New Metals in Engineering

L. B. PFEIL, O.B.E., D.Sc., F.R.S.*

The title of this paper covers so wide a field that any attempt to survey the subject as a whole would result in the presentation of a dull catalogue of developments. To avoid this, the author makes only passing reference to matters which have recently formed the subjects of papers to the Institute, and concentrates on metallurgical developments which bear on marine engineering and of which he has first-hand knowledge.

In marine engineering, as in other industries, non-ferrous alloys are taking an increasingly prominent position. Copper-, aluminium-, and nickel-base alloys have proved their value in many applications. An account of many of these was presented before the Institute in 1951 by Johnson and Bradbury(1), when dealing with the subject of corrosion-resisting materials.

Some supplementary information has recently become available on the cast copper-base alloys, such as gunmetal and high-tensile brass, which are widely used in marine engineering for the production of such components as propellers, stern tubes, shaft liners, pump bodies, valves, etc. Many of these castings are large, of heavy section, and play an important part in both the initial and running costs of a ship, yet little information is available to the designer regarding their mechanical properties.

One of the important factors that influence the mechanical properties of castings is the effect of section-thickness upon strength and ductility. The properties obtained from separately-cast test bars provide only a guide to the quality of the metal going into the casting: they do not establish the properties of the casting itself. Reichenecker(2) has recently published the results of an investigation showing how some of the more commonly used copper-base alloys are affected by casting section. In this work he employed a step-bar casting having a section varying from ⅜ inch to 2 inches in thickness, as shown in Fig. 1, and mechanical properties were determined on tensile specimens machined from the different sections. All the alloys examined showed a decrease in mechanical properties with increase in section thickness. High-tensile brass and aluminium bronze were the least affected by variations in section-thickness; gunmetal and tin-bronze alloys were affected to a greater degree.

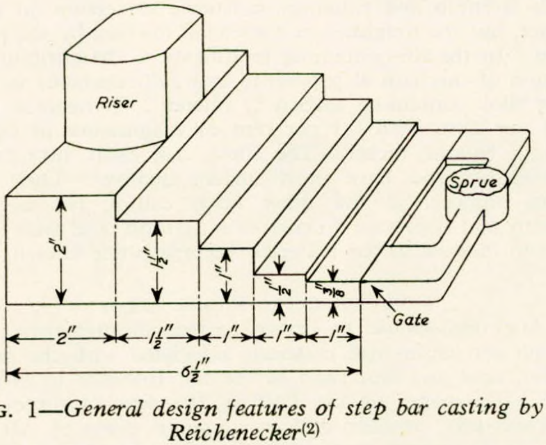


FIG. 1—*General design features of step bar casting by Reichenecker*(2)

In order to obtain further information on this matter, investigations have been undertaken recently in the laboratory of The Mond Nickel Company, Development and Research Department, using a similar form of step-bar casting, with modified feeding method. Some of the results likely to be of interest to the designer of marine components are shown in Fig. 2; typical compositions of the various alloys are given in Table I. For example, it may be deduced that increasing the section-thickness from 1 inch to 2 inches of a casting in 85/5/5/5 gunmetal does not necessarily double the load-carrying capacity of the section and, conversely, a reduction of section is not necessarily accompanied by a proportional loss of strength. Reference to curve A in Fig. 2 shows that the tensile strength of 85/5/5/5 gunmetal decreases from about 16 tons per sq. in. in a 1-inch section to 12 tons per sq. in. in a 2-inch

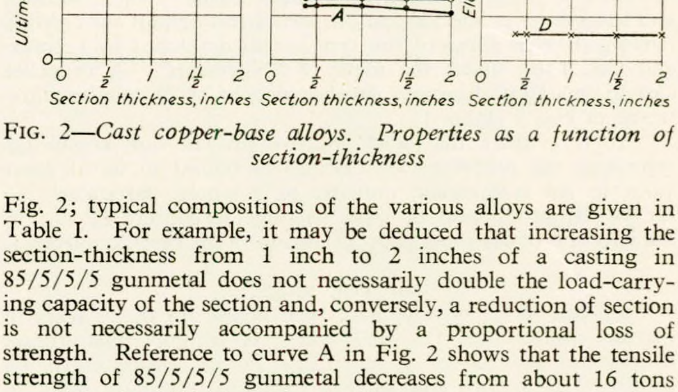


FIG. 2—*Cast copper-base alloys. Properties as a function of section-thickness*

---

* Manager, Development and Research Department, Mond Nickel Co., Ltd.

TABLE I.—COMPOSITIONS OF ALLOYS REFERRED TO IN FIG. 2

Mark	Type of alloy	Composition						
		Cu %	Sn %	Zn %	Pb %	Al %	Fe %	Ni %
A	Leaded gunmetal, as cast	85·0	5·0	5·0	5·0	—	—	—
B	Leaded gunmetal containing nickel, as cast	86·0	3·0	5·0	4·0	—	—	2·0
C	Ni-Vee bronze, as cast	88·0	5·0	2·0	—	—	—	5·0
D	Ni-Vee bronze, as cast and heat-treated*	88·0	5·0	2·0	—	—	—	5·0
E	Aluminium bronze, as cast	88·0	—	—	—	8·0	4·0	—
F	High-tensile aluminium bronze, as cast	81·5	—	—	—	8·5	5·0	5·0

*Heated 5 hours at 760 deg. C., cooled in furnace to 550 deg. C., and quenched in oil. Reheated at 350 deg. C. for 5 hours and cooled in air.

section. This decrease in tensile strength is accompanied by a marked reduction in ductility. It is quite possible that, as casting section increases above 2 inches, these changes may become even more pronounced: this aspect is receiving further attention.

If 2 per cent of nickel is substituted for an equal amount of tin in 85/5/5/5 gunmetal, different results are obtained, as will be observed from curve B in Fig. 2. The mechanical properties of the casting do not now decrease as section is increased and both tensile strength and elongation remain reasonably constant.

With some alloys, particularly those susceptible to precipitation-hardening on slow cooling, mechanical properties may actually improve as the casting section is increased. This tendency is shown by curve F, for high-tensile aluminium bronze containing 8·5 per cent aluminium, 5 per cent iron and 5 per cent nickel; it explains to some extent why alloys in this group have been increasingly employed during recent years for the manufacture of marine propellers. High-tensile aluminium bronze is superior to ordinary aluminium bronze and to high-tensile brass, both as regards resistance to erosion and the maintenance of mechanical properties in castings of heavy section. Unfortunately, within the compositional limits normally employed, alloys in the aluminium-bronze group are much more difficult to handle in the foundry, and this has undoubtedly restricted their development, particularly so far as the production of large castings is concerned.

Recently, however, alloys of modified composition have been introduced, in which the troubles associated with the founding of aluminium bronze have been largely overcome. Large castings, such as propellers, can be produced in these alloys without difficulty, up to weights limited only by plant capacity, and the castings are found to be clean and exceptionally sound. Furthermore, a fine grain size is maintained, even in heavy sections, resulting in sounder metal in these sections and less scatter in mechanical properties throughout the casting. Among the new alloys of this type is that developed by J. Stone and Co., Ltd., under the name of "Novoston". A propeller cast in this alloy, having a finished weight of 23 tons, is illustrated in Fig. 3 (Plate 1).

It is evident that any improvement in our knowledge regarding the properties of castings is bound to be of great value to the engineering industry as a whole, particularly so far as the production of large castings is concerned, and in the selection of the most appropriate alloys for specific purposes.

GRAPHITIC NICKEL

Leaded nickel bronzes have been in use for many years in marine applications, for such parts as sealing rings, thrust collars and wear plates on centrifugal pumps, piston valves on reciprocating pumps and labyrinth seals and packing rings on steam turbines.

The leaded bronzes have been preferred for these applications, due to their non-galling qualities, which are valuable in the absence of efficient lubrication. A typical alloy so used contains nickel 40, tin 8-10, lead 8-10 per cent, balance copper. Such materials have given excellent service over a long period, but with the advent of the higher steam temperatures which are now becoming general, this type of alloy is not entirely suitable, particularly where the service temperature is above the melting point of lead. There is, therefore, an urgent need for an alloy having a good combination of galling-resistance and resistance to corrosion. To meet this need a nickel-base alloy has been developed, in which advantage has been taken of the known lubricating qualities of graphite, and in which, in order to ensure improved mechanical properties, the graphite is modified to the spheroidal form by the addition of magnesium(3).

In a magnesium-free cast nickel alloy containing carbon 1, silicon 2·30, manganese 1·5 per cent, the graphite occurs solely in flake form, but when small amounts of magnesium are added the graphite structure is altered. At low magnesium levels the graphite occurs as a mixture of flake, nodules and spheroids with radial structure, as shown in Fig. 4 (Plate 1), but with more magnesium present, the graphite is converted to a predominantly spheroidal form, with associated rise in tensile strength and ductility (see Fig. 5 (Plate 1)). A typical composition of a fully-spheroidal-graphite alloy is carbon 1-2·5, silicon 2, manganese 1·5 per cent, with magnesium 0·05-0·15 per cent in excess of sulphur, balance nickel; it has a tensile strength of about 26 tons per sq. in., with an elongation of about 22 per cent, and shows excellent non-galling properties. Addition of tin to this type of alloy still further increases the tensile strength and enhances resistance to seizure on rubbing contact, but the toughness is somewhat lowered by the presence of tin. In the tin-containing modification, the optimum combination of mechanical properties and gall-resistance is secured in an alloy containing carbon 1, silicon 2, manganese 1·5, tin 2·5-4 per cent, with 0·1 per cent of magnesium in excess of sulphur, balance nickel. The alloys cast easily into pressure-tight shapes and have good surface quality. Their use in marine engineering and other fields calling for mechanical strength and resistance to corrosion, galling, and wear appears likely to increase as the materials become better known.

MODIFIED CUPRO-NICKEL ALLOYS

Attention should be drawn to the comprehensive discussion on condenser-tube materials associated with the paper by Gilbert, read and discussed before the Institute in November last(4). The paper by Dr. Gilbert, the detailed survey of the condenser-tube problem and its conquest given by Mr. Sherborne in discussion, and other contributions then made, constitute a valuable historical record of research and practical experience which have proved to be of incalculable economic

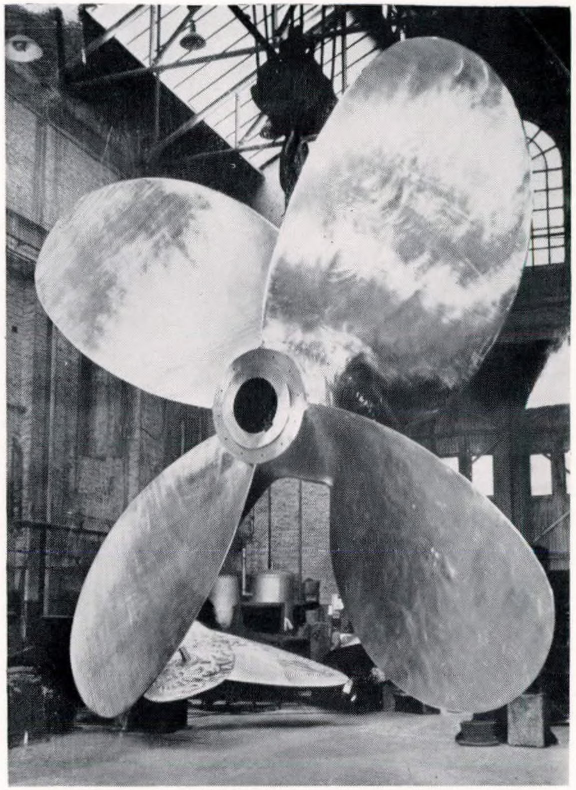
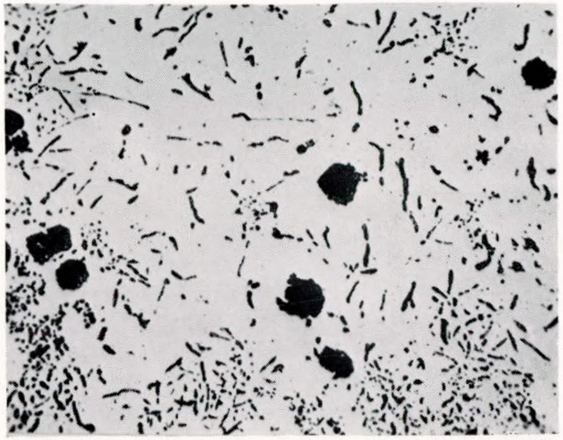
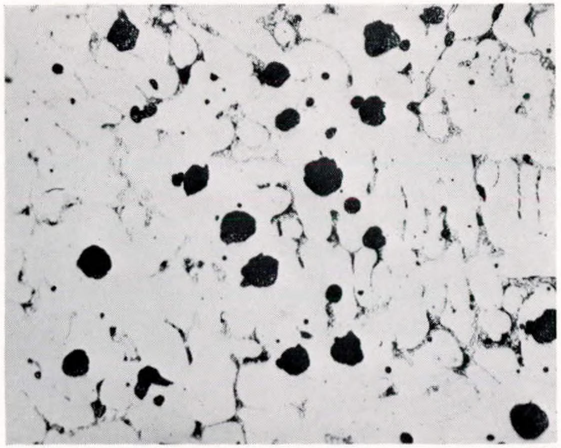


