alloy in the form of minute globules. When lead is added the percentage of tin is often lowered to below eight per cent. so that the alloy simply consists of the copper-tin solid solution and lead. Fig. 11 shows the structure of one such alloy. The lead-containing bearing metals, known in some cases as "plastic bronzes," are cheaper, more easily worked and have a lower rate of wear than the lead-free alloys.

G. H. Clamer has made an exhaustive study of the effect of adding lead to bearing bronzes. A summary of some of his tests are given in Tables 4 and 5. Table 6 shows the properties which might be expected from some lead-bronze bearing metals adopted as standard by the American Society for Testing Materials.

Zinc is sometimes added to bronzes with the object of producing sounder castings, but since it goes into solution in the copper-tin solid solution, making it harder, it tends to affect adversely the antifrictional and mechanical properties.

Zinc sometimes replaces tin altogether, giving the cheaper "brasses," but in the case of these alloys the tensile strength and ductility is not high and their use is limited to light work only.

Nickel is also added to bronzes to increase soundness but it is doubtful whether its effect is thoroughly understood.

Effect of Casting on Microstructure.

The second factor upon which the satisfactory service of a bearing metal depends is its microstructure in the bearing. As stated above, this is almost completely controlled by the casting of the actual part and it cannot be too strongly emphasised that the most expensive, best quality antifriction alloy can have its properties seriously impaired by faulty casting practice.

The successful melting and casting of any alloy is dependent upon a number of factors. These are (1) the highest temperature reached by the molten metal, (2) the time during which the alloy is in the liquid condition, (3) the casting temperature and (4) the rate of cooling after pouring, this being determined partly by (3), partly by the volume of liquid and partly by the size and temperature of the mould (*i.e.*, the shell and mandrel). The effect of these variables, on the casting of a bearing metal has been carefully studied during the past few

TABLE 4.

Compressive Strength of Bronze Bearing Alloys (*G. H. Clamer*).

Chemical composition (per cent.)				Compressive proportional limit.		Compression under load of 100,000 lb./in.^{2} (70·3 kg/mm^2).	Chemical composition (per cent.)				Compressive proportional limit.		Compression under load of 100,000 lb./in.^{2} (70·3 kg/mm^2).
Cu	Sn	Pb	Zn	kg/mm^2	lb./in.^{2}	per cent.	Cu	Sn	Pb	Zn	kg/mm^2	lb./in.^{2}	per cent.
95	5	0	0	12·7	18,000	31	75	5	10	10	13·4	19,000	32
90	10	0	0	17·6	25,000	26	75	5	20	0	10·5	15,000	—
90	5	5	0	13·4	19,000	32	75	10	5	10	19·0	27,000	19·5
85	5	5	5	12·7	18,000	33	75	10	10	5	20·0	28,500	22
85	5	10	0	12·7	18,000	36	75	10	15	0	16·2	23,000	32
85	10	5	0	15·5	22,000	26	70	5	25	0	11·6	16,500	—
80	5	5	10	12·7	18,000	32	70	5	10	15	13·0	18,500	30
80	5	10	5	11·3	16,000	34	70	5	20	5	12·3	17,500	—
80	5	15	0	11·3	16,000	39	70	10	20	0	14·8	21,000	—
80	10	5	5	19·0	27,000	21	70	10	5	15	28·1	40,000	17
80	10	10	0	16·2	23,000	29	70	10	15	5	18·3	26,000	—
75	5	5	15	12·0	17,000	28	70	10	10	10	20·4	29,000	17
75	5	15	5	13·0	18,500	—	65	5	30	0	10·5	15,000	—

years and the results of these investigations may be summarised as follows:—

The principal danger in getting the liquid alloy too hot is in the oxidation of the metals. Besides lowering the content of the hardening metals, antimony and tin, oxidation may lead to the inclusion of oxides in the bearing. As some of these are extremely hard (tin oxide is stated to be harder than hardened steel) increased wear and scoring of the shaft, etc., may take place. Brittleness and poor adhesion to the shell may also result. These effects are, of course, enhanced by repeated remelting to too high a temperature. In addition to this, Hudson and Darley* have pointed out a further deleterious effect of high temperature on molten white metals containing copper. They conclude that there is a critical temperature for each alloy; cooling without stirring, from above this point, (stated to be about 50°C. above the temperature of the commencement of solidification) results in an increase in size of the hard needle-like crystals, with a consequent embrittling effect, while by keeping below the critical temperature a suitably fine structure is obtained. In case of slight accidental overheating *careful* stirring will obviate a great deal of the last effect.

TABLE 5.

WEARING TEST OF SOME BRONZE BEARING ALLOYS
(*G. H. Clamer*).

Total number of revolutions 100,000 (525 r.p.m.).

Pressure 1,000 lb/in² (0·70 kg/mm²).

Chemical Composition (per cent.)				Temperature.		Wear.	
Cu.	Sn.	Pb.	Zn.	°C.	°F.	gr.	g.
85·76	14·90	...	...	28	82	0·2800	0·0181
95·01	4·95	...	...	29	84	·0766	·0049
90·82	4·62	4·82	...	29	84	·0542	·0035
81·27	5·17	14·14	...	32	90	·0327	·0021
68·71	5·24	26·67	...	32	90	·0204	·0013
85·12	4·65	10·64	...	31	88	·0380	·0025
79·84	4·71	10·30	5·44	37	99	·0466	·0030
74·28	4·68	10·51	11·04	38	100	·0846	·0055

* O. F. Hudson and J. H. Darley, "The Constitution and Structure of Certain Tin-Antimony-Copper Alloys," J. Inst. Metals, 1920, xxiv., p. 361.

TABLE 6.

TABLE SHOWING PHYSICAL PROPERTIES OF BRONZE BEARING METAL ALLOYS.

(Proc. A.S.T.M. 1920, XX, p. 565).

Alloy No.	Desired Composition.					Ultimate tensile strength tons per sq. in[1].	Elongation in 2 in. per cent.[1]	Brinell Hardness (500 kg. for 30 sec.)	Compression Elastic limit tons per sq. in.[2]
	Copper per cent.	Tin per cent.	Lead per cent.	Zinc Max. per cent.	Phosphorus per cent.				
1	85	10	5	0·25	0·70	12·5	12·5	60	8·0
2	80	10	10	0·50	0·70	11·2	8	55	6·7
3	80	10	10	2·00	0·05	9·8	8	50	5·6
4	77	8	15	0·50	0·25	8·9	10	48	5·4
5	73	7	20	0·50	0.05	8·0	7	45	4·9
6	70	5	25	none	none	6·7	5	40	4·5

[1] The tension tests were made on "sand cast-to-size" test specimens.

[2] The compression tests were made on machined test specimens (sand castings) of 1 sq. in. sectional area, 1 in. high. The elastic limit is taken as the load producing a compression in the specimen of 0·001 in.

The time during which the alloy is molten has to be considered mainly because of the above-mentioned oxidation troubles but also because of the tendency of the heavier portions of the liquid, more particularly lead, to sink to the bottom of the pot or ladle with the result that the metal poured first, either from the top or bottom of the container, will be of a different composition from that for which the alloy was originally made up. Especially may this be the case where the filling of a large bearing or a number of small ones is being attempted and the metal cools in the ladle too near or past the start of solidification. These effects are also operative in the shell after pouring the metal and when solidification has commenced, so that, if complete solidification is delayed over long, one part of the bearing may become of quite different composition and structure from another. (See Fig. 12). For this reason, pouring, once started, should be completed as quickly as is consistent with care.

The best temperature of casting will depend largely on the composition of the alloy. It must be high enough to allow the whole bearing to be filled before the metal loses its liquidity and yet must not be so high as to give the objectionable effects noted above. The tin-base white metals have an advantage in in this respect, the more viscous lead alloys needing much more careful temperature control.

TABLE 7.

(C. H. Bierbaum, Trans. Am. Inst. of Min. and Met. 1923 p. 972).

Name of Substance.	Width of Microcut, Average.	Micro-hardness, Average.
Lead, c.p., Picher	37·7	7·03
Tin, c.p., electrolytic	29·3	11·7
Copper, c.p., Raritan	11·8	78·4
Antimony, commercial	9·1	121·0
SnSb crystal as found in Babbitt	6·9	208·0
Nickel, c.p., International Nickel Co.	6·4	244·0
PCu_3 crystal as found in phosphor bronze... ...	6·1	267·0
Iron, Swedish, softest crystal	4·8	420·0
Cobalt, c.p., International Nickel Co.	4·0	625·0
$SnCu_3$, or delta crystal in copper-tin bronze ...	3·6	750·0
$SnCu_4$, hardest crystal in high-Cu hardened babbitt	3·2	1006·0
Hardened steel—Johansson test blocks	2·2	2229·0
SnO_2 (fused) as found in burned bronze	1·4	5390·0

The rate of cooling during solidification is of extreme importance. It is controlled to some extent by the casting temperature, but is also considerably influenced by the temperature of the mould (shell and mandrel). Too rapid cooling results in the partial or complete prevention of the separation of the hard particles, these compounds remaining partly dissolved. Even where they do crystallise their size remains small. Too slow cooling, on the other hand, will cause excessive growth of the hard constituents and a general coarsening of the microstructure with a consequent embrittling of the alloy. Figs. 13 and 14 show the effect on the cubic crystals in a tin-base white metal and Figs. 15 and 16 demonstrate the coarsening of the structure which may result in a lead-containing alloy on cooling too slowly. Experience indicates that the cubes of the antimony-tin compound should have sides of about 0·05 mm. for best service.

