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Steels and their Utilisation for High Steam Pressures and Temperatures.

READ

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On Tuesday, April 12th, 1938, at 6 p.m.

CHAIRMAN: MR. A. F. C. TIMPSON (Vice-Chairman of Council).

Synopsis.

EXPERIENCE and practice in the use of high steam pressures and temperatures in land power plant provides a reliable guide for corresponding development in marine practice. Position and capabilities of carbon steels are reviewed and it is suggested that they may be sufficient to meet most of the requirements of immediate development. Effect of temperature in changing structure and behaviour of carbon steels during service. Position of cylindrical parts under pressure when creep occurs more favourable than at lower temperatures. Land experience has reduced the selection of steels to one or two. Use of molybdenum steel for high temperatures; its mode of failure in common with other high creep-resistant steels by intercrystalline cracks. Influence of mode of failure upon permissible deformation. Important difference in the behaviour of welded carbon and high creep-resistant steels. Use of molybdenum and chromium-molybdenum steels. Effect of an alloy element in conferring advantage over a range of temperature.

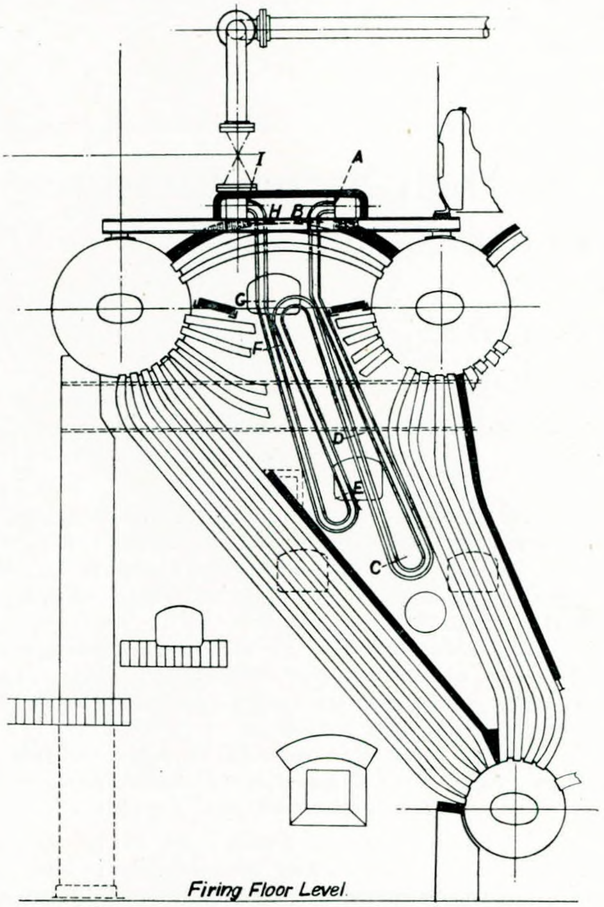
Important influence of the physical properties of steels at atmospheric temperature upon their selection for high temperature service. The problem of scaling and oxidation.

Design for creep conditions in pipes and tubes, pipes joined by welding, flanged joints, parts subjected to bending and centrifugal stresses.

Marine engineering practice due to its special conditions has been behind land practice in the use of high steam pressures and temperatures. Its need therefore for special steels to meet more severe conditions is less urgent than is the problem on land, and very largely the industry can afford to await the results of land development and experience in the selection of suitable materials and the choice of working conditions before making its own advance in the same direction. This is a fortunate position, due apparently to the fact that the utmost reliability under all circumstances must be assured and therefore the scope for untried development is correspondingly limited.

On land the demand for higher thermal efficiency, which cannot be satisfied by the use of internal combustion engines, because of the magnitude of the power required and of the general availability of coal at a comparatively low price, has resulted in considerable progress in the employment of high steam pressures and temperatures. Important advance has been made in understanding the phenomena and special problems involved. Improved steels have come into use and a new point of view and technique in design have been developed which have enabled changes in practice to be undertaken with confidence and success.