FIG. 3 *(above)—Marine propeller cast in Novoston high-tensile bronze; finished weight 23 tons*



× 100

FIG. 4—*Flake graphite and small nodules and spheroids of graphite in nickel alloy containing a small amount of magnesium*



× 100

FIG. 5 *(right)—Fully spheroidal graphite in nickel alloy of higher magnesium content*

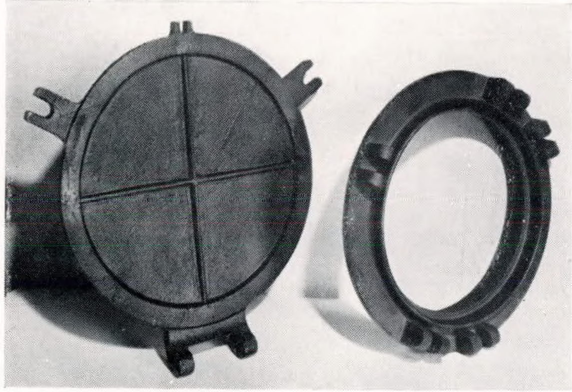


FIG. 7—*Porthole and cover in S.G. iron*

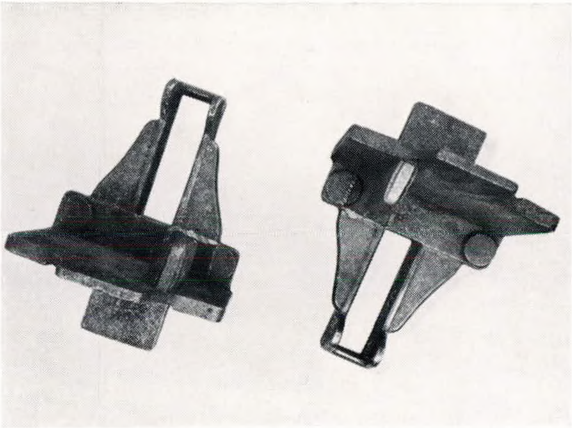


FIG. 8—*S.G. iron brackets for ships' hoists*

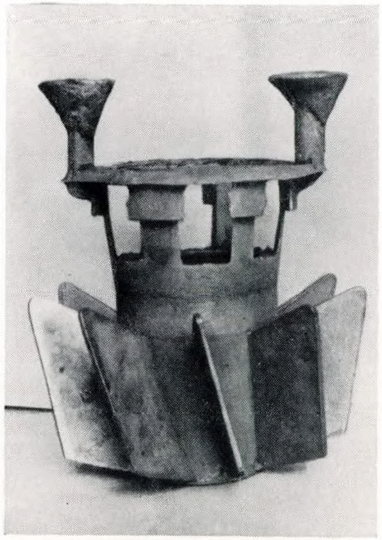


FIG. 9—*S.G. iron nozzle with cooling ribs, for oil burner*

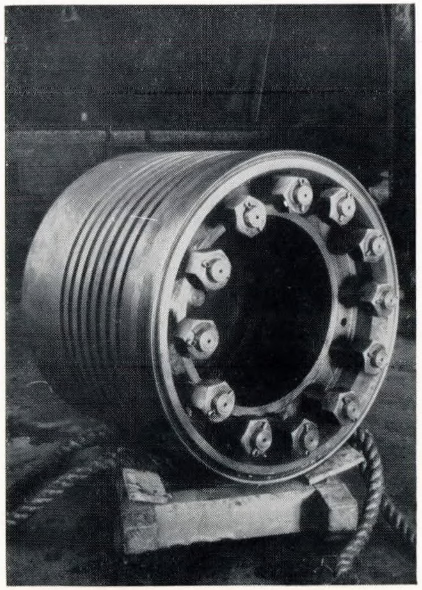


FIG. 10—*Large marine oil engine piston in S.G. iron, 30-in. diameter, 15 cwt. finished weight*

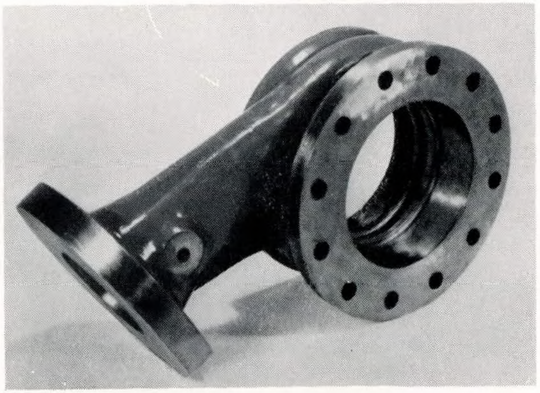
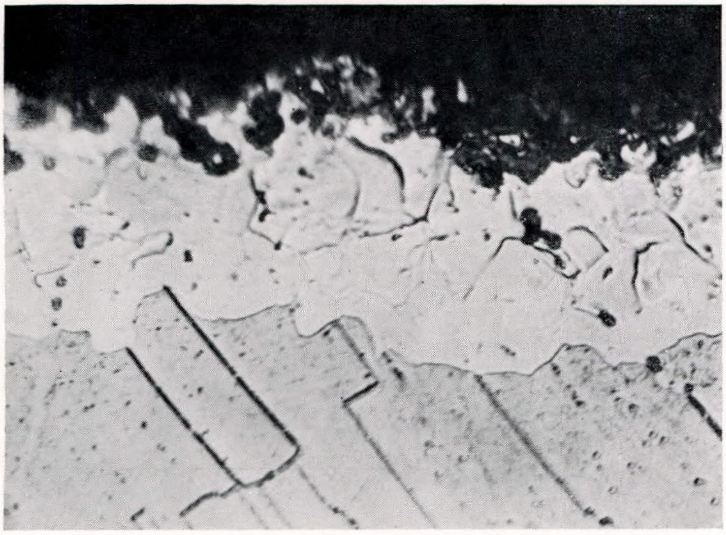


FIG. 11—*S.G. iron casing of single-stage turbo feed pump; capacity 20,000 gal. per hr.; working pressure 325lb. per sq. in.*



× 1,000

FIG. 12 *(left)—Taper section through edge of turbine blade in Nimonic 90 after service for 1,140 hours at 700-750 deg. C., showing the altered surface layer*

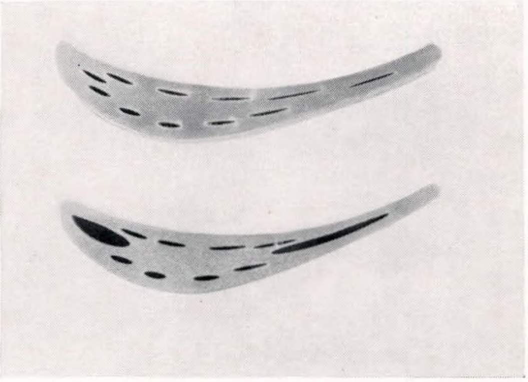


FIG. 13—*Sections of hollow gas-turbine blading produced by hot extrusion*

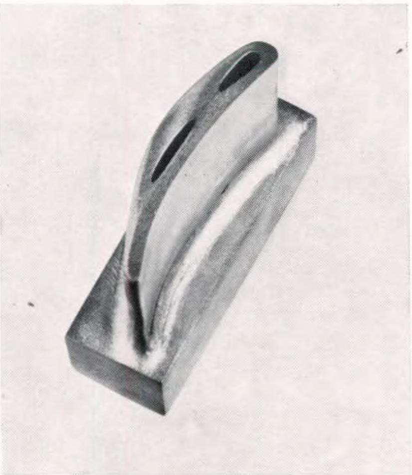


FIG. 14—*Integral-root type of extruded hollow turbine blade*

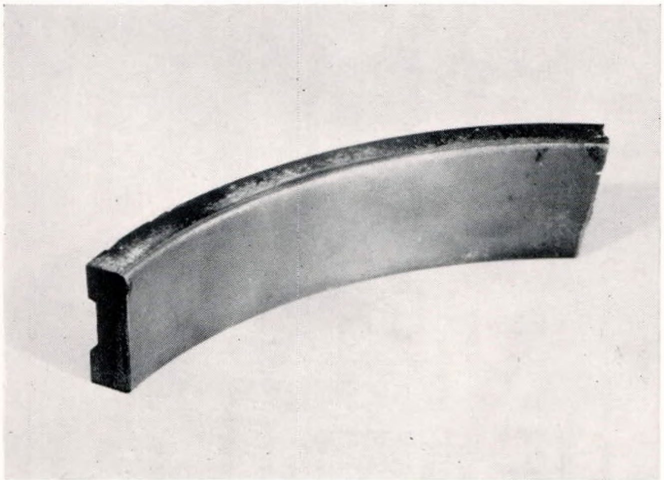


FIG. 15—*Fused-on coating of nickel-chromium-boron alloy, showing smooth surface of deposit*

× 70

FIG. 16—*Fused-on coating of nickel-chromium-boron alloy, showing good adhesion between coating and steel base*

significance. As stated by Dr. Gilbert, "thirty years ago condenser-tube failures were all too frequent an occurrence. Today it is confidently expected that condenser tubes will last for the whole life of the ship and a premature failure is an unusual and notable event. There is no longer an overall condenser-tube problem". There are, however, still certain outstanding individual problems calling for solution, in particular the development of alloys which will consistently resist corrosion by polluted harbour and estuarine waters, and the more severe conditions imposed by the higher water speeds to which condenser tubes are likely to be subject in the near future. Research on these aspects is continuing, and indications to date are that the iron-containing 70/30 cupro-nickel tubing alloy will prove adequate to meet the more drastic working conditions.

Although service experience on the new lower-nickel iron-containing cupro-nickels is not yet sufficient fully to establish their rôle in marine applications, preliminary trials on the 90/10 alloys promise that they will find their own sphere of usefulness. The 5 per cent nickel alloys are already in use, by both the Admiralty and the mercantile marine, for fire mains, water-trunking lines and other marine piping, where they show consistent superiority over copper.

SPHEROIDAL GRAPHITE CAST IRON

Cast iron has for many centuries been widely accepted as a cheap and adaptable material of engineering construction; it is easily cast into intricate forms, is readily machinable, takes a good finish, and is characterized by a useful degree of resistance to corrosion. Its inherent brittleness, however, has been a factor forbidding its use in many engineering applications. During the past twenty-five years much research has been devoted to improving the mechanical properties of cast iron, by modified techniques of production, and of heat treatment, and by the use of alloying elements. Fundamentally, improvement along these lines has been strictly limited, even in the high-strength irons, by the graphite being present in the form of flakes, which break up the structure in a manner precluding development of any substantial toughness and ductility. In 1947, however, announcements were made that a new type of cast iron had been developed, in which the graphite form of both unalloyed and alloy irons is changed from flake to spheroidal, a modification which is accompanied by increased strength and a degree of toughness and ductility never before attainable in cast iron. The obvious usefulness of such a material to engineers at once aroused considerable interest.

TABLE II.—PROPERTIES OF S.G. IRON, AS-CAST AND ANNEALED, COMPARED WITH HIGH-DUTY FLAKE-GRAPHITE CAST IRON

Property	High-duty flake-graphite cast iron	S.G. Iron	
		As cast	Annealed
Tensile strength, tons per sq. in.	18—22	35—45	27—35
Yield point, tons per sq. in.	—	25—35	20—25
Elongation, per cent	nil	1—5	10—25
Transverse rupture stress, tons per sq. in.	38—42	55—65	55—60
Compressive strength, tons per sq. in.	60—65	65—80	48—58
Compressive yield strength, tons per sq. in.	—	32—40	24—32
Elastic modulus, millions of lb. per sq. in.	18	25	25
Brinell hardness	210—240	230—280	140—180
Impact Izod 10 mm. sq. notched, ft.-lb.	1	4	12
Endurance limit unnotched, tons per sq. in.±	8·5	13—18	11—13

TABLE III.—PROPERTIES OF SOME ALLOYED IRONS

Matrix	Acicular		Austenitic	
Graphite form	Flake	Spheroidal	Flake	Spheroidal
Tensile strength, tons per sq. in.	26—36	40—60	10—14	24—27
Yield point, tons per sq. in.	—	30—40	—	15—16
Elongation, per cent	nil	up to 5	1—2	10—20
Brinell hardness	250 to 350		140 to 200	
Impact, Izod 10 mm. sq., notched	—	4	4·5	12

In a paper presented to this Institute by Hallett[(5)] in 1951, an account was given of spheroidal-graphite irons produced by the magnesium process and of their potential value in the marine as well as other fields. Since that date considerable further advance has been made with this process, and the rapidly expanding applications of S.G. iron include several which are of major significance to marine engineers.