In the case of the bronzes the rate of cooling must be such that the hard $\alpha + \delta$ eutectoid mixture is uniformly distributed, but yet does not form a continuous network, which is weakening. (See Figs. 9 and 10). The distribution of lead is of importance in these alloys also. Control of the microstructure of the bronzes is principally effected by means of the casting temperature.

There can be little doubt that, where it is possible, accurate temperature control by means of pyrometers is well worth while in the casting of bearing liners. Where, however, an occasional job only is done other means have to be adopted. The well-known method of determining casting temperature by means of the charring of a pine chip is useful when used with intelligence, keeping in mind the points mentioned above. Lead-containing white metals need to be poured at a lower temperature than the tin-base alloys and browning of the pine chip rather than excessive charring gives a correct indication. As regards the shell temperature, this will depend on its size and the amount of metal to be poured. For large bronze bearing shells 212°F. (boiling water) is suitable when pouring a white metal liner. With smaller shells a somewhat higher temperature is advisable. Steel shells usually need to be heated more than bronze. Care must be taken not to heat the metal to too high a temperature and to pour as soon as possible after reaching the correct point. Jolting of the bearing during the solidification period should be avoided*.

* It is suggested that it is worth while making a note of the conditions of lining each bearing and of the service obtained as a result. When the procedure that produces good service in any particular bearing is found it should be followed as closely as possible on future occasions.

Attention may be directed here to one detail of lining bearing shells, the beneficial effect of which is perhaps not as universally realised as it might be. This is the thorough cleaning and careful " tinning " of the shell before pouring in the white metal. If this is properly done (a 50:50 solder or the white metal itself may be used) the liner is held firmly to the shell over the whole bearing and distortion of the lining when it expands on heating may be avoided, while the metallic continuity improves heat conductivity and assists cool running.

One other practice which has been shown to affect the structure is that of hammering or " peening " the bearing after casting, with a view to bedding it more firmly in the shell recesses. This has been proved by microscopical examination to be distinctly harmful in some cases, resulting in the splitting up of the hard but brittle cubes and actually giving a softer surface†.

The Testing of Bearing Metals.

The question of an adequate test which may be applied to any particular material is of considerable importance to an engineer because it is the principal means available for judging the suitability of the material for the work for which it is required. Unfortunately, in the case of bearing alloys, especially the " white metals," no really satisfactory means of supplying this information by tests has yet been devised. One difficulty is that no single simple test can give easily interpreted data on all the properties required from an antifriction alloy. Another is that since it is the properties of the metal when in the bearing that are important, it is necessary that the test piece should have a somewhat similar microstructure to that of the alloy when in this position and the difficulties of reproduction in this respect will be obvious. For these reasons, standardisation has, up to the present, been practically impossible and it will be noticed how the details and types of test vary in the appended tables of results obtained by different authorities. The following observations on the various tests which have been applied, indicate the sort of information provided by the existing methods of testing.

Hardness.—Indentation tests of the type of Brinell's give some indication of the plasticity and tenacity of a bearing

† *See, e.g.*, H. E. Fry and W. Rosenhain, " Observations on a Typical Bearing Metal," J. Inst. Metals, 1919, xxii., p. 217.

metal. Owing to their simple nature they are also useful in a comparison of the properties of the alloy at ordinary and elevated temperatures. In applying these tests to soft alloys such as the white metals, the time of loading is important and should be stipulated. Increase of size of the impression may continue for as long as three minutes.

Tests of the Shore scleroscope type are sometimes used, but are not very satisfactory owing to the heterogeneous nature of the alloys.

Besides the hardness of the alloy as a whole the hardness of the various constituents is of importance. If the journal is softer than the harder grains in the bearing metal, scoring and rapid wear of the former is possible. A committee of the American Society of Mechanical Engineers have developed a scratch hardness test for determining the hardness of bearing metal constituents, and Table 7 shows some data so obtained. It will be noted that the copper-tin compounds are considerably harded than iron, and other results show them to be harder than 0·12 per cent. carbon steel, while the oxide of tin ($Sn\ O_2$) is twice as hard as hardened steel.

Tensile Test.—This, the most generally useful test to the engineer, is not of great value in connection with bearing metals, as they are rarely, if ever, stressed in tension. Percentage elongation and reduction of area may act as an indication of the plasticity of the alloy as a whole, but deductions from these have to be made with caution as, for example, in the case of the lead-containing alloys.

Compression Tests.—The compressive stress under which a bearing alloy begins to yield is of considerable importance, as is also that at which it will crack. Standardisation of the test is necessary, however, in order that comparison of results may be possible. Probably the simplest means of doing this in the case of the white metals would be the specification of the load necessary to diminish the length of a standard sized specimen by some given proportion (one-half, say).

Impact Test.—The impact properties may be important in the case of alloys used in positions where "pounding" occurs but cannot be said to be of general utility.

Lynch has devised a sort of combined impact and compression test which consists of dropping a weight on to a standard specimen for a given number of times and then examining the alloy. It is useful for comparison purposes.

None of the above tests, however, give information, except by somewhat doubtful inference, on the *Antifrictional Properties*, which are, of course, the most important of the characteristics of the alloys under discussion. Several machines have been devised for supplying this type of information. These mostly consist of a means for producing the rapid rotation of a journal in contact with a surface of the alloy, a known load being applied. Frictional losses are measured in various ways while the wear is determined either by weighing the specimen before and after the test or by measuring the impression made on a flat surface of the alloy by the rotating shaft. Even in this case, however, the value of the data obtained is still questionable owing to the large number of variables whose influence must be taken into account. The nature and method of supply of the lubricant and the temperature of operation are examples of the factors which are not easily controllable, while the necessity of running at high speeds in order to economise time may vitiate the results in some cases.

The *Spreading Power* of a lubricant is very largely affected by the metal and the nature of the surface with which it is in contact and a test for measuring this property has been devised by Dallwitz-Wegner*. Though this test should yield some interesting results, knowledge of the whole question of lubrication is as yet so meagre that it is quite uncertain how they will apply to the case of the oil film existing between a rotating journal and the bearing metal surface.

The importance of *Chemical Analysis* and *Microscopical Examination* will be obvious from the earlier portions of the paper. The question of the effect of impurities has only been touched upon but here also chemical and microscopical examination are invaluable in detection and control.

LUBRICATION.

Much might be written on the subject of the lubrication of bearings, but space forbids more than a short reference to the possible effect of the bearing alloy on the efficiency of the lubrication.

As mentioned above, it has been fairly widely stated that one of the principal, if not the chief, advantage of a bearing

* R. von Dallwitz-Wegner, "A Novel Simple, and Universal Method for the Investigation of Lubricating Oils and Bearing Alloys," Testing, 1924, i, p. 58

metal is in the beneficial effect which it may have on the preservation of the oil film in the bearing. In fact, the American Society of Mechanical Engineers goes so far as to define a bearing metal as " an alloy that is capable of retaining a lubricant on a bearing surface." The supposition is that the wearing away of the softer constituent results in the production of minute channels through which the oil is conveyed by something akin to capillarity.

Recent work on oil films would seem to enhance the reasonableness of this view. It has been shown that where the pressure is greatest the oil film consists of very few molecules (sometimes only two) and that the viscosity of the oil increases enormously as the film thickness decreases. It would therefore seem feasible that the mending of a broken oil film would be least easily accomplished where two perfectly smooth surfaces bear on one another, for here the area covered by the thinnest part of the oil film would be greatest. In the case of the roughened surface of a bearing metal, however, the areas of thinnest film thickness are small and are surrounded by channels in which the film is thicker and the viscosity therefore less. There appears to be little definite evidence for the above hypothesis except that it is well known that oil often spreads (upward) more easily on a rough surface than on a smooth one.

Another possibility arises out of the deduction that an " oily " surface is produced by an attachment (probably chemical) of one end of the molecular chains of the lubricant to the face of the metal. It would seem that, if this is so, adhesion of the film might be greater in the case of certain combinations of lubricant and metal than in others. The importance of these finer distinctions does not appear to be considered great at present, but it seems possible that, if speeds increase very greatly beyond what they are at present, questions of this kind may need investigation.

In conclusion it may be stated that before much further work on the metallurgical side of the question of bearing metals is possible two things are necessary. The whole problem of the testing of these alloys requires attention with a view to obtaining, if possible, some simple tests which may be standardised, while a fuller knowledge of the mechanism of lubrication is urgently needed. The latter question is being actively attacked at present and further information should soon be available. In the meantime it is considered that the metallurgy of the bearing metals has reached a sufficiently advanced stage to be worthy of the engineer's serious attention so that the most suitable type of alloy might be chosen for each bearing position and that the best service be obtained from that alloy by the production of the most advantageous microstructure during the making of the bearing. It is hoped that the information in this paper may be of some assistance in this direction.