The author's object is to present an outline of the more important aspects of the metals and parts for high steam temperatures in connection with land power plant. It is not intended to offer new information but it is hoped that a survey of the principal features will engender confidence where marine engineers may be considering the possibilities of higher steam pressures and temperatures for ship propulsion.



DRAWING SHOWING POSITION OF SUPERHEATER ETC IN BOILER

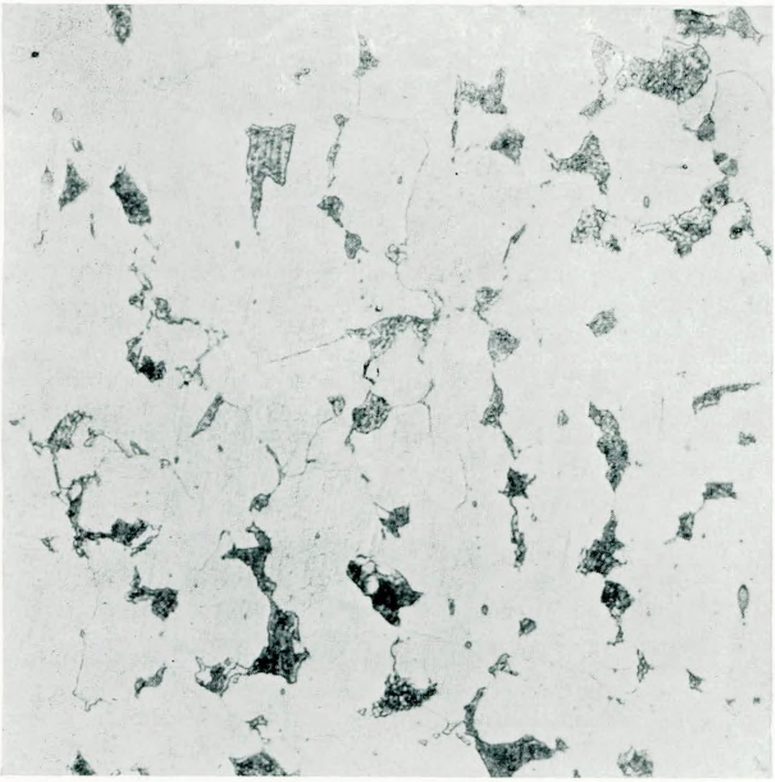
FIG. 1.

Carbon Steels.

Although steam pressures exceeding 1,000lb./in.^{2} have been used successfully on land for a number of years, and steam temperatures of 850-875° F. have been fairly common, it is perhaps unlikely that in marine practice pressures much exceeding 500lb./in.^{2} and temperatures exceeding 850° F. are to be expected to any extent for some time. Generally these conditions can be met successfully by the use of carbon steels for most parts, and only in a few special applications, such as bolts for joints under pressure, need special steels be considered. It is a mistake therefore to think that carbon steels are not suitable for elevated temperatures. Actually they may be the most suitable steels if working stresses permit their use. Examples could be given of the use of carbon steel for highly important parts operating at temperatures of 900° F. and over. It is therefore necessary to know with some completeness and precision the behaviour of carbon steel at elevated temperatures. It happens that the behaviour of carbon steels affords a good introduction to other steels of superior strength and endurance.

Long exposure of carbon steel to high temperature results in two effects, one due to temperature and the other due to stress. The former causes a change in structure and also to some extent a reduction in strength; and the latter results in continued permanent deformation or creep. Structural change is common in superheater tubes for example for quite moderate steam temperature, and would therefore not be new in marine engineering experience. It would become more pronounced of course with the use of higher temperatures, but it would not result in any unreliability. Similarly creep, if kept within appropriate limits by a proper choice of working stress, involves no risk. Indeed its presence in many cases is a distinct advantage because it leads to a more suitable distribution of stress and therefore actually facilitates the use of high pressures.