An indication of typical properties is given in Tables II and III, and Fig. 6[(6)].

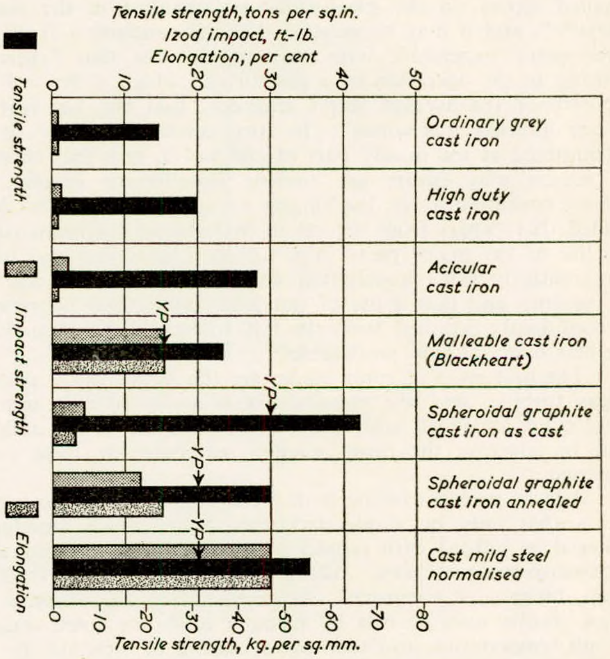


FIG. 6—*Properties of spheroidal-graphite cast iron in comparison with those of other cast irons and of mild steel*[(6)]

Reference to these tables and the figure demonstrates the striking increase in impact-resistance which has been achieved in the new irons, a feature which renders them suitable for many parts in which shock-resistance is a primary consideration and for which, therefore, flake-graphite irons could never be considered. In conjunction with these mechanical properties it is of interest, with regard to service in the marine engineering field, to note that the resistance of spheroidal-graphite cast iron to corrosion by sea water is equal to that of flake-graphite iron. The marine engineer has thus at his disposal a material offering properties which in many respects combine the advantages of steel and cast iron. These advantages are being increasingly recognized, and S.G. iron is likely to play a useful part in marine-engineering development in the near future. It is significant that in the U.S.A. a specification has been issued under the auspices of the Navy(7) to cover its use for electrical equipment, engine blocks, pumps, compressors, gears, hydraulic equipment, valves and staging clamps (variously replacing steel, bronze, malleable iron and grey cast iron), and there is reason to believe that the U.S. Navy is also adopting S.G. iron for other uses. In France, Le Bureau Veritas has accepted it for porthole frames and covers, bearings, and stuffing-box glands: in Belgium, l'Institut de Recherches pour Constructions Navales has sanctioned its use for several purposes, and in England, Lloyd's Register of Shipping is, according to normal practice, authorizing it for specified applications. The British Standards Institution is considering the drafting of specifications for S.G. iron in the near future.

Some typical castings for which S.G. iron has already been adopted are shown in Figs. 7 to 11 (Plate 2).

A further interesting use of S.G. iron, which is developing rapidly in this and other countries, is for crankshafts, for which its unusual properties render it especially suitable.

Although these are only selected examples, they serve to illustrate the extent to which this very new material has already established its position in the marine field.

HEAT-RESISTING MATERIALS

The interest of marine engineers in gas turbines for ship propulsion justifies some comment on materials for high-temperature service.

Papers recently read before this Institute have given a detailed report on the gas-turbine set installed in the tanker *Auris*(8, 9), and it may be recalled that the conclusion from the three years' experience with this engine was that "there is nothing in the operation of a gas turbine which is beyond the capacity of the average ship's engineer; that the gas turbine is not affected mechanically by any conditions likely to be encountered at sea in any part of the world, and that there is no reason why future gas turbine installations should not operate continuously on the longest voyages". It was also concluded that "apart from defects in material and workmanship, the life of the major parts (h.p. turbine blades excepted) of a conservatively rated installation will not be less than the life of the ship and that a life of not less than 10,000 hours may be confidently expected from the h.p. turbine blades if made of the best material now procurable".

The first rows of rotor blades are the most critical part of a gas turbine, and the metallurgist is set a difficult task in developing improved alloys, while the designer has a difficult task in selecting the most suitable materials for these components.

A basic problem facing both metallurgist and design engineer is that only by accelerated tests can a newly developed material be judged with respect to its suitability for long-time high-temperature service. Blade failures may occur through creep, fatigue, or corrosion. In creep-testing the demand for quick results may be met by using a high test stress and/or a high temperature, and then extrapolating to estimate the life under the design conditions. It is widely recognized, however, that extrapolation of high-temperature test data relating to one set of conditions, to other conditions in which temperature, stress or time is different, is unsafe. During long-time service alloys are commonly subject to structural changes which affect the properties, and the absence of this factor in accelerated tests may lead to unduly optimistic conclusions being drawn from them with regard to probable service behaviour. Most high-temperature alloys depend for their creep-resistance on the presence of a dispersed phase, particles of carbides or of intermetallic compounds, which may be too finely divided to be visible under the microscope. During prolonged heating these particles may agglomerate, with consequential loss in mechanical properties. Accelerating creep tests by raising the test temperature is more likely to allow this factor to come into operation, and is, therefore, to be preferred to the use of a raised stress alone. R. W. Bailey(10) has recently made a critical analysis of the various methods which are currently being used for the design of power plant for long life at high temperatures, dealing in particular with factors which tend to introduce discrepancies between data resulting from tests and behaviour under service conditions. His insistence on recognition of the vital significance of thermal action, as influencing the creep-resistance of materials at elevated temperatures, will receive strong support not only from those concerned with developing design data, but also from those engaged in the more fundamental study of creep phenomena. There will be general agreement with his conclusion that, in the interests of sound designing for long-term service, immediate and highly critical revision of test methods is imperative. In this connexion, some experimental data derived in the course of research on high-temperature alloys of the Nimonic series may be of interest in relation to materials for long-term service in marine and other gas turbines.

In work on Nimonic 80A, at 700 deg. C., at the stage when the maximum duration of test reached was about 2,000 hours, predictions were made by linear extrapolation to 5,000 and 10,000 hours, upon both double logarithmic and stress-log time plots. Tests had been made at several stress levels; three points on the fracture line and four on the 0·2 per cent strain line had already been obtained, and these gave good mean straight-line relations on both plots. Subsequent tests on the same batch of material at lower stresses, down to 7 tons per sq. in., and continued for 34,060 hours, made it possible to check the prediction with the results given in Table IV.

This shows that the established values vary above and below the ones predicted by the linear extrapolation on single logarithmic plotting, by amounts commensurate with the observed scatter of the experimental observations. There is a dominant trend, however, for the established values to be below those derived from the double-logarithmic plot. The question of scatter has always to be remembered in interpreting data, and it is made more difficult in long-time work by the practical difficulty of making repeat or duplicate tests. Attempts at statistical treatment are, therefore, impracticable, and the significance of isolated anomalous results cannot be assessed.

With respect to fatigue, not only must the factor of structural alteration be borne in mind, but, in addition, that of surface alteration. In even the best of heat-resisting alloys some surface change occurs during prolonged service. Some roughening of the surface due to oxidation is likely to occur and there may be also compositional alterations to a small depth, due to

TABLE IV.

Stresses for:—	Prediction at 2,000 hours		Established by tests up to 34,060 hours, tons per sq. in.
	From log stress-log time plot, tons per sq. in.	From stress-log time plot, tons per sq. in.	
0·2 per cent creep strain in 5,000 hours	11·2	10·2	10·0
0·2 per cent creep strain in 10,000 hours	9·9	8·2	7·8
Fracture in 5,000 hours	12·6	12·0	12·8
Fracture in 10,000 hours	10·9	9·7	10·6

diffusion and the preferential oxidation of one or more of the constituents of the alloy.

Fig. 12 (Plate 3) shows the altered surface layer on a Nimonic 90 turbine blade after service for 1,140 hours at 700-750 deg. C. The magnification is 2,000 diameters in the vertical direction—the altered layer has a thickness of 0·0005 inch. Extremely thin though this surface layer may be, it should not be ignored in the case of a turbine rotor blade which may be subjected to alternating stress in bending.

The fatigue testing of high-temperature materials is also complicated by the fact that the natural frequency of a turbine blade is generally greatly in excess of that which can be applied in laboratory fatigue tests. Fortunately, there is some evidence to show that, on the basis of cycles to failure, slightly higher stresses can be tolerated when the frequency is high.

In addition to the problem of ensuring adequate high-temperature mechanical properties in service, corrosion, arising from the fuel ash, is one of the major difficulties confronting those concerned with materials for gas turbines operating on fuel oil.

This matter has become familiarly known as "the vanadium pentoxide problem". The trouble arises not merely in the case of gas turbines, but also in superheater tube supports. The presence of vanadium, together with sulphur, chlorine and alkali-metal compounds, in fuel oils renders the turbine blades, in particular, subject to corrosion. The heat-resisting qualities of blading alloys depend on the formation of a protective surface film of oxide, but at temperatures above about 600 deg. C. the fuel ash is molten and acts as a flux, destroying the protective film and exposing the underlying metal to rapid destruction. Despite extensive research, no metallurgical solution to this problem is in sight. The rate of attack varies between different alloys, as has been shown, for example, by the work of Frederick and Eden(11), carried out in the laboratories of the Parsons and Marine Engine Turbine Research and Development Association (Pametrada), by Lamb and Duggan(9), by Evans(12), by Sykes and Shirley(13), and by Betteridge, Sachs and Lewis(14).

The relation between composition and resistance to attack by fuel ash is by no means fully established. It appears that the nickel-rich alloys are more resistant than the iron-rich alloys to attack by vanadium pentoxide, but the former are more susceptible to attack by sulphur compounds if combustion is incomplete. Unfortunately, it must be concluded that if working conditions are such as to involve metal temperatures exceeding 650 deg. C., none of the materials at present known is sufficiently resistant to offer promise of long service for the blading of industrial or marine turbines working on impure grades of fuel oil.

Various other methods of approach to this problem have been investigated and are still under consideration. For example, Shirley(13) and Frederick and Eden(11) found that resistance to attack can be improved by the use of protective coatings high in chromium, and in laboratory studies(11, 15) of the effect of certain inhibitory media, it has been reported that addition, to the ash, of controlled amounts of the oxides of magnesium, calcium, nickel, silicon or aluminium is beneficial, in raising the melting point of the vanadium compound and thus widening the temperature range in which metallic materials can operate without destruction of the protective film. Extensive research is currently in progress, under the auspices of the Council of British Manufacturers of Petroleum Equipment, Pametrada, and other organizations. In many cases the tests are being made in actual service conditions, in marine and industrial plant, and the results should eventually determine with certainty whether methods can be devised for preventing corrosion of materials in contact with fuel ashes, or whether it will be necessary to modify design of plants to provide for ash extraction.

The solution to "the vanadium pentoxide problem" may thus come from the oil industry, by virtue of inhibiting additions to the fuel oil, or otherwise. Alternatively, the solution may lie in the cooling of the critical components.

Much research has been carried out on the possibilities of producing turbine blades with axial holes for air cooling. It is well recognized that, if high efficiency is to be obtained, the least possible quantity of cooling air must be used, which points to the merits of a large surface area and small cross-section for the cooling passages.

Casting and sintering are two methods that have been tried for the production of turbine blades with a large number of small-diameter cooling passages. For highly-stressed parts operating at high temperatures, castings suffer from the disadvantage of being less uniform in properties, and hence less reliable than forgings, while the art of sintering has not yet been developed to the degree permitting mechanical properties to be obtained equal to those exhibited by wrought products of the same composition.

An interesting and promising recent development is the production of hollow blades by hot extrusion. In this process the heat-resisting alloy billet is drilled with the desired number of holes having the necessary shape and location. These holes are then plugged with an appropriate material. The billet is extruded to give the required section, and the plugs are removed by treatment in acid. Naturally, the plug or core material must be such that it deforms satisfactorily during extrusion, and dissolves readily in an acid which is non-corrosive towards the blade material.