Finally, the author wishes to express his gratitude to Messrs. Fry's Metal Foundries, Ltd., to Messrs. The Eyre Smelting Co., Ltd., and to Messrs. J. Stone and Co., Ltd., for supplying a number of samples of their bearing metal products. He is particularly grateful to Mr. A. H. Mundey of the first-named firm and Mr. Wesley Lambert of the last-named, for their kindly interest and assistance in providing some of the illustrations. Thanks are also due to those of his colleagues at the Research Department, Woolwich, who help in the production of the remaining photo-micrographs.

DISCUSSION.

Mr. L. F. P. Sorge: With regard to the cooling out of the metals, one slide showed some portions of the metal termed a compound, and others composed of separate needles and cubes. I should like to know whether this compound is an actual mixture of the tin and copper in the form of a separate alloy, or whether the needles exist in the tin as a mixture; also whether, if the temperature is too high, and oxidation takes place, one method of overcoming this is by stirring?

I should have thought that oxidation would occur more readily as a result. As regards plastic metals, every time I have tried to use them, no matter how carefully, they have been short and brittle, and inclined to break.

As regards engineers not taking sufficient interest in alloys generally, I find that even in a ship going to various ports where stocks of well-known brands of white metals are carried, when shells are sent ashore to be filled they still come back faulty.

Mr. F. O. Beckett: I would like to thank Mr. Griffiths for his valuable paper. He has raised a number of points which I did not anticipate. On proof page 6 he states that he finds that bearings with an oil film on rough surfaces work better than those with smooth surfaces. I cannot quite agree with that statement, and would be glad if he would illustrate it further.

Maudslay, Watt and several others tried various experiments on bearing surfaces to ascertain the effects of smoothness of surface and otherwise, and of oils of different viscosities. In one experiment they tried leather as a bearing surface material.

As regards the hammering-up of bearings, there are many instances of bearings other than white metal being treated in this way. I notice that the author objects to the practice, owing to the needles being broken, but I understand that there is a commonly accepted idea that the pouring process hardens the surface before machining. The tinning of the shell casting is certainly important, and I think that the castings should first be pickled with acid. I heard of a rather serious explosion which occurred at Liverpool, due to impurities in a bearing shell casting when the white metal was poured into it. I have frequently been surprised at the large number of bearings which I have seen re-lined in various foreign ports; the most unusual of these jobs was a thrust block where there was a straight surface—owing, I suppose, to the heat generated and the position for ventilation being unsatisfactory.

The author suggested that engineers do not always interest themselves in bearings; I think that, as regards some of the old horse-shoe bearings, the shafts were much too small in diameter.

Mr. A. H. Mundey (Visitor): I would like to congratulate Mr. Griffiths on two points, firstly, for his courage in coming here to lecture marine engineers who know all about bearings, and who were dealing with bearings before Mr. Griffiths thought of them. The marine engineer is naturally interested in bearings and the way they behave.

Mr. Griffiths has treated the subject so thoroughly in this paper that he has not left a brother metallurgist much scope for discussion. I would like to emphasise one or two points, not because Mr. Griffiths has not mentioned them, but you will already have realised during the Author's illustrated explanation how much more there is in the paper than appears on a first reading.

The first point is with regard to the pouring of bearing metals, a subject about which I can speak from somewhat considerable experience. Usually the engineer does not trouble to attend personally to the heating-up of the metal—he leaves it to a donkeyman or even a boy, who makes the ladle hot enough to enable him to run the whole lot of bearings, possibly a dozen or more. Perhaps he finds he has made it a little too hot, so he lets it stand for a while, or maybe a piece of cold metal is put in to cool it. That causes local cooling and enormous segregation of those crystals mentioned by Mr. Griffiths. The man then pours a series of bearing liners and no two of them turn out alike because there is a continuously descending scale of temperatures, and he is consequently gradually getting less and less of the less fusible metal into each bearing. Finally he has a ladle lined with a sort of shell composed of very rich antimony metal, whereas he has been pouring out a different metal all along. You would find that the last of the metal varies very much from the metal in the original ingot.

Mr. Griffiths mentioned the oxidation due to overheating, and the hardness of the tin oxide, it being twice as hard as hardened steel. Tin oxide is what is popularly known as "putty powder." It is one of the very best polishing materials obtainable, and one would hardly choose such a material to be a constituent of a bearing metal, and spread about in it like currants in a pudding. The original ingot may have been the very best bearing metal possible, but it has been spoilt during the melting and pouring operations.

In the case of phosphor-bronze bearings, the phosphorus is added chiefly as a de-oxidiser, but it does not at all readily de-oxidise tin, or the tin oxides into the metallic condition, consequently it leaves the very undesirable constituents still in the bearing.

With regard to tests, we all want good tests, but none of us seem to get them. Many of us are continually trying to devise tests which will satisfy everybody, but we do not succeed, and after all, the general engineering practice is quite excellent for engineering materials. It is generally objected that the tests do not exactly reproduce service conditions. The ordinary critic does not concern himself with the tensile strength of a bearing metal, but rather as to whether he has a material which has been tried and proved to be good in actual service. Then he may carry out a number of tests upon it—tensile, Brinell, compression, microscopic and analytical examination, etc., resulting in a collection of information about a material which has already been proved to be satisfactory by experience extending over a long period. Then a specification is drawn up, and I am sure you will agree that that is the best way in which a specification should be drawn up. Such a specification does furnish information as to whether the material under inspection conforms to the physical, mechanical, and chemical properties as a thoroughly good one. We are everlastingly being attacked by a demand for tests which show immediate service conditions, and we cannot always give them. We try to do so, but it is not necessary in all cases.

As regards hardness, we do require hardness and homogeneity. I was once very severely trounced by some scientific men on this subject, and I am glad that experience is supporting the fact that it is the want of homogeneity in an alloy which causes it to present a satisfactory surface—(not really a rough surface, but a relatively rough surface)—the surface looks beautifully smooth under ordinary conditions, but when it is examined under a microscope with a magnification of 100 the mixed structure is manifest (the piece shown on the screen would be covered by one spot from an ordinary pencil).

One gentleman criticised plastic metals. I think he was much too young to have been in the lines during the Great War. I do not know how the artificers would have managed without that plastic metal. The thousand and one repair jobs that were carried out on the spot by means of that metal! I do not know how many marine engineers would like to go to sea without a supply of plastic metal. It is cast or used in such difficult circumstances sometimes that I do not think we should quarrel with the fact that it is just a little more brittle than one would desire.

Regarding the hammering of bearing surfaces, hammering is still carried out in the Royal Navy. Admiral Dixon wrote to me some time ago and said that perhaps my condemnation of the practice was right, but they were still going on with it! But it does seem that hammering results in the rivetting over of the little hard bits, and I think that Mr. Griffiths has shown that it does break down the surface; if you drive the metal down hard you are obviously breaking down the crystalline structure, which, as Mr. Griffiths points out, it is desirable to preserve.

One speaker referred to differences between the engineers and the designers, but are not the designers engineers? We metallurgists get blamed by the engineers, but surely the designers are engineers and very considerable metallurgists too. Some of us have been associated with the metallurgical education of some engineers, and we really cannot help feeling that the general maintenance and executive engineer should tackle the designer if he does not provide bearings of a desirable character.

With regard to pickling, this is obviously necessary if the shell is not clean. One would never think of filling a bearing without first removing any grease and dirt by means of soap and soda or something equally effective before pickling. I can quite understand an accident being caused due to careless pouring, as mentioned by Mr. Beckett. Bearings may happen to be left damp sometimes, and that is probably the most fruitful cause of accidents.

In conclusion, I am sure that Mr. Griffiths has dealt with a subject which is of great importance to the engineer.

Mr. F. O. Beckett: The last speaker advocated pouring the metal from the ladle or vessel in which it has been melted; I would like to ask whether he recommends that the metal should be poured so that it rises into the bearing, as I presume that this would ensure homogeneity.

Mr. L. F. P. Sorge: I should like to thank Mr. Mundey for his compliment to the marine engineer. One thing which he has said helps to smooth away some of our difficulties; I refer to his explanation of what occurs if a number of shells are filled while the metal is altering its consistency. He also spoke about the antimony cubes; I am not clear as to whether these should be small in number but of large size, or large in number and small in size.

Eng. Rear-Admiral W. M. Whayman: Could the author suggest the common method used for determining the pouring temperature of white metal? It has been greatly impressed upon engineers that one of the difficulties in the foundry is that of controlling the casting temperature. The engineer is interested in the best method of temperature control, whether it is by pyrometer or otherwise.

As regards the Admiralty practice, I am not sure that hammering is a universal custom. I think that the instructions state that a heavy hammer should not be used, so that in respect to that perhaps the Admiralty is wise. When once you have settled the material you are going to use, the temperature of pouring is an important point, but a still more important point is the method of pouring and being able to determine the temperature of pouring, so that the work may be carried out in the foundry with much more certainty than is obtainable by what might be called the rule of thumb method.