Referring first to structural change, Fig. 1 shows a superheater and Figs. 2A and 2B the microstructure of the tube material at the inlet A and at the high temperature zone E. Fig. 2A represents the initial microstructure of the tube, because it is known that the inlet steam temperature, which must have been fairly closely that of the tube, could not have produced noticeable change. The tube had been in service 16,000 hours, the temperature of the steam leaving the superheater having been 645°F. In the hot zone much higher metal temperatures had been attained and it is seen that considerable grain



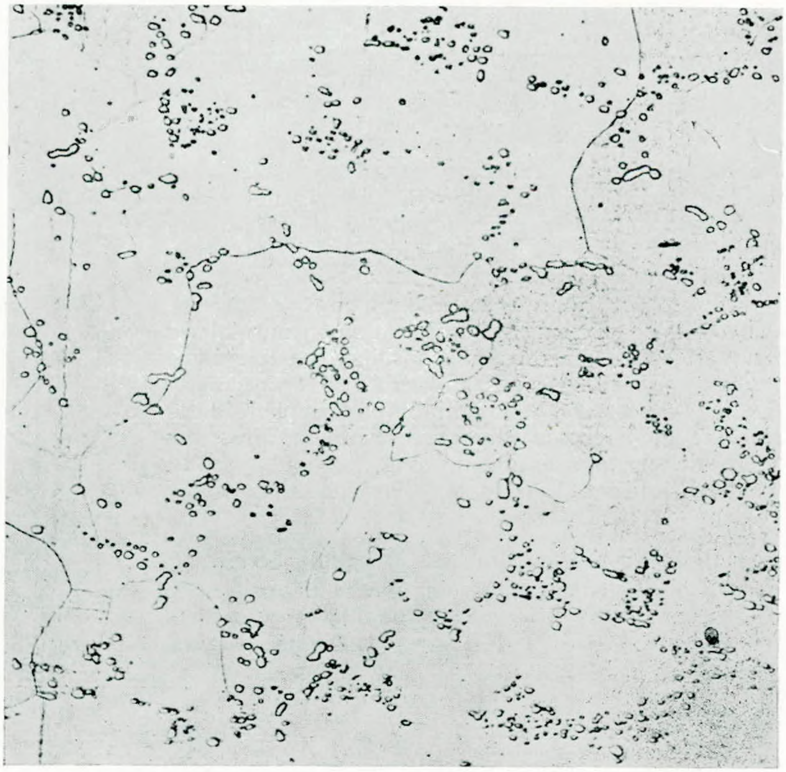
× 800.
FIG. 2A.

growth has occurred, and the original pearlite grains have been replaced by globules of cementite or iron carbide. The originally lamellar iron carbide has become spheroidised. Spheroidisation of carbide is a normal structural change to be expected in some degree in carbon steels at elevated temperatures. Generally it will not become pronounced except in parts of the superheater and in all cases, except for a weakening effect which is not serious and which, where necessary, can be allowed for, it is not in itself of much significance. The time at different temperatures to produce a specific change of structure by carbide spheroidisation is represented approximately by* :—

$$t\ (\text{hours}) = Ae^{\frac{33000}{T}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where A is a constant depending upon the initial condition of the steel, i.e. whether cast, forged or cold worked, e is the base of Napierian logarithms, and T is the absolute temperature in degrees Centigrade. Experiment shows that the relationship (1) with the same value of A is true for a given material whether the material is free from stress or under any permissible working stress. It is possible with the aid of (1) to choose a short thermal treatment at an elevated temperature, for example say 650° C., which is equivalent to a period of service, say 100,000 hours, at the working temperature. Thereby the effect of service can be anticipated, and tests may be made upon such artificially aged material. Table 1 following gives the times of heating at 650° C. equivalent to 100,000 hours at the temperatures stated to produce carbide spheroidisation in annealed and normalised carbon steels.

Although considerable data exist upon the creep behaviour of carbon steels, very little of it is directly applicable to design. Also the effect of carbon content upon creep resistance is still doubtful, although apparently it is not very important. Until its influence is authoritatively established the author would suggest that Fig. 3 may be taken for carbon steels to represent the tensile stress at different temperatures for a total



× 800.
FIG. 2B.

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* Bailey, R. W. and Roberts, A.M., "Testing of Materials for Service in High Temperature Steam Plant". Proc. I. Mech. E., 1932, Vol. **122**.

TABLE I.