Where taper or twist is required, further working operations may precede the removal of the cores. Where blades with an integral root are required two extrusion operations are applied. Firstly bar, having a cross-section near to that of the root, is extruded. This bar is cut into slugs, which are re-extruded singly, using a die corresponding to the desired blade section and with an arrangement to stop the press so that the metal necessary to provide the integral root remains in the container. Such blades may be subjected to a drop-forging operation before the removal of the cores.

It appears to be an economic procedure to produce hollow blades by this technique, with passages limited in number, size, and shape only by the operations involved in machining the original billet. Some sections of blades which have been produced by this method are illustrated in Fig. 13 (Plate 3). An example of the integral-root type of extruded hollow blade is shown in Fig. 14 (Plate 3).

The application of extrusion to high-temperature alloys has opened up a wide field for further advancement. The metallurgist is faced with the demand for alloys which will be stiff at high service temperature and yet be amenable to hot-working, so as to develop the characteristic merits of a wrought structure. Service temperatures have been continuously rising, with a corresponding reduction in the difference between the operating temperature, when the material must be stiff, and the forging temperature, at which the material must be readily malleable. Furthermore, higher operating temperatures demand higher alloy contents, which involve a reduction in forgeability. A stage is being approached where alloys for still more onerous service cannot be forged economically by normal techniques.

Fortunately, extrusion is a less severe operation than forging, the metal being well supported as it is deformed. The danger of cracking is thus reduced, and once the coarse-grained cast structure of the ingot has been broken down, forgeability is greatly improved and ordinary hot- and cold-working operations may be applied to give the desired finished dimensions.

Nimonic 90, a well-established gas-turbine blade alloy, has the composition: chromium 20, cobalt 16, titanium 2½, aluminium 1¼ per cent, balance nickel. The combined contents of titanium and aluminium (3¾ per cent) primarily determine the stiffness of the alloy at high temperatures, but are also responsible for the difficulties in hot-working. When the initial breakdown of the ingot is done by extrusion, it has been found that the titanium + aluminium content can be raised to levels exceeding 5 per cent, and this points to wrought alloys becoming commercially available which will withstand considerably more onerous service than those currently employed.

The recent introduction of Nimonic 95 represents a step in this direction. In this alloy the titanium content is designed to be 3 per cent and the aluminium content 1¾ per cent—a total of these stiffening additions of 4¾ per cent. The normal composition is thus—chromium 20, cobalt 16, titanium 3, aluminium 1¾ per cent, balance nickel. By virtue of the higher titanium+aluminium contents, Nimonic 95 exhibits properties equal to those of Nimonic 90, but at a temperature about 25 deg. C. higher. The alloy gives valuable short-term service at 925 deg. C., but the long-term properties have not, of course, yet been determined. There is good reason to anticipate that it may be possible to use still higher percentages of titanium and aluminium, with corresponding further improvement in properties.

HARD-SURFACING MATERIALS

A relatively recent development which appears to have far-reaching practical interest in the marine field is that of hard-surfacing, with materials which will withstand corrosive, erosive, and high-temperature conditions. Welded-on coatings of the cobalt-chromium (Stellite) type have been employed for many years for facing of cutting tools, steam-valve seats, parts of centrifugal pumps, and other components, and an outstanding example of the usefulness of facing treatment in high-temperature engineering is provided by the coating of valve heads with 80-20 nickel-chromium alloy, the well-known Brightray coating, which has been successfully applied in the automobile and aero-engine fields.

A still more recent development of the same principle is the use of fused-on coatings, employing powder alloys of nickel-chromium base in which a substantial percentage of boron is incorporated. The nature of these alloys is such as to confer a valuable combination of hardness, and resistance to corrosion and erosion, which is well maintained at elevated temperatures. The U.S. Naval authorities have reported successful experiments in treatment, by "fused metallizing" of propellers and propeller shafting, using a nickel-chromium-boron alloy containing a small percentage of silicon(16). The coatings were found to give good resistance to sea-water attack, and the process is being developed, not only for treatment of the components mentioned, but also for protection of the arrester hooks of carrier-based aircraft.

The nickel-chromium-boron alloys provide hardness values similar to those obtained with cobalt-chromium alloys, and their resistance to corrosion is better, particularly in contact with softened boiler-feed waters. The main advantage in the use of the nickel-chromium-boron alloys is, however, the ease with which they can be applied. The temperature of application is considerably below that necessary for the cobalt-chromium alloys (melting points of the two types are 1,050 deg. C. and 1,175 deg. C. respectively), and the nickel-base alloys are much more fluid, with the result that they can be deposited, by spray-welding methods, to tolerances of 0·005 inch. Application is normally effected by spray gun, using powder directly, or an extruded plastic wire incorporating the powder, after which the sprayed deposit is fused by oxy-acetylene torch.

The possibility of maintaining close dimensional tolerances and minimum machining or grinding allowances is due largely to the very smooth surface of the deposited nickel-alloy coating (see Fig. 15 (Plate 4)) and this smooth surface also makes it possible to machine the coatings with tungsten-carbide tools. The adhesion of the coating to the base material is excellent, as indicated in Fig. 16 (Plate 4).

This paper has been centred on some recent developments in cast copper-base alloys, spheroidal-graphite cast irons and high-temperature alloys, with which the author has been closely associated. As much again could well be said about aluminium alloys, titanium alloys and numerous other materials, the metallurgy of which has been advanced significantly in recent years. On some of these subjects there is already a significant literature.

BIBLIOGRAPHY

1. JOHNSON, L. W., and BRADBURY, E. J. 1951. "Corrosion-resistant Materials". Trans.I.Mar.E., Vol. 63, pp. 59-74; Discussion, pp. 75-80.
2. REICHENECKER, W. J. 1953. "How Section Size Influences Strength Properties of Sand Castings". Materials and Methods, Vol. 38, July, pp. 80-81.
3. EASH, J. T., and LEE, G. L. 1953. "Properties of Graphitic Nickel Alloy Castings". Trans.Amer. Foundrymen's Soc., Vol. 61, pp. 552-559; Discussion, p. 560.
4. GILBERT, P. T. 1954. "Resistance to Failure of Condenser and Heat-exchanger Tubes in Marine Service". Trans.I.Mar.E., Vol. 66, pp. 1-6; Discussion, pp. 6-20.
5. HALLETT, M. M. 1952. "Ductile Cast Iron". Trans.I. Mar.E., Vol. 64, pp. 25-30; Discussion, pp. 30-35.
6. EVEREST, A. B. 1952. "The Engineering Properties and Applications of Spheroidal-graphite Cast Iron". Fourth International Mechanical Engineering Congress, June 1952; 23 pp.
7. Military Specification. "Iron Castings: Nodular Graphitic (Ductile Iron) (For Shipboard Applications)". U.S. MIL-I-17166A (Ships); 10th April 1953.
8. FORSLING, B. E. G. 1953. "The Marine Gas Turbine". Trans.I.Mar.E., Vol. 65, pp. 265-273.
9. LAMB, J., and DUGGAN, R. M. 1953. "Operation of a Marine Gas Turbine Under Sea Conditions". Trans. I.Mar.E., Vol. 65, pp. 277-292; Discussion, pp. 293-304.
10. BAILEY, R. W. 1954. "A Critical Examination of Procedures Used in Britain and the United States to Determine Creep Stresses for the Design of Power Plant for Long Life at High Temperatures". Proc.I. Mech.E., Vol. 168.
11. FREDERICK, S. H., and EDEN, T. F. 1954. "Corrosion Aspects of the Vanadium Problem in Gas Turbines". Proc.I.Mech.E., Vol. 168, pp. 125-131; Discussion, pp. 131-134.
12. EVANS, C. T. 1951. "Oil Ash Corrosion of Materials at Elevated Temperatures". Amer.Soc.Testing Materials. Symposium on Corrosion of Materials at Elevated Temperatures, pp. 91-105; Discussion, pp. 106-113.
13. SYKES, C., and SHIRLEY, H. T. 1951. "Scaling of Heat-resisting Steels. Influence of Combustible Sulphur and Oil-fuel Ash Constituents". Iron and Steel Inst. Symposium on High-temperature Steels and Alloys for Gas Turbines. Iron and Steel Inst. Special Report 43, pp. 153-169.
14. BETTERIDGE, W., SACHS, K., and LEWIS, H. "Influence of Vanadium Pentoxide on the High-temperature Scaling of Heat-resisting Alloys", to be published shortly.
15. MONKMAN, F. C., and GRANT, N. J. 1953. "An Investigation of Accelerated Oxidation of Heat-resistant Metals due to Vanadium". Corrosion, Vol. 9, pp. 460-465; Discussion, pp. 465-466.
16. SAYRE, H. S. 1952. "Development of Fused Metallized Coatings". Welding Jnl., Vol. 31, pp. 35-39.

Discussion

Mr. M. M. Hallett, M.Sc. (Member) said that it gave him particular pleasure to open the discussion because he had the great privilege of working under Dr. Pfeil for some twelve years, a period which he looked back to as one of great happiness and considerable profit to himself. He did not know what Dr. Pfeil thought about it!

Considering first the copper-base alloys, Dr. Pfeil's demonstration of the dependence of the mechanical properties of the common 85/5/5/5 alloy on section-thickness and the much better showing of the other more complex alloys, such as the aluminium bronzes and particularly those with nickel, was very convincing.

He was not familiar himself with the work of Reichenecker which was cited in the paper, and he was intrigued by the step-bar casting Reichenecker had used. The geometry of the steps did not appear to be consistent. While the thinner ones were sufficiently wide for the influence of the section to be related purely to thickness, the heavier sections were squares, and their rates of cooling must be very markedly dependent on their neighbouring sections.

As a foundryman, looking at the riser he would have been very doubtful whether it was large enough to feed that heavy section. He wondered whether the deterioration in the properties of some of these alloys in the heavy section was, in fact, a matter of micro-porosity. That did not appear to be entirely likely, because in fact the 85/5/5/5 had a fairly good reputation in the foundry.

He had one other remark to make on soundness. In certain limited cases, one could make use of centrifugal casting to give absolutely sound alloys in aluminium and other bronzes, but only in certain applications where the shape was suitable, such as propeller shaft liners.

Graphitic nickel was a fascinating alloy and one for which he had always felt there ought to be some good application. But he had not yet found a customer who was prepared to pay for it in reasonable quantities. He was afraid he looked at this alloy rather from the cast iron point of view. He wondered whether the conferring on it of really good mechanical properties by turning the graphite into spheroidal-graphite might be at the expense of its self-lubricating properties—its gall-resistance, if one preferred to put it that way—because there was not much doubt that the self-lubricating properties of flake-graphite irons were better than those of spheroidal-graphite irons. It might be that the ordinary flake-graphite nickel would prove better in some applications.

To carry on the same thought, another alloy with which Dr. Pfeil was very familiar was also used widely in marine engineering for special cases of gall-resistance; namely, high silicon Monel, S-Monel. Was there any reason why these two developments should not be combined and why there should not be a spheroidal-graphite or flake-graphite S-Monel, giving an ideal matrix and an ideal form of graphite, suited to particular applications?

With regard to spheroidal-graphite iron, he would suggest, with very great trepidation, that Dr. Pfeil had been a little optimistic in quoting his Izod impact values. He would seem to have quoted maxima rather than averages. Far be it from him in any way to decry the thought that spheroidal-graphite iron had a very much better impact strength than flake-graphite iron. It was, of course, enormously superior. But he was frightened that someone might come along and insist on applying as a specification requirement for "as-cast" spheroidal-graphite iron an impact value of 4 ft.-lb. He would hate to meet that specification. It could be met at great expense in certain types of iron but one would be very lucky to get it with ordinary types of pig iron available commercially in this country. For the annealed material, 12 ft.-lb. would be a little nearer the truth, but even that would represent the best combination of the most favourable factors.

Dr. Pfeil himself said that he did not believe the one ft.-lb. value on flake-graphite iron, and his (Mr. Hallett's) comments on impact values applied just as much to the one ft.-lb. as to the others, so the relationship between the various irons was perfectly correct.

Dr. Pfeil had rightly devoted a considerable part of his paper to the development of heat-resisting alloys for gas turbine applications. This was a field in which Dr. Pfeil had played an absolutely predominant part by developing the Nimonic series of alloys which were unquestionably one of the keys to the successful use of gas turbines today.

Looking back, perhaps, some ten years, he remembered the thought developing that the most successful creep resistance was achieved when the added elements were at about the solid solubility limit. Did that theory still hold today? As Dr. Pfeil had just pointed out, Nimonic 95 contained large amounts of titanium plus aluminium. Without being too familiar with the exact solid solubilities in these complex alloys, he would expect that these limits were in excess of solid solubilities. It might be that thought on this matter had changed. Admittedly, one had to bear in mind hot workability, a position which had been eased by the developments in extrusion.