Mr. R. Morton: If it is not outside the scope of the present paper, I should like to ask whether there is any chemical explanation of the detrimental action which salt or salt water has upon a bearing, causing the metal to flake off. And if the presence of salt is absolutely unavoidable, is there any neutralising agent which will get rid of the salt?

Mr. W. Hamilton Martin: With reference to the testing of bearing metals, it is often necessary to obtain a comparative test of different alloys. It may be of interest to describe the method we adopted when we wished to compare quickly two bearing metals offered up, under identical running conditions as regards compression stresses, revolutions, vibrations, rubbing speed, contact surfaces, resultant friction and temperature under the same applied load to ultimate breakdown. Two blocks of the metals to be compared were carefully prepared and shaped alike, and then clamped round an available revolving shaft of, say, 2in. diameter by means of two bolts. The blocks did not fully envelop the shaft, their adjacent faces being about ⅛in. apart when clamped loosely on the shaft. The bolts were then gradually tightened on the blocks, which were both held stationary in a wooden frame while the shaft revolved. We thus found which of the two broke down first under practically identical running conditions. The simplicity of this method has much to commend it, and to my knowledge there is no scientific testing device in use to-day which would do better.

Mr. Mundey: Were the blocks lubricated?

Mr. Martin: Sometimes; at other times they were not.

The Author: I would like first to thank those gentlemen who have taken part in the discussion for their complimentary remarks, and Mr. Mundey in particular for his addition to the paper. In a paper of this kind, one has naturally had to abbreviate and condense a great deal, and I hope that, as Mr. Mundey has suggested, you will find that it contains more than is perhaps apparent on first reading.

I next wish to say that it was certainly not my intention to infer that marine engineers as a whole were not sufficiently interested in the question of bearings. In the majority of cases experience, perhaps "bitter," has taught them how to turn out good bearings. My aim has simply been to provide the metallurgical reasons for past success, with the added hope that perhaps the paper might elucidate some of those awkward small points which sometimes "make all the difference."

Mr. Sorge asked some questions concerning the nature of the compounds and solutions which occur in white metals. I must confess, as a research metallurgist who has closely followed all published information on the matter, that we still do not know quite what the so-called intermetallic compounds are and the precise ways in which they differ from the solid solutions. Especially is this difficulty noticeable when one is considering solutions of a compound in a metal. Certainly in compounds the atoms of the component metals appear to tend to arrange themselves in definite fixed groupings, while they are closer together than in any other form. The matter is exceedingly complex and cannot be dealt with in a few words. What is of importance is that the needle-like and cubic "compounds" existing in the white metals are harder than the material which surrounds them, this material itself being a mixture of two or more constituents.

Certainly, if much oxidation exists, the effect of stirring will be bad and great care will be necessary to avoid mixing the oxide into the metal. What was advocated in the paper was "careful" stirring in order to obviate, after "slight" overheating, the embrittling effect indicated by Hudson and Darley.

I think Mr. Mundey has dealt adequately with the question of "plastic metal." Plastic metal must, of necessity, be somewhat brittle because, in order to widen the solidification range, the hard and brittle constituents have to be increased.

In regard to the point concerning rough and smooth surfaces raised by Mr. Beckett, as has been pointed out, the term "rough" is purely comparative, the "roughness" in the case of the white metals being on a microscopical scale only. But although the surface may appear smooth to the touch and unaided sight, it is considered that there is a small but definite difference in level between the harder constituents and the softer, which is essential to good antifriction properties.

Concerning "hammering," it is usually assumed that this operation causes hardening of the surface, but it has been definitely proved by measurement that it actually produces softening.

With regard to pickling, I assumed that the shell surface would be cleaned as thoroughly as possible before "tinning" and pouring. Cases have come to my notice recently where this certainly has not been done, with the result that considerable bearing trouble and delay has been caused during a voyage.

Admiral Whayman raises the question of the best means of measuring pouring temperatures. Personally, I consider that, wherever possible, pyrometers should be used. Rule of thumb methods which rely upon the instinct or intuition of the workman, do, in a majority of cases, yield astonishingly good results. But, owing to the human factor, it might be questioned whether the best results are always obtained, and trouble is sure to arise sooner or later. Therefore, providing that sufficient attention is paid to the details of its application, such as necessary calibration and care in use, pyrometric control seems to me preferable.

Regarding the chemical action of salt, I have not much information on that subject. Salt can corrode bearing metals rapidly, the compounds thus formed resulting in the breakdown of the whole bearing. It is to avoid this that the alloys containing considerable quantities of zinc are used.

The comparative test mentioned by Mr. Martin is of interest. The great difficulty of all these wear tests is, as was pointed out, the necessity of being absolutely sure that one is really repeating the working conditions. We know so little about lubrication that we cannot be certain that the test is representative, even when the most elaborate precautions are taken. At the same time, tests such as that outlined by Mr. Martin have proved of use in certain cases and certainly represent the best we can do at present.

The CHAIRMAN: It is my privilege to ask you to join with me in according to Mr. Griffiths a very hearty vote of thanks for his paper. I would also like to thank Mr. Mundey for his contribution to the discussion. (Carried unanimously).

A New Form of Electric-Hydraulic Steering Gear.

By Dr. HELE-SHAW, F.R.S., and T. E. BEACHAM, B.Sc.

READ

On Tuesday, April 27, at 6.30 p.m.

CHAIRMAN: MR. A. H. MATHER (Member of Council).

About 15 years ago the first-mentioned of the two authors wrote, with Mr. Martineau, a paper* which was read before the Institution of Naval Architects on the results obtained with a new steering gear. This gear was of the electric hydraulic type in which advantage was taken of a new form of variable stroke rotary oil pump driven by an electric motor. The oil supplied under pressure by the pump was employed to operate one or other of two rams, each acting on the rudder head so as to move the rudder as required to port or starboard.

The novel feature of this electric hydraulic gear was the employment of the property in the pump of reversibility, so that a simple form of lever connected with the ordinary floating link of a rudder was part of the system by which the telemotor either varied the stroke of the pump or reversed the flow of oil. Among other points dealt with in the above paper was the sensitiveness of the new gear, and this fact was demonstrated by means of what were called "Lag" diagrams, which were obtained automatically by a special instrument devised for the purpose. Comparative results obtained of the new gear and the steam steering gear on the *Albion* afforded convincing evidence on this point.

The late Sir William White, who presided at the meeting, commenced one of the able speeches, for which he was famous, by saying "I have not the slightest doubt that this method of steering gear will be widely employed"; and pointed out that the previous electric steering gear of the *Albion* had been replaced by steam steering gear, which in turn was replaced by the electric-hydraulic gear.

The makers of this gear, Messrs. John Hastie and Co., Ltd., in a recent prospectus say: "When we first introduced it our chief difficulty was to persuade shipowners that it was as reliable as a steam steering gear, but its great success has now settled all doubts. There never was any question as to the saving in running cost and upkeep which can be effected by its use, and all our predictions have been fulfilled in actual practice."

* Steering-Gear Experiments on the Turbine Yacht "Albion": Inst. Naval Architects Apr. 7, 1911.

The makers go on to say that a number of sets have now been constantly at work for 10 years without the slightest hitch, and with very appreciable saving in the fuel bill of the ships in which they were installed.

The electric hydraulic system has been successfully adopted in the Merchant Service, not only for motor vessels but for steamships, and has also been fitted in most of the principal navies of the world. The foregoing remarks sufficiently indicate that the success of the hydraulic principle has been completely established, and the appreciative remarks not only of Sir William White but of other eminent naval architects who were present at the meeting, have been amply justified.

No matter what success an invention may have, experience is sure to lead the way to further improvement, and in the new steering gear which is shown to-night, although the electric-hydraulic ram system in conjunction with a variable stroke pump is not departed from, the following new features are adopted :—

(1) A new, and it is believed, greatly improved variable stroke pump.

(2) A control valve for obviating the necessity of reversing the pump itself.

(3) An automatic valve for preventing injurious shocks from the action of the waves causing any injury to the structure of the ship.

(1) The pump which was seen in operation by many members of the Institute at the Shipping, Engineering and Machinery Exhibition last year, operating deck winches and other appliances, was described and illustrated in various journals*. It is sufficient to say that this pump, although also of radial type with central valve, is an improvement on the original Hele-Shaw Pump in one or two important particulars of special moment in its application to steering gear. The chief of these is the fact that in place of the rotary cylindrical valve taking the thrust on the cylindrical surfaces, the valve of the new pump runs on roller bearings. Instead of the pressure necessitating two different metals such as steel and phosphor bronze (which have unequal expansion) to secure proper wearing action, the two parts can be made of the same metal (say cast iron) and thus very little clearance is necessary, assuring at all temperatures a minimum of leakage or slip. A point of the greatest

* Engineering, Oct. 16, 1925, Engineer, Dec. 18, 1925, Machinery Market, Jan. 29, 1926. Mechanical World, Feb. 5, 1926.

importance, however, is the fact that when the steering gear runs for a long period in the zero position, the danger of heating and abrasion of the cylindrical valve is entirely obviated. Thus it is not then necessary to arrange for leakage of oil (often considerable) to ensure lubrication. Another great improvement is in the greater silence of the new pump. The cause of the noise which is in the form of a disagreeable hum or buzzing sound in the old pump, which noise may be transmitted throughout the whole ship, has now been discovered, and it may be said to be entirely obviated owing to the form and construction of the new pump.