		Service temperature.				
	°F.	750	800	850	900	950
	°C.	399	426	455	482	510
Time in hours of heating at 650° C. equivalent to 100,000 hrs. at service temperature		0·16	1·04	6·83	35·2	167

creep of 0·001 inch per inch, and 0·003 inch per inch in a period of 100,000 hours. The curves are based upon tests upon a normalised 0·4 per cent. carbon steel, the results having been modified so as to correspond with a condition of spheroidised carbide. It is suggested that Fig. 3 be assumed to apply to steels with spheroidised carbide of different carbon contents. If the carbide is lamellar as produced by normalising and annealing (with not too slow cooling) and carbide spheroidisation is not likely to occur in service as judged by the following Table II, the stress may be increased in the ratio shown by Fig. 4.

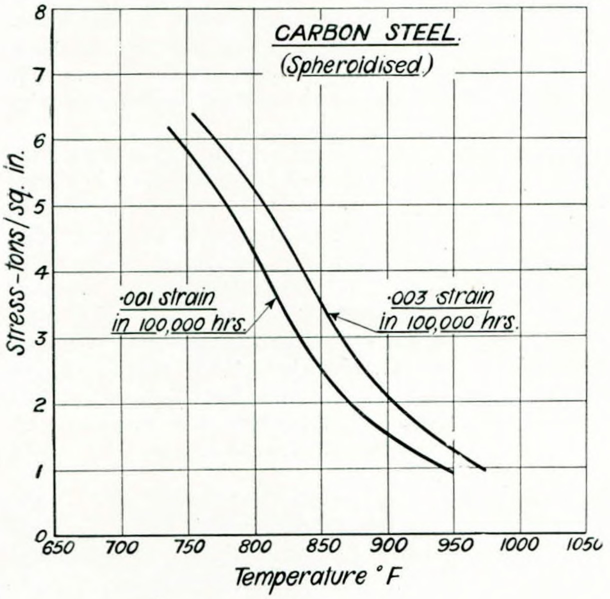

FIG. 3.

Evidently only with temperatures above 850° F. need carbide spheroidisation in normalised and annealed forgings be considered. The same remark applies to pipes and tubes, but not infrequently these parts have initially partly spheroidised carbide and therefore the increase in working stress suggested as permissible by Fig. 4 should not be utilised unless initially a lamellar condition of the pearlite is ensured.

Permissible Deformation and Working Stress.

Working stress must of course depend upon the amount of deformation one is prepared to permit during the life of a part. If the life is taken as 100,000 hours (11·4 years continuous) a total strain of 0·001 inch per inch is satisfactory for all parts (except press fits) where very small creep is essential. For tubes and pipes as much as 0·003 strain and more could be allowed with carbon steel, although because of a need for some margin a greater amount than 0·003 strain would not be advocated. Consequently the curves given by Fig. 3 and those derivable therefrom by means of Fig. 4 can be regarded as representing permissible working stresses, where creep is the determining factor. Reference is made again later to the subject of working stress where creep is not the limiting consideration.

Cylinders, Pipes and Tubes.

These parts enter so much into steam plant construction that their behaviour under creep conditions should be known with fair certainty. The subject has been investigated in some detail by the author but it is unnecessary here to do more than record the more important conclusions. These are :—

(1) Creep of a cylindrical part under internal fluid pressure takes place only on the diameter.

(2) Bending moment and twisting moment due to thermal expansion effects in such parts as piping are quickly relieved at operating temperatures by creep.

(3) With wall thicknesses up to as much as 15 per cent. of the bore, cylindrical parts may be safely designed, treating the part as though it were a thin cylinder, and

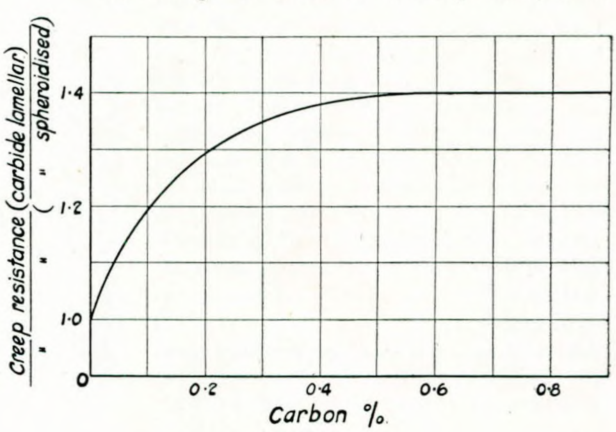

FIG. 4.