Mr. B. Todd, M.Eng., said he must first tender the apologies of Mr. L. Baker who was unfortunately unable to be present, and for whom he was deputizing. The remarks he was about to make were mainly Mr. Baker's with a few of his own thrown in.

He would like to begin by thanking Dr. Pfeil for a very instructive survey of a collection of alloys most of which were new to marine engineers and, he must confess, to a metallurgist employed in the marine engineering field.

Although a lot could be said about several of these alloys, he intended to confine his remarks to spheroidal-graphite cast irons. These irons were being used to an increasing extent in marine engineering, and a lot of experience was being gained about them. It would be to the benefit of all if this experience were shared.

His company's first venture in the spheroidal-graphite iron field was with a main engine piston described by Arnold*. This casting had now been in service for three years and was quite satisfactory as regards scaling resistance and wear and also resistance to cracking, which was important in any Diesel engine piston. Assuming that the cracking often found on an

---

* Arnold, A. G. 1953. "The Burning of Boiler Oil in Two- and Four-stroke Cycle Diesel Engines and the Development of Fuel Injection Equipment", Trans.I.Mar.E., Vol. LXV, p. 57.

ordinary cast iron piston was caused by a process of creep and consequent residual stress, the nodular iron piston offered a very likely remedy.

Foundries usually supplied spheroidal-graphite irons either in the as-cast condition with a pearlitic matrix or in the annealed condition with a ferritic matrix. Sometimes the engineer was uncertain as to which to order, and the foundry, often unfamiliar with the job in question, was not qualified to give advice. As an example of this, when his company placed an order for a number of auxiliary engine cylinder liners without specifying the microstructure required, the foundry supplied them in the annealed (ferritic) condition. A short time after some of these liners were placed in service, a piston seizure was experienced in one of them. In several zones round the skirt of the piston and on the liner there was what appeared to be a surface disintegration, as though particles had been torn bodily from the piston surface and the liner surface. This failure might very well be attributed to the very soft matrix of the liner. The piston was, of course, an ordinary grey iron one. This did illustrate the danger which might arise from ordering the wrong type of spheroidal-graphite cast iron.

One curious feature of the failure, however, was a change in dimensions noted on the liner. This was found to be 7 thou oval in the bore. The ovality was not caused by wear, however, but by a decrease in one diameter of the bore. This would have been dismissed as consequential damage due to the piston seizure but for the fact that there was a report of a partial piston seizure in another spheroidal-graphite iron liner. In this case, a short time after fitting the liner, the chief engineer by some means—intuition or otherwise—felt that the engine was not running as smoothly as it should. He opened up the cylinder to investigate and found that the initial clearance between piston and liner had entirely disappeared. The piston was removed and found to be gummed up. It was covered with a kind of varnish. This was cleaned off and the piston was returned to service. It had run satisfactorily ever since. Could Dr. Pfeil offer any explanation for these changes in dimensions which, although doubtful, might be real?

Whilst on the subject of cylinder liners, and in passing, he would like to state that these liners had only been in service for a short time, and it had not been possible to obtain any reliable wear figures from them. In spite of the undesirable microstructure, however, the wear had been too small to measure in about 2,000 hours' service.

He was pleased to note that the British Standards Institution was considering drawing up specifications for spheroidal-graphite irons in the near future. He hoped they would do so. Such a specification was most necessary, as there were many factors to contend with in ensuring a satisfactory spheroidal-graphite iron casting. In his own opinion, the problem was less acute where fully annealed castings were required, since the heat treatment would tend to remove mistakes in foundry technique which might produce a faulty as-cast structure. However, in the as-cast condition, where the foundry attempted to produce an all-pearlitic matrix for optimum strength and wear resistance, a satisfactory specification was much more difficult to produce. It would have to ensure that the matrix was as nearly pearlitic as possible in the important parts of the casting. On a piston, this would be the ring grooves and crown. That would imply some correlation between the size of the test block used to test the casting and the section of the casting under consideration, as well as some form of metallographic acceptance test. The latter would have to be applied to the test bar made from the block to ensure that the structure was what was wanted.

In conclusion, he would like to ask Dr. Pfeil whether he thought anything could be done to increase the number of foundries making spheriodal-graphite irons. At present, production was concentrated mainly on fairly large mass production foundries which required large orders for economical production. Although this was satisfactory for large orders, it was most unsatisfactory where a single casting was required in a hurry. In the ordinary grey iron field the need was met satisfactorily by the small jobbing foundry. Before the uses of spheroidal-graphite iron could be expanded to the full, these small foundries would have to be encouraged to take up its production in order to meet replacement requirements.

MR. J. MCAFEE (Member) said that Dr. Pfeil opened his instructive paper with some observations on the effect of section thickness on the properties of copper-base alloy castings and pointed out that test bars did not establish the properties of the casting itself. He did suggest, however, that the test bar provided a guide.

The bronze propeller was the largest and most important casting of this type with which the marine engineer had to deal so that perhaps one might be forgiven for enlarging on this aspect of the matter. Before acceptance of such castings, it had been the practice for many years to ensure that test pieces cast with the propeller complied with certain standards of tensile strength and ductility, it being assumed that if the desirable characteristics were obtained in the test pieces, then the propeller material itself would also be satisfactory.

The failure of blades in service, without evidence of shock or overloading, had put in doubt the value of this method of testing, particularly when it was revealed that samples cut from the broken blades gave results widely different from those obtained from the original test pieces.

He had examined various broken propellers made both in this country and on the Continent and found that in all cases the conspicuous feature was low elongation of the order of 6 per cent to 12 per cent on 2-in. gauge, figures which would not have been accepted had they been revealed by the original test pieces. This had made him wonder if the part of the propeller to which the test piece was attached had any influence and he had accordingly arranged for a number of large solid propellers of various sizes to be made with a test bar cast edge on to each blade at various radii and also one on each boss. Tests made from these pieces all indicated that position had little influence, there being uniformity between any one set from the blades and only an insignificant drop in the characteristics obtained when the piece was situated on the boss. Different authorities had different requirements for propeller testing, some calling for one test piece only, others for a test piece from two opposite blades, or else one on one blade and one on the boss. From what had been said, however, it was now suggested that these detailed requirements were not necessary and the main issue was to determine what value could be attached to the present general system of testing.

He had recently come across an article in the Italian technical press describing an interesting investigation on six manganese bronze propellers, which was carried out by two of the officials at Messrs. Ansaldo's works in Genoa. They had first of all positioned test pieces at various points and results from these confirmed the opinion stated above, as the average difference in tensile strength between test pieces of blades and boss was only a little over ½ ton per sq. in. with a corresponding average drop in ductility of 1·26 per cent on 5D. Three of these propellers, ranging from 4½ tons to 14½ tons in weight, were then cut up and test pieces prepared from various sections. The results were startling, showing that the actual tensile strength of the blade material was on the average 20 per cent below that indicated by the test piece, whilst the drop in ductility was even greater, being only about one-half of the test piece value.

He himself had an opportuninty to carry out tests on two damaged propellers with somewhat similar results:—

	Test piece		Actual blade material	
	U.T.S. tons per sq in.	Elongation, per cent	U.T.S. tons per sq. in.	Elongation, per cent
Propeller No. 1 ...	34·8	20	27	12
Propeller No. 2 ...	28·5	19	23	12

One feature of all the results which had struck him was the complete lack of any consistency in the drop in values between test bars and plate material, which made him doubt if it were strictly true, as Dr. Pfeil had suggested, that the test piece was a guide to the characteristics of the casting. This lack of consistency was perhaps to be expected since results depended on grain size, which depended in turn on rate of cooling. One peculiarity in this connexion was revealed by sectional examination of blades and confirmed by mechanical tests taken at various points across the same blade thickness section. These showed a finer grain with corresponding superior mechanical qualities in the part of the blade lowermost in the mould, which was usually the ahead driving face. No doubt the mould itself as well as the metal to be cooled played its part in the rate of cooling, but he was puzzled to know why the upper and lower halves of the mould produced different effects and wondered if the average brass founder gave the same attention to such matters as was evident in the steel industry. One could imagine the consternation which would arise if it were suddenly revealed that the common steel test piece bore little or no relation to the steel casting or forging which it was supposed to represent.

It was known, of course, that certain propeller manufacturers had vigorously tackled these problems and were producing castings of much improved characteristics from new alloys such as Dr. Pfeil described. The normal manganese bronze propeller of approximately 56/44 copper-zinc base would, however, be produced in foundries throughout the world for many years to come and this was an excuse for dwelling on an old matter which, as such, was somewhat outside the title of such an interesting and varied paper.

MR. R. MUNTON, B.Sc. (Member of Council) said that from the copper-base alloy point of view, the propeller was the most important application in the marine field. One very important test that had not been covered by the results given in the paper was the fatigue test. It was his own experience that where a complete fracture had occurred, apart from actual impact, there was evidence of fatigue failure. Fatigue test results from the step-bar casting would be of interest.

There was one specific reference in the paper to "Novoston". As far as he was aware, however, it was not covered by Dr. Pfeil's table, and particulars of that alloy with comparable test figures would be appreciated. The other new alloy that was offered for propellers—the Manganese Bronze and Brass Company's "Nikalium"—approximated to the F specification in the table.

He certainly had the impression—and he thought it was shared by other people—that the modern cast irons were not so good from the corrosion point of view as the older cast iron made without anything like the same control. Many of the uses for which cast iron was employed in the marine field required good corrosion resistance and Dr. Pfeil stated that the new cast irons with the spheriodal-graphite structure were as good as the older ones. Unfortunately (from the corrosion point of view), associated with the S.G. irons was the increase in mechanical properties. He himself felt that in applications where corrosion-resisting qualities were desired, too much advantage might be taken of the higher mechanical properties, so that although the specific resistance might be as good, a much quicker actual corrosion through to the danger point would occur.

MR. R. N. RICHARDSON (Member) asked whether he would be in order in referring to certain propeller questions, which had been raised by some previous speakers.

The CHAIRMAN said that that would be quite in order.

MR. RICHARDSON drew attention to Dr. Pfeil's statement that little information was available to the designer regarding mechanical properties. With every deference he would like to ask whether that was correct. After all, one could very easily obtain tensiles, yield points, elastic limits, elongation, corrosive fatigue, Uncle Tom Cobley and all, but he would like to know on what properties the engineer based his design. He might be quite wrong, but as far as he could make out there was no unanimity on this subject. Perhaps Dr. Pfeil would kindly enlarge on that.

On the Reichenecker tests he was going to be extremely bold and to query some of Dr. Pfeil's figures. For example, for F he showed for ½-in. and 2-in. section respectively, tensile strength increasing from 38 to 39 tons and elongation increasing, as far as one could read the somewhat small figures, from 12 to 25 per cent. Dr. Pfeil suggested that this was because this particular alloy was of the type influenced by heat treatment, and that it was due to the rate of cooling. If that were so, would it not be true to say that that increase would be progressive to some extent, and that tensile strength and elongation would increase with section increase over 2 inches? He did not know, but he would say with considerable assurance that 38 tons and 12 per cent were extraordinarily bad figures which would not be tolerated. A more normal minimum figure was the higher one—39 tons and 25 per cent, although perhaps 20 per cent would be nearer the mark and 40 tons was easily obtainable in an alloy of the 80/10/5/5 type. It was conceivable, therefore, that the smaller test bars were not as sound as they might be, a point to which Mr. Hallett had, he thought, referred. By the same token it might be of interest to note that if the thickness be increased to six inches the tensile and elongation figures remained about 85 to 90 per cent of those of the 1-inch separately cast bar.

He could fully endorse Dr. Pfeil's remarks about the foundry difficulties with these alloys. It was very curious because they had been used for many years for small castings, and everyone felt, not unnaturally, that it would be a simple matter to increase the size of castings, but it did not turn out that way. The company with which he was associated managed one- and two-tonners quite satisfactorily. Then they went to three, four and four-and-a-half tons and after that, they thought they could go to ten-tonners but they had so many failures, which were so expensive, that they nearly gave it up. He was glad to say, however, that they had persevered and eventually they had found out how to do it. There was no abracadabra; he supposed it was largely trial and error.

Mr. McAfee, who mentioned Italian propellers, was obviously talking about manganese bronze and not one of these new alloys. He agreed that with manganese bronze the thicker the section the lower the mechanical test figures. To avoid this it was necessary to find a method of increasing the rate of cooling of heavy sections so that a section of, say, 12 inches could cool at the same rate as a 1-inch section. Nobody had found out how to do that as yet. To repeat, that was manganese bronze, and one of the major advantages of the new alloys was the close relationship between the properties of thick and thin sections.

The failure of the propellers might or might not have been due to the discrepancies referred to. It was very important to bear in mind that a lot of propeller failures were due, not to the material being intrinsically at fault, but to the fact that they were overstressed in service, i.e. the blade thicknesses were inadequate.