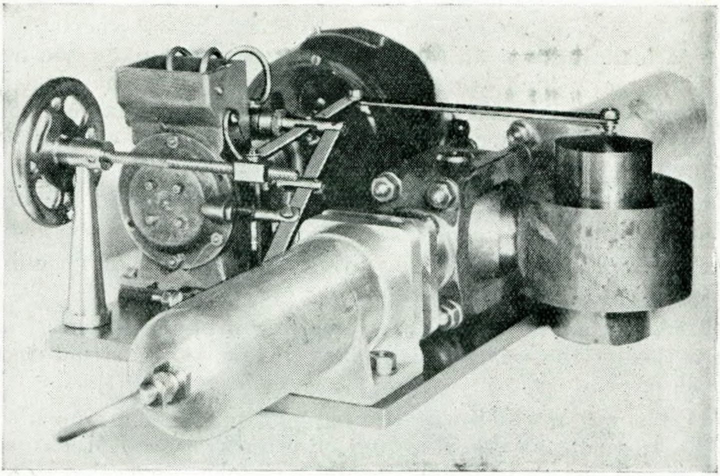


Fig. 1.

(2) The next point is the control valve. In the original system the rotary valve could not be made without a certain amount of leakage, as it rotated on its cylindrical axis; and the same is true of the new pump, although leakage has been considerably reduced. The introduction of a control valve which does not rotate but has merely a movement in the direction of its axis, enables a working fit to be obtained, resulting in almost complete absence of leakage. Incidentally this control valve obviates all necessity for reversing the pump itself, as its operation, which is perfectly simple, reverses the direction of flow and thereby effects the same result as the reversal of the pump.

Fig. 1 is a section of the control valve which is hollow. It will be easily seen that as the movement of the valves takes place from the central position shown in the figure, while the flow from the pump is always in the same direction before it reaches the valve, its flow from the valves to the two ports above

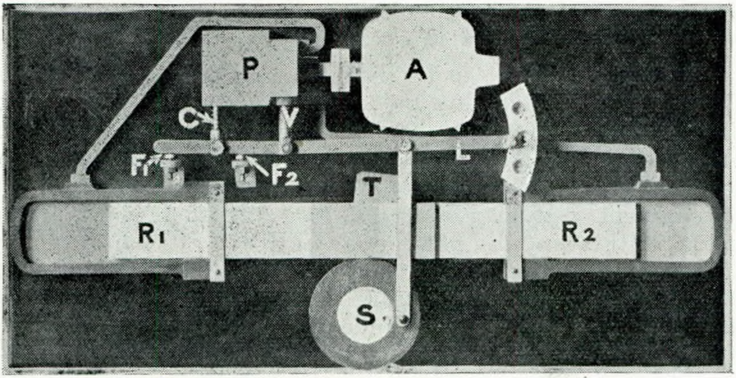


Fig. 2.—Model of a new form of Electric-Hydraulic Steering Gear.

the valve can be reversed. The way in which the stroke of the pump is varied to and fro by means of the pump spindle on one side of the zero position while the control valve is moved

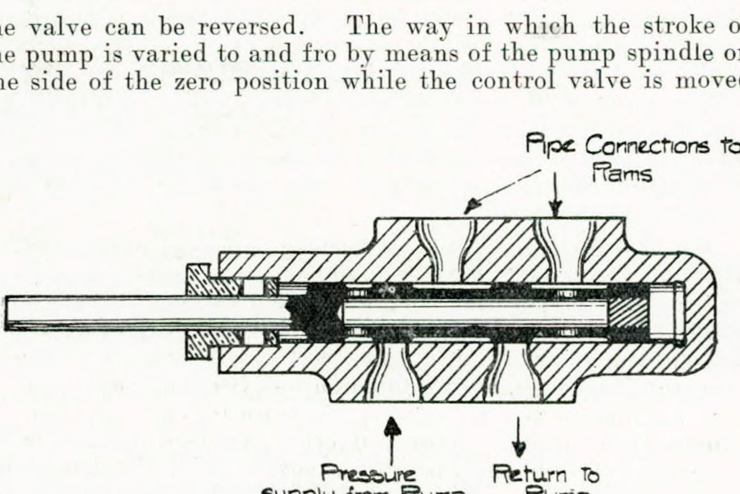


Fig. 3.

to and fro on opposite sides of the zero position is shown in Fig. 2. This figure represents a working model, A being the electric motor, P the pump, R_1R_2 the rams operating directly on the tiller T, and so producing the required movement of the rudder post S, L is the floating link, F_1F_2 the two fulcrums. It will be easily seen that the two fulcrums produce exactly opposite movements on the pump spindle and control valve spindle respectively. Fig. 3 is a general view of an actual steering gear which has been made for a motor yacht and will replace the hand steering gear now in operation.

(3) The last point to be dealt with is the valve by which shocks on the rudder are prevented from being communicated to the deck of the ship. The actual idea of employing such a valve is not by any means new, but the valve itself has novel features which it is impossible to describe in the limited time at our disposal. It may be stated, however, that whilst previous valves of this kind did not operate until the full hard over pressure was reached, the new valve is arranged to act when the rams by their reversed motion provide a pressure of less than half the maximum in the cylinders.

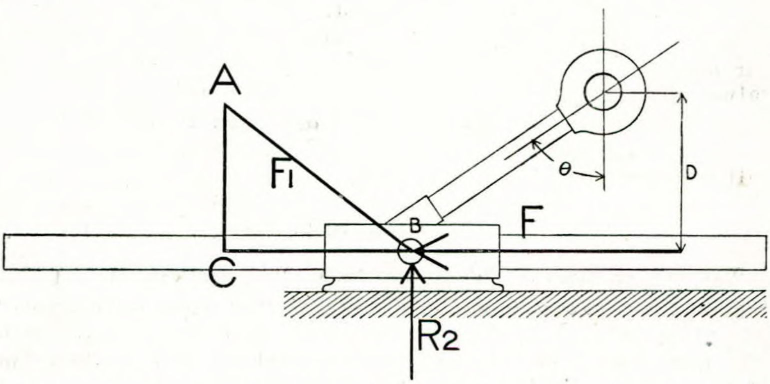
DISCUSSION.

The Chairman: I think we shall all agree that Dr. Hele-Shaw's remarks supplementary to the printed paper have greatly increased the value of the paper itself and the interest with which we have listened to it. His remarks on the construction of the pump were more by way of description, but the paper deals primarily with the steering gear. I think you will agree that the value is an excellent example of ingenious design in making one piece of apparatus perform two duties of equal value with equal efficiency.

Mr. W. McLaren: Referring to the leverage exerted by the tiller on the rudder head, I understood the author to say that the moment is constant. I am inclined to differ with him; I suggest that there is a change in the leverage as the rudder goes hard over.

As the gear stands, it is suitable for working from amidships; how does the author intend to operate it from the forward part of the ship? I note that he mentions the telemotor.

With regard to a ship in the Arctic regions, presumably the author has foreseen that difficulty and I suppose he intends to use glycerine as the working fluid? I was on one occasion voyaging from Stettin to Swinemunde and we had hydraulic steering gear. We used $CaCl_2$ to keep the water from freezing, but owing to the hurry to get under way, there was none put into the tank, and at the time scheduled for our departure, instead of being able to use the gear the hydraulic pipes to the steering gear were found to be bent and out of use, and we had to use the hand gear. I should think the temperature was about 10° below zero. I assume that such contingencies as that are provided for in this apparatus. I think the whole design of the gear is very simple, and that the action of the relief value is a great improvement. We know how severely rudder pintles suffer from time to time owing to the great stresses applied to them.



If the angle of the helm to midships position be θ and F the force of the ram, there will be a reaction R_2 at right angles to the ram. The total force on the tiller F_1 is the resultant of these two forces ABC being the triangle of forces so that $F_1 = \frac{F}{\cos\theta}$. The distance of the force F_1 from the rudder stock is $\frac{d.}{\cos\theta}$ so that the resulting movement on the stock is $\frac{Fd}{\cos^2\theta}$

Dr. Hele-Shaw: We propose to use the telemotor for distant control of this gear. It was a long time before the Admiralty would accept the telemotor for use in destroyers, but its adoption in the Royal Navy is now practically universal, and its method of operation is well known.

As regards the oil to be used, it is what is known as the "Arctic" brand. There is no question of that oil enabling the gear to work in any temperature. Mr. McLaren is perfectly right in thinking that in this particular gear there is a change in the leverage as the rudder goes over. I am afraid in making a passing remark on the subject I overlooked the fact that our gear differs from another steering gear where the leverage is constant. I will ask Mr. Beacham to explain what is the actual variation in the case of our own gear.