TABLE II.

		Service temperature.				
	°F.	750	800	850	900	950
	°C.	399	426	455	482	510
Time in hours to produce complete carbide spheroidisation of annealed and normalised forgings		20×10^6	3×10^6	500×10^3	90×10^3	19×10^3

using the stress found from tensile creep tests (e.g. Fig. 3).

All these facts favour marine conditions where space is limited. Because of (1) no provision for axial expansion due to creep is needed. On account of (2) the steam piping system will not be under appreciable bending moment or twisting moment at operating temperature, although it would be under the full straining actions associated with thermal expansion when cold. Analysis suggests that where the diametral creep of a pipe is 0·001 inch per inch for the life period the bending moment and twisting moments would have fallen to 10 per cent. of the maximum possible (i.e. due to the full thermal expansion) during the first 10 per cent. of the life. Under (3) minimum wall thicknesses are obtained and therefore maximum flexibility of a piping system and minimum loading due to thermal expansion.

With the advantages thus conferred by creep conditions carbon steels have still a wide field of utility for higher pressures and temperatures than are at present favoured in marine practice.

Alloy Steels.

Investigation and land practice have established that when a steel more resistant to creep than carbon steel is required this is best provided by a carbon molybdenum steel. The addition of molybdenum to a carbon steel increases the creep resistance in a marked degree. Improvement is obtained with additions up to 1 - 2 per cent. molybdenum but something like 70 - 80 per cent. of the maximum obtainable results from an addition of only 0·5 per cent. molybdenum. Consequently 0·5 per cent. molybdenum steels have come largely into use for high temperature service. As normalised they have a creep resistance usually 2 -3 times that of the corresponding carbon steel and consequently where really high pressures are combined with high temperatures they become essential. Experience has shown that they are reliable steels in all the usual forms such as castings, forgings, pipes and tubes.

Fig. 5, taken from a paper by the author*, shows the properties of a 0·3 per cent. carbon, 0·5 per cent. molybdenum steel. Its superiority over carbon steels will be apparent by comparing with Fig. 3. It is found, however, that 0·5 per cent. molybdenum steels weaken considerably when heated at a high enough temperature and for a sufficient time such as would produce carbide spheroidisation in carbon steels and their advantage over the latter is reduced and may only then be as little as 50 per cent. superior. It is very important therefore for the heat treatment to be closely controlled. Normalising is a very satisfactory heat treatment, but if this is followed by a tempering treatment a temperature of 650° C. should not be exceeded. Parts in 0·3 per cent. carbon, 0·5 per cent. molybdenum steel, if larger in thickness than 1·25in., even when water quenched, do not harden. Larger parts therefore, whether oil or water quenched, have a structure which is virtually a normalised structure. This was the case of the steel represented by Fig. 5, which refers to 5in. dia. bar material water quenched. Fig. 5 can be taken to represent what may be expected from normalised 0·5 per cent. molybdenum steel.

The weakening effect of heating at the higher temperatures is revealed by the rapid fall in the stress curve for temperatures in excess of 500° C. or 932° F. It is most probable that the slow cooling in a furnace associated with annealing is responsible for the inferior creep resistance of annealed 0·5 per cent. molybdenum steel compared with normalised (or equivalent) steel. This inferiority may be expected at temperatures up to about 500° C. or say 925° F. and it is associated with the period of cooling during which carbide spheroidisation can occur. For parts of small thickness such as tubes and pipes, normalising without subsequent treatment would assure the high creep resistance of which the steel is capable. Parts of larger size where normalising would be accompanied by undesirable internal stress, should be given a stress relief treatment. In such cases the two treatments are conveniently combined by normalising, i.e. air cooling down to a temperature of about 400° C. followed by a stress relief treatment at 600° C. with furnace cooling to 200 - 300° C.