On the 85/5/5/5 alloy, the gunmetal, he merely sought for information. Dr. Pfeil had pointed out that the substitution of 2 per cent nickel for part of the tin maintained the mechanical properties in heavier sections. Did this affect the bearing qualities of the alloy?

Nickel-containing speroidal graphite was new to him and was extremely interesting. Would it be fair to assume that the spheroidizing worked in the same way as in cast iron by the addition of the magnesium, and was the mechanism of the action of magnesium known?

He was not qualified to discuss "condenseritis" in detail, but whenever this subject cropped up someone was bound to say, "Yes, but the material one obtains nowadays is nothing like what it used to be". If one asked for precise details, one was told that there were more impurities in the copper or nickel or what have you. But (*a*) was that correct? and (*b*) was it considered that minute percentages of impurities could have such effects as they were said to have?

On the question of nodular versus ordinary grey cast iron, Dr. Pfeil made a remark which he could only describe as naïve. He said that the corrosion resistance of the nodular iron was equal to that of ordinary grey cast iron. That might well be so but he had never understood that cast iron was generally chosen on account of its resistance to corrosion.

Dr. Pfeil did not actually refer in his remarks to the final part of his paper, which mentioned an extraordinarily interesting process of nickel-chromium-boron being used for surfacing or fused-metallizing of propellers. He mentioned a somewhat high temperature of 1,050 to 1,175 deg. C. That made him (Mr. Richardson) wonder whether he was referring to the metallizing of steel or iron or bronze propellers, or what sort of propellers they were. Perhaps Dr. Pfeil would enlarge on that and would give further information. It would be particularly interesting to know what happened when a little bit of the surfacing was knocked off. Would not a little galvanic battery, as it were, be formed which would increase local corrosion?

Finally, it was a little disappointing that Dr. Pfeil had not referred to the so-called wonder element, titanium, about which so much was heard nowadays. As far as he was aware, titanium alloys had so far been used essentially for aircraft because of their specific tenacity. But everyone, he thought, would like to know whether it had applications to the marine world. If he might ask a specific question, was he correct in saying that an aluminium bronze containing up to 5 per cent titanium had proved to have interesting mechanical properties and marked corrosion resistance?

MR. G. S. JACKSON (Member) said he wished to apologize for the absence of Mr. R. K. Craig who was to have made a few comments. He must first bring to the notice of the meeting the wonderful new alloy for propellers, "Novoston" or "Nikalium". It did not matter which one called it: the composition was almost the same. Its properties had been tested over a period of about fifteen months and they had proved to be as outlined, particularly in regard to corrosion resistance.

He himself was concerned mainly with costs in operation. With the normal manganese bronze propeller and the finer-section solid propeller that had been used latterly for high efficiencies and so on, one was faced with complete renewal after about six years, owing to erosion or corrosion. The new metal had solved that difficulty to a great extent. He did not propose to dwell too long on that point, but there was every hope, in the future, of keeping the costs within hailing distance of operating efficiency.

Engineers looked upon graphitic nickels with hope, but the cost again was beyond any owner or engineer, except for experimental purposes, at the moment.

With packing rings, or labyrinth packing in between turbine stages, referring particularly to steam turbines with a fair amount of superheat, 750 to 800 degrees, was there any fear of creeping or galling due to fluctuating temperatures and consequent rotor bending on some such condition? The idea had occurred to two or three people, and he would be glad to know whether there was any information on this subject.

One point struck him as being a bone of contention with regard to spheroidal cast iron. Due to corrosion-resisting properties, for many years cast iron had been looked upon as a stand-by and friend in all jobs for sea valves and such applications. Was there any hope that ultimately it would have the same strength as cast steel and produce none of the corrosive fatalities that were obtained with cast steel? Some of the speakers seemed to have some doubt about corrosion. Corrosion resistance was said to be improved with spheroidal-graphite cast iron, but could that question be elucidated? Under present regulations, the owner had to fit cast-steel ship-side valves and/or gunmetal valves. But many people clung to the idea that cast iron had not quite vanished as far as ship-side valves were concerned.

He would like to draw particular attention to the reference to vanadium pentoxide trouble. That, unfortunately, was ever with them! At the moment, the oil-engine users and the boiler operators were very much alive to it. It was certainly manifest, in reading today's press, that colossal profits and trading accounts of oil concerns showed definitely that the shipowner was paying much too much for the oil he used in comparison with the trouble regarding this vanadium pentoxide that followed the purchase. Could not metallurgists and chemists come to some quick understanding so far as the solution of this problem was concerned, with particular reference to wastage and breakdown in heat-resisting steels used in boilers and Diesel engines?

The interest shown by so many people in the wonder metal, titanium, might be due to the fact that they had all read the "Readers' Digest" for this month, which contained an article by an American who expected everything from it. As far as engineering was concerned, they were all very interested in its future and in whether it could be used in high-tempered carbiding on heat-resisting alloys or in safeguarding fatigue and wear in high temperature jobs. Would it, in fact, have any bearing on future design? As far as heat transference was concerned, with atomics to be used as power in the future, was there any development in that connexion?

MR. G. P. SMEDLEY, B.Eng., B.Met., said, with regard to the section on heat-resisting materials, that he found it difficult to interpret the significance of the extrapolation of the creep data given in Table IV of the paper. The results, derived from creep tests of less than 2,000 hours, were stated to have been plotted on both a stress-log time basis and a double-log basis and then extrapolated. It seemed fairly obvious that if the plot on a stress-log time basis was a straight line, it should also be the same straight line on a log-log plot. However, the given values of extrapolation to 10,000 hours were different, whereas it appeared to him that they should be the same. Admittedly, an extrapolation on a basis of three to four points might account for this discrepancy, but he would like to have Dr. Pfeil's opinion. He considered that the best method of extrapolation was to obtain a few more points by short time test and then obtain a regression equation by statistical methods which could be extrapolated and should give the same values for either plot.

With reference to the surface layer formed on Nimonic alloys at elevated temperatures, he wondered whether the author would give a little more information of the influence of these layers on the fatigue strength of the material. It was stated in the paper that the influence of this layer should be taken into account when considering the bending fatigue strength of turbine blades, but he was not quite sure how this could be achieved without reliable information. He also asked whether its importance was of such a magnitude as to annul the increase in fatigue strength obtained at higher frequencies of vibration.

Finally, with regard to the spheroidal-graphite high-tensile cast irons, only room temperature properties had been quoted. There had been considerable expression of opinion of their suitability for service at elevated temperatures as steam valves and fittings. However, these opinions were not generally accepted and he would like Dr. Pfeil's comments on what he regarded as the maximum operating temperature conditions for these nodular cast irons.

Correspondence

MR. F. J. COLVILL (Member of Council) wrote that the paper, in addition to giving a valuable survey of some of the more important new alloys now available for use in marine engineering, also provided interesting information on the question of the influence of thickness on the mechanical properties of castings made from the common copper-based alloys.

The material in which he was particularly interested was the S.G. cast iron and its possible application to such fittings as ships' side valves including main and auxiliary inlets and discharges, scupper and sanitary discharges and side scuttles.

It had been realized for some time that ordinary grey cast iron was most unsuitable for castings for the purposes mentioned. When vessels sustained damage due to collision, grounding or ranging against a quay wall, the shell plating was set in and any fittings made from brittle cast material which might be in the vicinity invariably fractured, with the resultant flooding of the compartment. With castings made from ductile material which were capable of bending, considerable damage could be sustained with negligible or controllable leakage and this was of vital importance where the safety of life or loss of a valuable ship might result from the use of unsuitable material at a small saving in cost.

The Merchant Shipping (Construction) Rules 1952 issued by the Ministry of Transport and Civil Aviation to implement the Safety of Life at Sea Convention of 1948, and which applied to passenger ships, required cocks and valves attached to inlets and discharges at shell plating and main and auxiliary inlets and discharges of more than 3-in. bore in the machinery spaces to be made of steel, bronze or other equally efficient material. Such material would be expected to be capable of bending under excessive loads to a suitable angle and of yielding appreciably without fracture.

Perhaps the author could give some more information on properties of S.G. cast iron, especially in connexion with bend tests, as to what angles of bend had been obtained or could be expected on the standard 1-in. by ¾-in. test piece. The properties given by the author in Table II gave an elongation of between 10 and 25 per cent for the annealed condition; did this mean that the usual elongation was in the neighbourhood of 10 per cent and that 25 per cent was only likely to be obtained under laboratory conditions? The range appeared to be very wide and did not tend to create confidence in the consistency of this important property. In this connexion it was interesting to note that the tentative specifications for nodular iron castings issued by the American Society for Testing Materials required an elongation of 3 per cent for grade 80/60/03 and 10 per cent on grade 60/45/10 on a length of 2 inches.

Could the author enlighten them on whether the American specification was all that could be expected in this property of elongation from commercial quality S.G. iron from the average foundry?

The superiority of the S.G. cast iron over the ordinary grey variety was unquestionable in all its important properties and undoubtedly it would play an increasing part in marine engineering development. In the absence of a suitable British Standard Specification, any further information which the author might be able to give to assist in deciding on possible fields of application, would be most welcome.

Author's Reply

DR. PFEIL said that he was indeed happy to have the discussion opened by Mr. Hallett, on whose association with the Birmingham Laboratory all his colleagues looked back with pleasure.

In reply to Mr. Hallett's comment on the step-bar casting used by Reichenecker, admittedly the geometry of the steps was not consistent, but the same could be said about the design of most castings used in industry, and it was considered that the advantage of obtaining results comparative with those of another worker in this field outweighed the minor criticism regarding design. Furthermore, it might be pointed out that the particular design of step-bar casting employed had certain economic advantages, since it minimized the weight of metal required while simultaneously ensuring that each individual metal section was of ample size to provide the required number of machined test-pieces. It should, however, be emphasized that in the work in their own laboratories they had considered it preferable to modify the feeding method employed by Reichenecker, by using a large tapered riser covering the entire top of the heaviest section.

Regarding the effect of the form of graphite on the gall-resistance of cast graphitic nickel, there could be no doubt that in alloys of equal carbon content the self-lubricating properties of flake-graphite were better than those of spheroidal graphite. Results of gall tests given in the paper by Eash and Lee(3) indicated that in order to obtain comparable anti-galling properties a greater amount of spheroidal graphite than of flake graphite was needed. Flake graphite, being more widely dispersed and having a greater surface area, provided more uniform lubrication.

In reply to Mr. Hallett's suggestion as to a graphitic form of "S" Monel, one of the great difficulties attached to the practical development of spheroidal- or flake-graphite "S" Monel was the effect of copper on the solubility of both carbon and silicon. Whereas nickel would retain about 5·5 per cent silicon in solution, solubility decreased to about 1·6 per cent in cast Monel containing 30 per cent copper. Increasing the silicon content to 3 or 4 per cent resulted in the formation of free silicides, which increased hardness and tensile strength, but reduced elongation and impact value. It had been found that the addition of appreciable amounts of carbon to "S" Monel gave rise to a marked reduction in mechanical properties and that the properties required in commercial castings could be obtained only by ensuring that the carbon content did not exceed 0·15 per cent.

With regard to the impact figures given for S.G. iron, he would confirm that the values were typical of those readily being obtained in large-scale practice, although it would naturally be recognized that specification minima would have to be scaled down somewhat. The important point, however, was that the shock-resistance of S.G. iron was so substantially greater than that obtainable in flake-graphite irons that S.G. iron could be successfully used for applications for which cast iron was previously prohibited due to its inherent brittleness. An important factor in this connexion was the impact-transition range. Recent work by Carr and Steven* had demonstrated that by control of composition it was possible readily to produce S.G. iron castings, the transition range of which was well below room temperature. Pellini† had also demonstrated the same feature, and had shown that it was practicable to specify, for S.G. iron, properties which were acceptable to the U.S. naval authorities for marine castings. With regard to mode of determination of impact properties, it was generally agreed that the Izod test was not really satisfactory for any cast iron, and alternative tests were under review.

Mr. Hallett had also raised the question of a connexion between creep-resistance and the solubility limit for titanium and aluminium. The theory that optimum creep-resistance was achieved in alloys of the Nimonic type when the added elements were at the solubility limit had proved to be less tenable than had at one time been anticipated. Improved hot-working techniques had, as Mr. Hallett suggested, allowed rather deeper penetration beyond the solubility limit, with consequent benefit to properties. In addition, data which had been steadily accumulated over several years had resulted in a better appreciation of some of the complex factors which influence creep-resistance, and today one would hesitate to associate this property solely with solid solubility or any other single factor.