Mr. J. B. Harvey: As regards the new safety valve, would it be necessary for the valve to be of the same diameter as the plunger, or would you have a smaller valve?

Dr. Hele-Shaw: The valve need not be large since all that is required is to allow the oil from the ram to follow up the piston valve until the circular aperture for escape is reached.

Mr. L. F. P. Sorge: I take it that the amount of movement of the oil will be very small indeed?

Dr. Hele-Shaw: It need not be very large but oil is very nearly incompressible, and as it is so inelastic, when it receives a sudden blow, that instead of a pressure of 1,500 lbs. being suddenly reached (at which the valve is set) a gradual giving way is provided and the blow caused by the wave is taken up on the moving ram.

Mr. Sorge: I think this valve will come into operation when the rudder is absolutely stationary. Under these circumstances, is not the pressure of the oil in the two rams balanced?

Dr. Hele-Shaw: When the rudder is amidships there is very little pressure on it. The danger is of a broadside wave suddenly striking the rudder and the pressure wanting to jump to 1,500 lbs. instantly. If the helm is hard over at that moment, probably there is already a pressure of 1,000 lbs., and the safety valve is ready to open when the impact of the wave occurs.

Mr. T. A. Bennett: If the maximum working pressure is 1,500 lbs. and the pressure due to the sea striking the rudder, is, say, only 1,200 lbs., I presume the valve does not operate?

Mr. T. E. Beacham: The energy of the wave acting on the rudder will be absorbed by the spring, the pressure will never reach the maximum and the piston will just come back.

The Chairman: I think perhaps one point of Mr. Sorge's question was that a very small amount of travel of the actual ram itself would cause quite an appreciable travel of the valve owing to the difference in diameters; *i.e.*, a valve of 2in. and a ram of say, 8in.; 1-16th inch travel of the ram would represent a much greater travel of the valve.

Dr. Hele-Shaw: There is all the difference between 1/16th inch travel and no travel of the ram. All that is required is to provide some yielding—a travel of 1/16th of an 8in. ram means a yield of 16 times as much on the valve. This, however, is only 1in., and our valve provides for a much greater travel than this.

Mr. L. F. P. Sorge: If this valve comes into operation in that manner, presuming that the rudder has been set in one position and you get this shock occurring so that some oil passes from one cylinder to another, does the hunting gear come into play in order to correct the position of the rudder?

Dr. Hele-Shaw: Whenever you put the wheel—you may go faster or slower—the floating lever will bring it back into its right position as long as the electric motor is working the pump. That is not new, it is of course an existing device.

The Chairman: I have had a question handed up to me enquiring what is the principal difference between the apparatus shown by the authors and the original Hele-Shaw Martineau gear? I think, for myself, I can see what it is, but as the question is asked I would like Dr. Hele-Shaw to reply to it.

Dr. Hele-Shaw: The essentially new feature of the Hele-Shaw-Martineau steering gear was a variable stroke pump with a reversible direction obtainable in the pump. The invention which I have described to-night is entirely different because we do not reverse the pump but we do reverse the flow through the valve.

Mr. James Harvey (Visitor): The idea of having a reversible motion of the fluid is an excellent one. In the old gear the motion was reversed by the lever, whereas in this case the fluid is always moving one way, and I think that is a great advance on the old method.

Mr. L. F. P. Sorge: One point about the pump is not quite clear to me. I take it that the pump itself is somewhat like a torpedo engine with the piston revolving about the crank. Are the valves of the pump controlled by the pistons themselves? And is the actual delivery of the oil to the pump controlled by the pistons?

Mr. T. E. Beacham: The valve ports are formed in the cylinder casting itself, and the only valve is the fixed central valve.

The Chairman: I think we are very much indebted to Dr. Hele-Shaw and Mr. Beacham for giving this paper at such short notice. I propose a hearty vote of thanks to them. Carried unanimously.

Notes.

Referring to page 158, August issue, and to the comments which have been made in several quarters as to the education and technical training of engineers for marine service, the following is an extract from our Annual Report, Session 1896-7. The present day workshop is so well equipped with machinery that experience with hand tools is not readily obtained, although its importance is emphasised in the Board of Trade Regulations.

Annual Report 1896-7.—"Recommendations made to the Board of Trade three years ago, September, 1893, on the subject of the minimum qualifications necessary for engineers of the mercantile marine, have not yet been actually adopted and passed into law, but it is hoped that in the interests of the whole community the points especially recommended will soon be put into force. There are indications that the President of the Board of Trade is dealing with the question, and we look forward to the publication of a Bill shortly, which will include the following points:—

Minimum service in the workshop of five years.

The introduction of a third-class certificate.

The necessity of defining the meaning of nominal horse-power.

The recognition of the engineers as officers of the ship, and as such, the representation of the engine department on enquiries affecting the department.

Subsequent discussions held during the session evoked the following resolutions, and as the question of N.H.P. is involved in another Bill, at present engaging the attention of Parliament, the attention of the Board of Trade is again specially invited to the subject.

Resolution.—"That, in the opinion of this meeting, it is highly necessary to amend the present regulations as to second-class certificates for engineers with regard to service in the workshop, where the minimum service should be five years, and that the attention of the Board of Trade should be called to the desirability of creating a third-grade certificate, which should be granted to those who have served at least five years in an engineering work, and one year at sea, and pass the prescribed examination."

The Colonial Parliaments have had under consideration the subject of N.H.P., qualification of engineers, and other matters, and the results have been in many respects satisfactory, although we may not agree with all the terms of the Bills passed for the Colonies. The discussions held in connection with these matters will be found in the Transactions, where the following Resolution is recorded as passed:

Resolution.—"That having read the altered regulations with respect to service and qualifications for engineers' certificates, including that of third engineer, in the Bill which had been passed by the New Zealand Legislature, we fully endorse those clauses relating to service in the workshop and at sea, but we do not altogether concur in those relating to the number of engineers to be carried, neither do we think that the number of engineers should be rated by the power alone, and we also agree that the present anomaly of N.H.P. should give way to some other means of enabling the power of the engines to be determined, and consequently the effect of its bearing on the status on the second engineer's certificate."

It is gratifying to observe that the subject of the engineers of the Royal Naval Reserve is being dealt with in the Naval Estimates. Our President and others interested in the subject are to be congratulated on the fact that their efforts have so far met with recognition, the paper and subsequent discussions and correspondence on the Royal Naval Reserve materially assisting this.

It is no less pleasing to observe that the conditions and positions under which the Engine Department of H.M.'s Navy are operated have been receiving more attention and consideration on the part of the Government, and that some considerable improvements are on the eve of being made, both in respect to the Engineers and their staff of artificers and stokers.

The appointment of a representative Engineer on the Board of Admiralty appears to be most desirable.*

In our letter to the Board of Trade in September, 1893, the following points were emphasised:—

Engineers who seek to join the mercantile marine should be as efficient as possible, and with this in view, it is considered that five years experience in the workshop is necessary to meet the requirements.

*This was advocated by the Duke of Montrose, one of our Past Presidents, in the House of Lords, on July 4th, 1926, when the Royal Naval Engineers' Status was referred to. (See p. 98 July Issue).

The object to be attained by the five years apprenticeship is a high standard of efficiency.

The desire at the back of the recommendations is for the maintenance of the highest efficiency in the engine-room staff, believing that thus only can we expect to cope with the increasing responsibilities devolving upon the Engineers of the mercantile marine. So also upon the Engineers of the Royal Navy increasing responsibilities rest.

In the interests of those who have shares in steamships, and steamship owners, it becomes the duty of the Institute to point out that the conviction is very strong that while three years may have been a long enough minimum apprenticeship when the present Board of Trade Rules were framed, for exceptional lads to obtain experience in the handling of tools, and education in the theory of their business, the time has more than come when it is both expedient and necessary to amend the Regulations in the direction indicated.

That a high standard of efficiency should be aimed at and encouraged, is emphasised as manifest from the facts stated as follows:—

(a) Greater and increasing responsibilities upon the Engineers of to-day as compared with the past.

(b) Foreign competition is greater and increasing. It rests largely with the most intelligent use of material in the engine department to gain advantage in the competition.

(c) There is less hand and more machine tool work in the workshops now than formerly, and therefore all the more reason for an extended apprenticeship.

(d) In large steamers there are many young engineers who sail for years in a junior capacity who have had no opportunity of passing for the 2nd certificate, but who might be granted an opportunity of obtaining a 3rd class certificate as a means of encouragement.

The following are from "The Engineer and Iron Trades Advertiser," August 10th:—

CHROME SILICON STEEL FOR VALVES.—A number of different materials has been tried for the valves of petrol engines, which have to withstand rapidly varying stresses and impacts at high temperatures. Among the metals tried may be mentioned mild steel, mild steel stems with cast-iron heads, 25 per cent. nickel steel, nickel-chrome, chrome-vanadium and tungsten steels. The latter alloy steels have generally given the best results, and have withstood the high temperatures and corrosive action of the gases to a fairly satisfactory extent. Chrome silicon alloy steel valves have for some time now been used as standard equipment on the Fordson tractor. This type of valve is particularly desirable in a heavy duty engine like the Fordson, since the conditions of service are such as tend to produce high cylinder temperatures. The principal advantages of the new type valve are:—1. The use of a chrome silicon steel alloy obviates warping of the valves. It also reduces oxidation and scaling to a minimum, thereby preventing pitting or breaking off of the valve heads. 2. Valves are heat-treated, hardened and ground. This minimises wear on the end of the stem and on the guide bushing. Air leakage at the latter point due to wear is a frequent cause of faulty carburation. 3. Owing to its greater hardness, the new valve does not require as frequent grinding; it forms and maintains an ideal seat in the cast iron cylinder block, which is a very important factor in retaining good compression. 4. The valve is easily removed and installed. The valve spring is held in compression by a steel seat which is locked in position by a split conical collar fitting in a groove on the valve stem. This eliminates the use of a pin, which has to be lined up with a hole in the valve stem.—"English Mechanic."

Apprenticeship.—The manual art of apprenticeship has been in vogue throughout the ages, coming down through the guilds of old to the more modern methods of to-day. Manufacturers and educators have experimented from time to time as to the best means of educating and bringing up workmen to carry on a given industry. Many feel that mass production of to-day, which has developed the operator trained to single operations, has eliminated the necessity for the man trained to do everything. Nevertheless, there is a constant complaint that there is a shortage of skilled labour, says a writer in "Mechanical Engineering." The fact is that there is need to-day not only for the skilled operator who is able to handle all kinds of jobs on one type of machine, but for skilled workmen who can turn their hands to any job that they may be called upon to do. School training, when successful, prepares a man to obtain the advantages of shop training in a much shorter time than is apt to be the case with an untrained mind. No matter how well the school shop training is carried out, however, it can in no way take the place of actual shop conditions. Apprentices in a shop should be under a supervisor, and the selection of the proper supervisor is an important thing. He must not only be a thoroughly trained mechanic, but he must also be a man of character, capable of handling his job sympathetically, and must be able to keep the boys enthusiastically interested in their work.

The following letter from Sir Alfred F. Yarrow, appeared in "The Times" of August 19th. It has been favourably commented on in several journals, as it contains many points of interest and of value for the consideration of all concerned in the welfare of their country, desirous of eliminating class warfare elements:—

LABOUR AND STRIKES.

Sir,—In the year 1860 I gave a lecture dealing with the laws which govern the business relations between employers and employed. After a long life of industrial activity I still hold the same views as I expressed 66 years ago, and I thought possibly it might be of interest to quote a few extracts from my address:—

"One of the most common forms of interference with the natural laws upon which rates of wages depend is a mutual agreement among workpeople to withdraw their labour in order to endeavour to secure a higher rate of wages. This is called a "strike."

Past experience has shown that strikes are mostly unsuccessful, and, in such cases, clearly injurious to all parties.

Suppose a strike has been organised and carried through successfully, in cases where the increased wages to be paid are in excess of what the industry can afford, the cost of production would be increased and the price of the article raised, leading to a diminished demand and less labour being required. Moreover, during a strike, consumption is going on and no production is taking place; the wealth of the country would be reduced, and there would be less capital for the employment of labour.

The only sound conclusion that can be come to, is that wages can only be raised by increasing efficiency in order to augment what is produced, and increase the stock of capital, which would be employed in further developing industries and giving employment."

Until social science (often called "political economy") is taught in schools, educating the rising population in the laws which govern the value of labour and determine the rates of wages, I do not believe any real progress will be made in avoiding the constant disputes between employers and employed. One thing is certain: the natural laws which govern the value of labour should be allowed free action, as if they are interfered with by employers, workers, Governments or by benevolent persons outside the industry, disaster is sure to ensue.

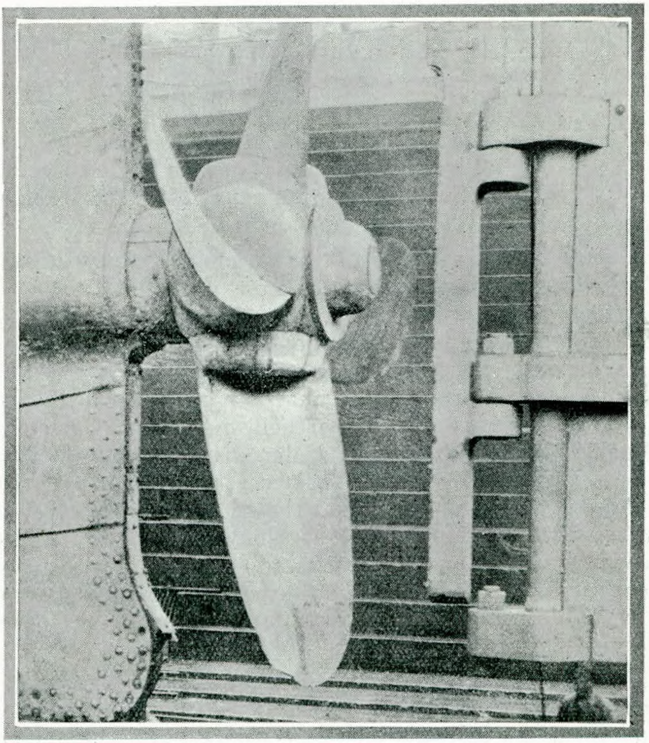
I am, Sir, yours faithfully,

A. F. YARROW.

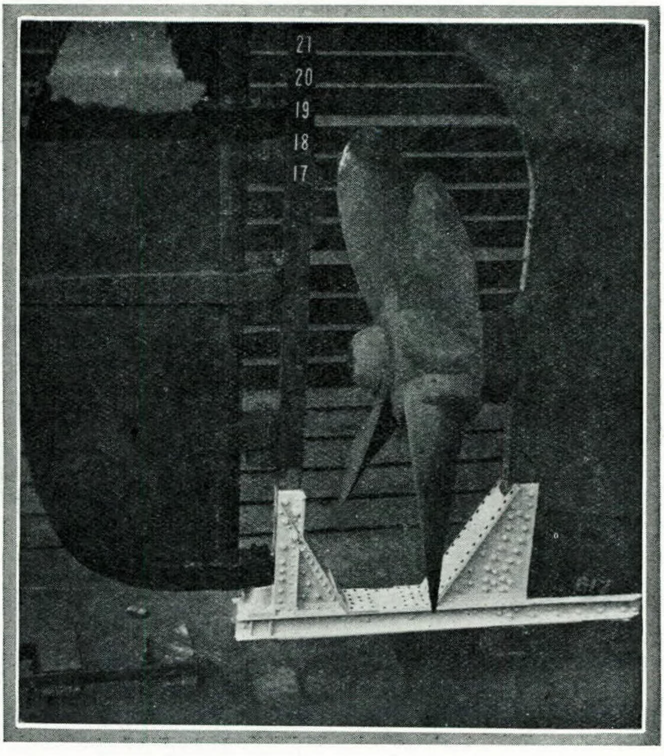
From "Lloyd's List and Shipping Gazette," of August 19th. In the "Syren and Shipping" of August 25th the Repairs are also described, and illustrations shown:—

THE *Clan Macnaughton*.—REMARKABLE REPAIRING FEAT BY SHIP'S ENGINEERS.—The story of how the Clan Line steamer *Clan Macnaughton* was repaired by her own engineers at Melbourne after having been damaged by stranding, as the result of being driven ashore by strong currents when outward bound from the Tasmanian port of Launceston on February 10th, was told to-day after the ship was berthed in Barclay, Curle & Co.'s Dry Dock at Elderslie. As a first step divers executed sufficient repairs to enable the ship to proceed to Melbourne. In dry dock there it was discovered that the whole lower portion of the stern frame was broken off, the aftermost keel plate was pierced and several plates on the starboard side were badly dented. The cargo on board had not suffered by the mishap and the most valuable part of it was transferred to another homeward bound vessel of the same line.

Some difficulty was experienced when the question of repairs was entered into. The labour unions at Melbourne said they would only allow full repairs to be carried out. The owners of the vessel, wishing to lose no time, as there was still a large amount of cargo on board, desired only to make temporary repairs. Fully one week was lost by this delay, and, finally, the engineers of the *Clan Macnaughton* determined to do the work themselves. The chief engineer designed a new bottom portion for the stern-post, with some difficulty several steel girders and plates cut to desired sizes were procured on shore and taken to dock and there they were bored, riveted and fitted up in place by the staff of the vessel. A long girder was riveted to the broken portion of the stern frame where it joined the keel plate and projected aft until it met and connected with other two girders which were attached to the forward and aft upright portions of the stern frame. The corners of the rectangle formed by these girders were then strengthened by plates in the form of brackets and a frame strong and rigid enough for all ordinary purposes was completed.