He would like to thank Mr. Todd for his very interesting contribution. With regard to his experience with the Diesel liner, it would be agreed by all metallurgists that the annealed iron, with its ferritic matrix, was in the wrong condition to give good results in this type of service, and it would appear likely that the explanation of the seizure was associated with this factor. It would, however, be impossible to offer any explanation of the surprising change in dimensions without making an examination of the metal and having full knowledge of all the factors involved. Mr. Todd's remarks on the points to be taken into consideration in drawing up specifications for S.G. iron were noted with interest and would be borne in mind. With regard to the views which he expressed on the licensing, for S.G. iron production, of a larger number of small foundries capable of carrying out urgent orders for single castings, it had to be remembered that successful development of S.G. iron called for the introduction of methods of technical control, including chemical analysis and micro-examination, for which many of the smaller foundries were not adequately equipped.

Mr. McAfee's remarks on the mechanical properties obtained from separately and cast-on high-tensile brass test bars, in comparison with those cut from actual propellers, were indeed interesting, and confirmed the need, urged by the author, for a better knowledge of the properties of actual castings in copper-base alloys. Separately-cast test bars could indicate only the properties of the metal before it entered the mould, but bore little relation to the properties of the metal in the casting.

In reply to Mr. Munton, it was agreed that data on corrosion fatigue was extremely useful for certain specialized applications, such as marine propellers, but it was probably not so important in the general run of copper-base alloy castings employed in engineering. The responsibility for such tests could, therefore, best be left with those having specialized interests.

In reply to questions raised by Mr. Munton and others on the corrosion-resistance of S.G. iron in marine conditions, he thought that the position could be summed-up quite simply. Experience in this field had shown that grey cast iron parts usually had three to five times the life of cast steel or mild steel. To date, laboratory tests, confirmed by service experience, had demonstrated that the corrosion rate of S.G. iron was similar to that of flake-graphite iron, and the combination of this characteristic with the improved strength and shock-resistance of the new iron would go a long way towards meeting the requirements of marine engineers. S.G. iron was indeed already being used, *inter alia,* for sea-water valves. It would, of course, be conceded that no metallurgist would claim that cast iron was a corrosion-resistant material in the generally accepted sense of that term, but in this connexion it should be remembered that in chemical plant, building construction, marine engineering and other applications, many thousands of tons of cast iron were giving reliable service over many years, in conditions in which some other common metals, for example mild steel, would fail after a relatively short period.

In reply to Mr. Richardson's remarks, there could be no doubt whatever that, in general, little information on the properties of actual copper-base alloy castings was available to the designer, and the need for such data was recognized by the non-ferrous foundry industry, as could be observed from papers and reports recently presented to the Institute of British Foundrymen and the Institute of Metals. Such information, referring to the actual castings was of course entirely different from, and infinitely more valuable than, that obtained from separately cast or cast-on test bars. The question as to what property should be used by the engineer as a basis for design was rather outside the scope of the present paper, and obviously there could be no unanimity on this subject, for the required properties must surely depend upon individual service requirements.

The apparently low mechanical properties obtained from the step-bar cast in high-tensile aluminium bronze (F) could be readily explained by the fact that the aluminium content of this particular casting was found to be slightly below the nominal figure given in Table I. Aluminium content was a critical factor in alloys of this type, exerting a marked effect on mechanical properties. The requirements laid down in B.S.1400 for this particular alloy specified an aluminium content between 8·5 and 10·5 per cent, with an ultimate tensile stress of not less than 40 tons per sq. in. and not less than 12 per cent elongation on separately-cast test bars. The particular step-bar casting concerned had an aluminium content of only 8·3 per cent and did not contain manganese, and the test results varied from 38·0 to 39·5 tons per sq. in. ultimate tensile strength, with 12·0 to 25·0 per cent elongation, which could be considered quite satisfactory in view of the modified composition, and the fact that these values were obtained on test bars cut from the step-bar casting.

The effect on the bearing characteristics of 85/5/5/5 gunmetal of substituting 2 per cent nickel for an equal amount of tin would depend largely on the percentage of tin in the final casting. If the casting contained 2 per cent nickel and 4 per cent tin, bearing properties would probably not be affected, but if it contained 2 per cent nickel and only 2 per cent tin, a difference would probably be observed. Speaking generally, 85/5/5/5 gunmetal was not recognized as an alloy with exceptionally good bearing properties.

It could be broadly stated that the formation of spheroidal graphite in cast graphitic nickel, resulting from the addition of controlled additions of magnesium, could be considered as similar to the effect produced in spheroidal-graphite cast iron. The mechanism of the action was not as yet fully understood.

With regard to Mr. Richardson's remarks on the quality of condenser tubes and the influence of minor impurities, it could definitely be stated that quality had improved rather than deteriorated during recent years, and that the continuing research to which reference had already been made had helped

---

* Carr, A. L., and Steven, W. Sept. 1953. "The Impact Properties of Annealed Spheroidal-Graphite Cast Iron". International Foundry Congress, Paper MO-3, 20pp.

† Pellini, W. S., Sandoz, G., and Bishop, H. F. 1954. "Notch Ductility of Nodular Iron". Trans.Amer.Soc.Metals, Vol. 46, pp. 418-445.

to foster such improvement. Any apparent falling off in performance was traceable rather to the increasing severity of service conditions, resulting either from the higher water speeds used in design of modern plant or to the worsening conditions of harbour water due to increased sewage content. The effect of minor impurities on performance was not great, and was a complex subject: it was not likely to worry the user who took the precaution of buying tubes of good quality.

Mr. Richardson had also raised the question of the basis metal on which nickel-chromium-boron hard-surfacing was used. Such facings were most commonly applied to ferrous materials but there was no reason to suppose that this process should not also prove successful with non-ferrous metals, provided that the melting point of the base alloy was not lower than that of the metal deposited. Actually, the example cited in the paper referred to steel propellers.

In connexion with the addition of titanium to aluminium bronze, the only information available was that given in British Patent 672,263 taken out by Rolls-Royce, Ltd., covering an alloy of copper with aluminium, iron and nickel in varying proportions, together with between 1 and 4 per cent of titanium. Such alloys were claimed to combine good forging properties with high resistance to corrosion, creep, and fatigue, at temperatures of 300 to 350 deg. C.

The comments of Mr. Jackson on the behaviour of nickel-aluminium bronze propellers in service were most encouraging.

When operating conditions and service life were taken into account, alloys of high initial cost such as cast graphitic nickel, might not necessarily be too expensive to be economic. With the higher steam temperatures and pressures employed today in marine engineering, many alloys which had formerly proved satisfactory were no longer adequate. Such components as centrifugal pump shroud and sealing rings, internal bearings and guides in manœuvring valves, piston valves, labyrinth seals and packing rings, could be mentioned as a few examples of components which have given cause for anxiety during the past few years. Invariably, these parts had to operate in corrosive or erosive environments, often at elevated temperatures, without adequate lubrication, and they must possess good resistance to galling or seizure. High-nickel bronzes containing substantial amounts of lead were widely used for such applications and could be relied on to give excellent results at temperatures not exceeding 600 deg. F. However, when higher temperatures were involved, the lead in the alloy began to melt, with resulting serious reduction in both strength and frictional properties. In such cases cast graphitic nickel should provide a useful alternative.

The subject of S.G.-iron ships' side valves had been raised also by Mr. Colvill and was referred to in the reply to his questions.

Mr. Jackson had pleaded for a quick solution of the "vanadium pentoxide problem", but he was probably underestimating the difficulties involved in arriving at a comprehensive solution to a corrosion problem in which conditions could vary within wide limits. Attention had already been directed, in the paper, to the fact that in spite of intensive research there was at present no sign of any metallurgical solution, and there was the additional complication that the corrosive conditions encountered in boilers were so complex that the order of merit of a number of alloys in resisting corrosion might vary from one boiler to another or even from one part to another of any one boiler. If the problem were to be solved by processing the oil in some way, to eliminate or at least reduce the effect of harmful constituents, Mr. Jackson would appreciate that such a technique must be developed on a satisfactorily economic basis. Complete removal of vanadium from the oil would be both a difficult and a costly procedure, indeed a figure of 1s. per ton of fuel oil treated had been suggested as possible.

With regard to the extrapolated values given in Table IV of the paper, Mr. Smedley was in error in assuming that the stress-log time plot and the double-log plot led to the "same straight line" and would, therefore, necessarily give the same extrapolated values. Mathematically, if one of these plots was rectilinear, the other would not be so, but in practice both plots might give close approximation to straight lines within the limits of experimental scatter of the observations. This was expressed in the paper by describing both methods of plotting as giving good "mean" straight lines. It had not been the purpose of this paper to discuss the relative merits of the various possible methods of extrapolating creep-test results, but merely to point out that extrapolated long-time data might give misleading comparisons if not obtained by the same method.

Investigation of the surface layers formed on Nimonic alloys during service at high temperatures had not yet been sufficiently exhaustive to make possible expression of their effect in terms of loss of fatigue strength. An illustration of the possible severity of the effect was, however, provided by results of some experiments in which a layer of somewhat different type (produced by shot peening), but similar in some respects to that observed on blades, had reduced life in Haigh fatigue tests to about one-third the value obtained on the same material in the unpeened condition.

The point raised by Mr. Smedley with regard to the need for data on the elevated-temperature properties of S.G. iron was one which was fully appreciated by many concerned with the use of the new material. Data on short-time high-temperature properties and on creep-resistance were being accumulated as rapidly as possible, for both the normal and the high-alloy grades of S.G. iron. Information obtained to date had indicated that the normal grade of the iron had a useful degree of mechanical strength up to about 450 deg. C. and that the high-alloy (austenitic) grade was useful to about 650 deg. C. The actual safe operating temperature for any S.G. iron would, of course, depend on many factors, e.g. loading, nature of the part for which it was used, and other variables. For furnace castings, S.G. iron was being used with considerable success at still higher temperatures, e.g. up to 800 deg. or 900 deg. C., a particularly useful feature being its markedly superior resistance to growth, as compared with flake-graphite irons.

In reply to Mr. Colvill, and also in connexion with related questions raised by Mr. Jackson, it could be stated that S.G. iron was proving of considerable interest in many countries for ships' side valves and fittings, and that it had already been adopted for these parts in some types of vessel. The requirements for passenger ships referred to by Mr. Colvill were well known to them, and The Mond Nickel Company was currently carrying out experiments to determine how far S.G. iron would meet the bend test specified in those regulations. At first sight the test appeared to be a severe one, but it was believed that it could be met in the new material.

With regard to elongation, this, like other properties, must necessarily depend on composition, section-thickness and other variables. The figure of 10 per cent for the annealed iron could be regarded as a specification minimum which could be reached under a wide range of conditions for general castings. For individual special applications, figures well above 20 per cent were regularly being obtained under commercial conditions. Further to the statement made in the paper, it could now be confirmed that the British Standards Institution had a committee working out a specification for S.G. iron castings.

INSTITUTE ACTIVITIES

Minutes of Proceedings of the Ordinary Meeting Held at the Institute on Tuesday, 27th April 1954

An Ordinary Meeting was held at the Institute on Tuesday, 27th April 1954, at 5.30 p.m., when a paper by Dr. L. B. Pfeil, O.B.E., F.R.S., entitled "New Metals in Engineering", was presented and discussed. Mr. J. P. Campbell (Chairman of Council) was in the Chair. Sixty-five members and visitors were present and seven speakers took part in the discussion. A vote of thanks to the author was proposed by the Chairman and awarded by acclamation. The meeting ended at 8.0 p.m.

Local Sections

Calcutta

A meeting of the Calcutta Section was held on 7th April 1954, in the lecture hall of the Directorate of Marine Engineering Training. Mr. J. Connal (Local Vice-President) was in the Chair and sixty-nine members and visitors were present, including forty-two students.

A film entitled "The Marine Gas Turbine Goes to Sea" was first shown and was greatly appreciated; then Mr. S. Kasthuri (Member) presented the paper by Mr. John Lamb, O.B.E. (Member) and Mr. R. M. Duggan, B.A. (Associate Member) entitled "The Operation of a Marine Gas Turbine Under Sea Conditions", by reading extracts from the paper under seven headings—weight ratio, tonnage, maintenance, fuel consumption, heat exchangers, no boilers, and constant inlet temperature. Capt.(E) T. B. Bose, I.N., Mr. Y. Arakie and Mr. Kasthuri contributed to the discussion which followed.

South Wales

Golf Meeting

A record entry of forty-eight members and their guests competed in the fourth annual golf meeting of the Section, when an 18-hole Medal Competition was played in excellent weather conditions. The competitors included many well-known shipping and marine engineering personalities, who came from as far afield as London and Newport in the Eastern area and Swansea in the West.