The damage to the after keel plate was treated in a different manner. It was impossible for the engineers, with their very limited facilities, to remove this plate and replace it with a new one. A most ingenious expedient was, however, adopted. A wooden mould was fitted round the damaged portion and cement poured in between the mould and the plate. The cement adhered firmly and made an absolutely watertight job. The plates which had suffered in other parts of the vessel had not been pierced, but the cement in the double bottom had broken away. The broken material was removed and the exposed portions recemented, thus putting finishing touches to a remarkable piece of work. The engineers of the vessel are given great credit by the captain and the owners for the manner in which they tackled what must have seemed at first to be an almost impossible task. The *Clan Macnaughton* is now to be fully repaired by Messrs. Barclay, Curle & Co.



The above illustrations show the damage to the stern and rudder post and the repair made to bring the ship home to Glasgow. We are indebted to "Syren and Shipping" for the loan of the blocks.

There are larger illustrations in "The Shipbuilding and Shipping Record" of August 26th.

It is gratifying to know that the work of the repair was carried out so faithfully and well; also that the accomplishment was highly appreciated. Warm thanks were accorded to the Engineers for their acumen and ability, by the owners, who endorsed their thanks by handsome gifts.

The following letter was in "The Times," August 23rd:—

ROYAL NAVAL RESERVE.—May I champion the cause of the Royal Naval Reserve? I have often served with officers of the Royal Naval Reserve, and many of them are deserving of higher praise than I am capable of expressing in words. Now when the officers of the Royal Navy are compelled to spend so much time on shore, studying and serving in shore establishments, we need more than ever the co-operation and assistance of our comrades of the mercantile marine. Also we need to abolish all traces of the misunderstanding and discord which do sometimes exist between the officers of the Royal Navy and the Royal Naval Reserve. There is no good reason why officers of the Royal Naval Reserve should not wear the same uniform as the officers of the Royal Navy, and if this could be done, it would go a long way towards increasing the friendliness and harmony between R.N. and R.N.R. so necessary for real co-operation and efficiency.

Rear-Admiral J. D. ALLEN.

Red Cottage, St. Albans.

A letter appeared in "The Times," August 27th, on the conditions of the industries of the country, due to the tactless leading of the Miners' by officials who seek to beg all round, at home and abroad, rather than to work towards a desirable end. A letter from Japan was quoted in which it was stated that the employees of a company which was striving to carry on in adverse circumstances, had decided to help the undertaking by suggesting that they would work at reduced wages to carry on until business improved. The company did not approve of the suggestion at first, but on the matter being again urged, it was agreed upon, and the business was kept going, all working harmoniously together towards a common end.

The lessons which ought to be brought home to those closely associated with the coal industry, by the experiences of the past and present day conditions, accompanied as they are by more or less severe discomfort and loss on the part of the whole community, are that all may look towards the most desirable end, which is to work harmoniously and consistently for the good of all, each doing his best with an ungrudging spirit. This is applicable to all industries, as the national well-being and progressive advancement depend upon each and all being carried on harmoniously, the individual worker doing his best to enhance the value of his work, without increasing unduly the initial cost, so that there may be an all-round national benefit as an asset to the good.

The waste and loss due to strikes have been quoted in various journals, and the cost in monetary loss conveys a heavy item to the reader, but other thoughts arise in the mind as to the troubles and afflictions which cannot be reckoned. Cannot reason be brought to bear upon the subject, and a better system organised to avoid the evil clash and uphold the good call.

The "Morning Post" had the following paragraph after the strike in May. It has been looked out as an appropriate addition to the foregoing:—

"The abuse of Trade Unionism is the tyranny of the inefficient, and if we can embark upon a new era in which efficiency will set the standard and every man work, not with a grudge, but with his whole heart, then even the disastrous wastage of the strike will not have been wholly in vain. It is for that reason, among others, that goodwill is essential. The strikers have suffered bitterly from following bad counsel; they have been beguiled into a heavy injury to themselves as much as to their employers; they have tasted the bitter fruits of the Marxian tree of knowledge. All the promises made to them by their political leaders have led only to disaster. It is now the chance of the employer to point the true way to industrial happiness. If master and man deal fairly by each other, exchanging the best possible wages and conditions for the best possible labour, if both co-operate for the salvation of the industrial system by which both must live, we shall not only continue to make good this waste of time, but even to profit by it. We shall overcome evil with good."

Boiler Explosion, No. 2744.—While the steam fishing vessel *King Harold* was sea bound from Grimsby, and soon after the anchor was lifted, the assistant driver attended to the boiler fires and then with the co-operation of a trimmer set to work to clear the ashes from the stokehold, when suddenly a stream of water gushed from a manhole doorway and scalded the assistant driver. He fell on the port side, whence there was no exit to the engine-room. Fortunately he was able to get across to the starboard side, shouting to the chief driver, who opened the door in time for escape. The door was then closed as the stokehold was filling with steam and damping the fires, the main damper being closed, as it was not possible to draw the fires. The assistant driver was helped upon deck and a tug hailed to tow the vessel back to Grimsby, and the injured man was taken to hospital and attended to till recovery.

The investigation of the cause of the mishap was made by Mr. Jas. Jarvie, Board of Trade Surveyor, Hull, who reported that the boiler was of the ordinary marine type, of steel, 11 ft. 6 in. diam. by 10 ft. 3in., with two plain furnaces, the manhole 14 ins. by 11½ ins., being between them, of the McNeil type, steam pressure 200 lbs. The boiler was made in 1911.

No damage had been done to the furnaces or the boiler due to the outflow of water when the accident happened. It was found that the door was ¼ in. slack at the spigot and that about 3 ins. of asbestos joint had been blown out. The threads of the studs were bound up with dirt near the nut when screwed up, and this would lead to difficulty in closing up tight.

The space was made up by electric welding, the threads cleaned and the door refitted.

The Engineer Surveyor-in-Chief, Mr. Carlton, made the following observation based upon the report. The manhole door was a bad fit and the effectual jointing of the door was more or less uncertain. It is surprising how frequently these ill-fitting doors escape the notice of the Inspectors, who are responsible for the examination of the boilers.

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Election of Members.

List of those elected at Council Meeting of September 6th, 1926 :—

Members.

William Anderson, *c/o* Messrs. Butterfield and Swire, Shanghai.

Heward William Archer, 15, Elm Avenue, Garden Village, Hull.

Bertram Penrhyn Arrowsmith, *c/o* Commonwealth and Dominion Line, 9/11, Fenchurch Avenue, E.C.3.

Frederick Charles Ashby, 7, Cedar Villas, Cedar Road, East Croydon, Surrey.

Edward Lytton Hope Baird, Cornwall House, 56, Valentines Road, Ilford, Essex.

Albert Ernest Boyes, 49, St. Johns Road, East Ham, E.6.

Bryce Campbell, Lyndhurst, Drumchapel, Glasgow.

Robert Carruthers, C.N.Co.'s Agents, *c/o* Butterfield and Swire, Shanghai, China.

William Walker Fawcett, Polygon House, Southampton.

John Russell Low, Lago Oil and Transport Co., Ltd., Aruba, Dutch West Indies.

George John Mansfield, "Killarney," Avonmouth, near Bristol.

Walter James Duncan Middleton, 228, Halley Road, Manor Park, E.

Douglas Robertson, "Staffa," Dunoon, Argyleshire.

William Taylor, Ravenscraig, Paisley Road, Renfrew.

Thomas Buck Thompson, No. 6, Maple Grove, New Moston, Manchester.

Einar K. Underdahl, The East Asiatic Co., Ltd., Bangkok, Siam.

Oswald Wans, The Manor House, Waddington, Lincoln.

William George Wicks, Place House, Icklesham, Sussex.

Associate Members.

Edwin Berry Dodd, 57, Westbourne Park Road, Bayswater, W.2.

Edgar Lionel Luly, 28, Norton, Tenby, South Wales.

Richard Treharne Maddison, China Navigation Co., Shanghai.

Frank Buckie Monks, Craigmillar Cottage, Woodside, Collin, Dumfriesshire.

Harry Stafford O'Brien, 66, Victoria Street, S.W.1.

William Abdy Sycamore, White Lodge, Brightlingsea, Essex.

Associates.

Vincent James Burns, 16, Naughton Terrace, Kilbirnie, Wellington, N.Z.

Albert Victor Grayston, 3 Canal des Brasseurs, Antwerp.

Dennis MacDonald, 338, Priory Road, St. Denys, Southampton.

John Whelan, 22, Mount Pleasant Avenue, Limerick.

Graduates.

John Smerdon Elliott, 24, Vespasian Street, South Shields.

John Charles Hersey, Municipal Technical Institute, Limerick.

Brinley Pugh, 211, Holton Road, Barry Dock, Glam.

Transferred from Associate Member to Member.

William Grassick, Mayfield Tillyoch, Peterculter, Aberdeenshire.

J. McCullagh, "Inver-Mudal," Knock, Belfast.

Transferred from Associates to Associate-Members.

Edward James Parish, 31, Cornwall Road, Portsmouth.

Thos. A. McLellan, "Oakdene," Gordon Road, Finchley, N.3.

Transferred from Graduate to Associate.

Douglas Lomas, Grove Street, Wilmslow, near Manchester.