Prizes for the best net scores (Members) were awarded to R. Reid (76) and T. Grieve (77); the prize for the best net score for a member with a handicap of 18 or over was won by D. Skae (81). J. Nixon (66) and A. Pearson (73) received the first and second prizes respectively for the best net scores among the guests. The Members' putting prize was won by J. D. Buchanan with 33 putts, the Guests' by J. Spurway with 31 putts. "Hard Luck" prizes were won by G. K. Beard (Member) and Glyn Jones (Guest).

Whilst the golfers were playing on the course, some twenty non-golfing members and their guests competed in a round-by-round competition on the practice putting green, small prizes being awarded for each round.

In the evening a total of sixty-four members and their guests sat down to supper, which was served in the clubhouse. Mr. J. H. Evans, M.B.E., Chairman of the Section Committee, presided, and proposed "The Loyal Toast". He welcomed the guests and then called upon Mr. David Skae (Vice-President) to present the prizes. The presentations made, Mr. J. Wormald (Member) proposed a vote of thanks to the captain of the Glamorganshire Golf Club and to its committee and members for having placed their very fine course and clubhouse at the disposal of the meeting, which had gone far in providing a most pleasant evening; he concluded by saying how they all looked forward to playing over the course again. Mr. W. S. B. Walker, Captain of the Club, in responding on behalf of his committee and members, warmly welcomed the Institute Members and their guests, remarking that this was the fourth occasion when his club had been complimented by being asked to house the meeting, and he hoped the Institute would return in succeeding years. Mr. L. Howard Emery thanked the Members of the Institute for their hospitality on behalf of the guests, and Mr. F. F. Richardson proposed a vote of thanks to the Chairman.

In his concluding remarks, the Chairman thanked Mr. Richardson and the assembled company and recorded his own pride and pleasure in presiding over such a happy gathering; he thought that the fine attendance at the meeting must surely constitute a record for any golf meeting held under the auspices of the Institute of Marine Engineers in this country.

Sydney

General Meeting

A meeting of the Sydney Section was held at Science House, Gloucester Street, Sydney, on Tuesday, 1st June 1954, at 8.0 p.m. Mr. H. A. Garnett (Local Vice-President) was in the Chair and seventy-four members and guests were present. Engineer Captain G. I. D. Hutcheson, R.A.N.(ret.) (Member) presented his paper on "The Manufacture of Modern Marine Steam Turbines in Australia", which was illustrated by large diagrams; samples of turbine blading and nozzles in various stages of manufacture, also gauges, etc., were exhibited. Messrs. Butcher, Weymouth, Morrison, C. McLachlan, Munro, Lees, Longes, Buls, Cooke and Graham contributed to the discussion.

Afterwards, the Chairman announced that he had retired from his position as principal surveyor in Australia for Lloyd's Register of Shipping and was returning to England the following week. He had, therefore, resigned from his position as Local Vice-President of the Institute in Sydney and as Chairman of the Sydney Local Section. Mr. Garnett informed the meeting that the committee had elected Engineer Captain G. I. D. Hutcheson to the chairmanship of the section, that Mr. N. A. Grieves had been elected Honorary Secretary and Mr. H. Gerrard Honorary Treasurer.

At this stage Engineer Captain Hutcheson took the Chair, and, after thanking members for the honour they had done him in selecting him for the Chairmanship, he invited Mr. W. G. C. Butcher to propose a vote of thanks to Mr. Garnett for his services; this was seconded by Mr. H. P. Weymouth and carried with acclamation.

Farewell Luncheon for retiring Local Vice-President

On Friday, 4th June 1954, a farewell luncheon was held at the Wentworth Hotel for Mr. Garnett and was attended by forty-four members and guests. In addition to the local members, the guests included a number of shipowners and others prominent on the waterfront in Sydney, and the function was most successful. The Toast to Mr. Garnett was proposed by Engineer Captain Hutcheson, by whom he was presented with a wristlet watch for himself and a powder compact for Mrs. Garnett. Mr. Garnett would be greatly missed in Sydney but the section are fortunate that his successor as principal surveyor in Australia for Lloyd's Register of Shipping is Mr. B. P. Fielden (Member), already closely connected with the Sydney Section.

Membership Elections

Elected 29th June 1954

MEMBERS

John Allan
Daniel Joseph Baillie
Sidney Cornelius Beaumont
Francis Austin Beswick
Joseph Robert James Bodington
Matthys Albert Willem Bos, Cdr.
Gerald Richardson Cook, Capt.(E), O.B.E., D.S.C., R.N. (ret.)
John Graham, O.B.E.
Keith Henry Harrison
Claude Albert Hill
William Blackwood Johnstone, O.B.E.
Robert McKendrick
James McKnight
Russell McLuckie
John Joseph McMullen
Frederick Alan Irving Muntz, B.A.
Arthur Alfred Reason, Lieut.(E), R.N.
Henry Charles Shaw
William Shepherd
Einar Peter Christian Stahl
Robert Walliker
James Albert Edwin Weeks, Lieut.-Cdr.(E), R.N.

ASSOCIATE MEMBERS

William John Samuel Croll
Dirk, Herman Everaarts, Lieut.(E), R.N.N.
John Malcolm Griffiths
William Grierson High, B.Sc.
Keith Alec Holes
Thomas Gerald O'Neill, B.Sc.
William Renell Seward
Sudershan Singh Soin, Lieut.(E), I.N., B.Sc.

ASSOCIATES

Richard John Bates
Thomas Alexander Beaton
Lloyd Beck
Gwynne Bowen
Frederick Charles Bown
Ikiriko Frank Obu Briggs
Horace Ronald Brown
Fred Adams Burnham
Harold Clark
Arthur James Cousens
Terence Clark Davison
John Stanley Dixon
Derek Flood
James William Foster
Alister Thomas Gray
Syed Mohammed Hasin
Alan Leslie Hunt
Frederick William Jones
Charles Norman Keeble
Richard James Norman Kerr
Gudmundur Eggerz Kristinsson
Andrew Lake
Thomas George Lashmar
David Ferguson MacDonald
James McPherson
Richard Thomas William May, Lieut.(E), R.N.
Roydon Dallewy Meredith
Andrew George Morrow
Robert Reid Munro
Peter Penfold
George Herbert Premadasa Perera
Horacio Person
Arthur Labron Plint
Alan Edward Radcliff
Sidney Victor Rainey
Mohammed Salahuddin
Philip Charles Secretan
Charles William Staniforth
John Gatcliffe Sweetman
Joseph Tingle
John Watt
Norman Wilkins

GRADUATE

John Arthur Beart

STUDENTS

Ian Walter Edmondson
William Peter Green
Michael George Mayhew
Wilson Wijesekera

PROBATIONER STUDENTS

John William Braley
William Gair
Colin Robson

TRANSFER FROM COMPANION TO MEMBER

Edgar Wikner Percival

TRANSFER FROM ASSOCIATE MEMBER TO MEMBER

Basil Eardley Leon Deckker, Ph.D., M.Sc.

TRANSFER FROM ASSOCIATE TO MEMBER

James Waldie Greenhill
Albert Walter Hutson
Charles Pinto

TRANSFER FROM ASSOCIATE TO ASSOCIATE MEMBER

Francis Colin Smith

TRANSFER FROM GRADUATE TO ASSOCIATE MEMBER

Robert Henry Crowther, B.Sc.
Peter Guy Edwards, Capt., B.Sc.
Eric Victor Lockney, B.Sc.
Eric David Simmons

TRANSFER FROM PROBATIONER STUDENT TO STUDENT

Alan James Cruickshank

OBITUARY

George Nathan Davison (Associate Member 6191) was connected with the firm of John I. Thornycroft and Co., Ltd., throughout the whole of his long business career of over fifty years. He served an apprenticeship with the firm at Chiswick from 1898 to 1904. On the transfer of the firm to Woolston, Southampton, in 1906, he was brought down and served as a fitter for several years. In 1919 he was chosen to go to Rio de Janeiro, Brazil, on the staff of the Leopoldina Railway Company (Costeira S.A.), whose technical direction Thornycrofts had taken over. On his return he was made foreman of the outside fitters and in 1926 he was responsible for the installation and trials of the torpedo boat destroyers, merchant vessels and repairs undertaken by the firm. During the period 1926 to 1937 the firm built thirty-seven warships for the British Admiralty and foreign powers and Mr. Davison's control of the engine room contributed in no small degree to the firm's success.

He was appointed works superintendent in 1937 and senior engineering works superintendent in 1944. In 1945 he was made works manager of the engineering shops, which position he held until his retirement in July 1950; during this period he was awarded a British Empire Medal.

Mr. Davison, who died on 30th April 1954 at the age of sixty-nine, was elected to membership of the Institute in 1929.

Samuel Hiddleston (Member 3673) was born in Edinburgh in 1893 and was educated at Roseburn School, Murrayfield, and Eastbank Academy, Glasgow. He served his apprenticeship with D. and W. Henderson, Ltd., of Glasgow. He spent fourteen years at sea and during the first World War he served as Engineer Lieutenant, R.N.R., in the auxiliary cruiser *City of London* and in the minesweeper H.M.S. *Pebble* and H.M.S. *Pollybridge*. He held a First Class Board of Trade Steam Certificate with a motor endorsement. In 1928 Mr. Hiddleston joined James Howden and Co. (Land), Ltd., as chief inspector, and under his leadership the company's erection department was built up. He was taken ill suddenly after assisting at an entertainment held in the Company's London office on 3rd May 1954, and died in St. George's Hospital nearby a few days later, on the 7th.

Mr. Hiddleston had been a Member of the Institute since 1919.

Leonard Lang (Member 9403) was born in 1898. He served an apprenticeship with Palmers Shipbuilding Co., Ltd., from 1914-19, and after some months at the Marine School, South Shields, he joined the British India Steam Navigation Co., Ltd., sailing in their vessels until 1924. He then joined the Embericos Shipping Company as third engineer, subsequently, from 1927-29, serving as third to chief engineer with the Ben Line, Leith. During 1930 and 1931 he was second engineer, first with the Dalgleish Company of Newcastle on Tyne and then with the Tyne-Tees Shipping Co., Ltd. In the meantime he had obtained a First Class Steam Board of Trade Certificate.

From 1934 until his sudden death on 22nd June 1954, Mr. Lang was employed by the British Oxygen Company, at Witham, Essex, until 1938 as maintenance engineer and subsequently as foreman engineer in charge of the Witham and Ipswich branches.

He had been a Member of the Institute since 1942.

Herbert Joseph Lawton (Member 5671) served an apprenticeship with J. Samuel White and Company, Cowes. He joined the British India Steam Navigation Co., Ltd., in 1922 and after serving as fourth, third and second engineer officer he was appointed chief engineer officer in 1942, in which capacity he was employed until his death on 22nd May 1954. Mr. Lawton served during the whole of the last war in the motor ship *Dalgoma* and for this he was awarded the M.B.E. at the 1942 Birthday Honours. He had been a Member of the Institute since 1926.

William Sinclair (Member 2392) died on 10th May 1954, aged seventy-six years. He was born in Dunoon, Scotland, and went to Australia at the age of ten. He served an apprenticeship with Mort's Dock and Engineering Company, Sydney, and spent several years at sea with the Adelaide Steamship Co., Ltd., and the Canadian-Australian Line, obtaining a First Class Board of Trade (New South Wales) Steam Certificate. In 1904 he joined the firm of J. Wildridge and Sinclair Pty., Ltd., of which he was a director for many years, being chairman of directors from 1930 until his death. In 1926 he joined the Board of Clyde Engineering Co., Ltd., becoming chairman of directors in 1940, a position he held until January 1946; he was deputy chairman until December 1947 and resigned from the company six months later.

Mr. Sinclair had been a Member of the Institute since 1910. He was also a member of the Engineering Association of New South Wales, contributing papers on refrigeration and serving on their council for a number of years; on the formation of the Institute of Engineers, Australia, he became an associate member.

Mr. Sinclair's experience in refrigeration covered an extensive field, taking in a period of more than fifty years. Amongst his more important contributions to the industry is the work done in his capacity as consulting engineer to the Queensland Meat Export Company, Townsville, where new buildings and specially designed refrigeration work was carried out. He gave valuable service to the Standards Association of Australia, being a member of the drafting committee which sat a few years before the war and brought out the original S.A.A. Refrigeration Code.

Peter Weir (Member 2920) was born in 1879. He served an apprenticeship with Bow, McLachlan and Co., Ltd., Paisley, and then joined the British India Steam Navigation Co., Ltd., sailing in their ships from 1905-12. He obtained an Extra First Class Board of Trade Certificate. From 1912-17 he was inspector of steam boilers and prime movers in Sind, India, when he was appointed chief engineer in the Deccan Sugar and Abkhari Co., Ltd., Samalhot, East Godavari District, India, continuing in this employment until his retirement in 1946. Mr. Weir died on 29th May 1954. He had been a Member of the Institute since 1914.