Reference should be made to the mode of failure under creep of 0·5 per cent. molybdenum steel, which is characteristic of probably all high creep resistant steels. In investigating molybdenum steels Jenkins and Tapsell of the National

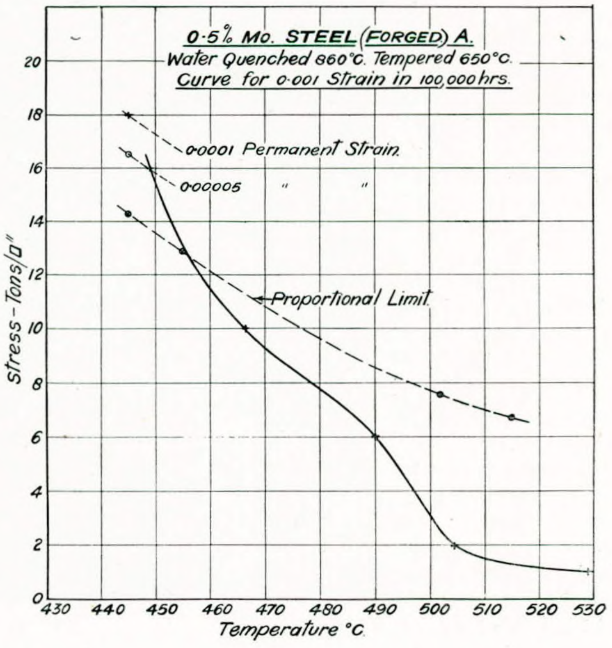

FIG. 5.

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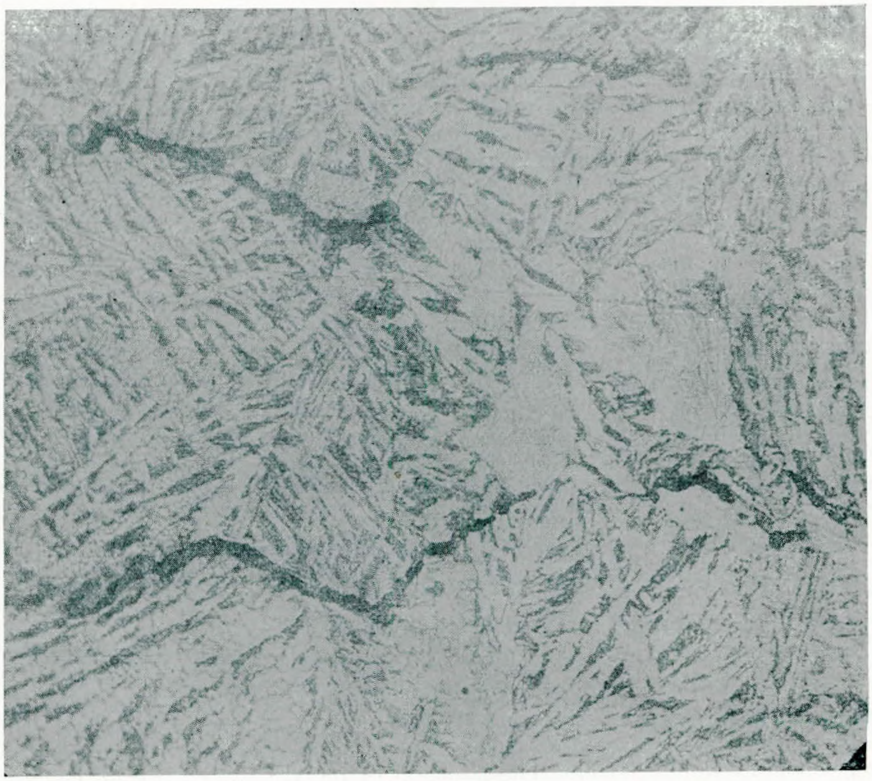
* Bailey, R. W. "Utilisation of Creep Test Data in Engineering Design". Proc. I. Mech. E., 1935, Vol. 131.

Physical Laboratory discovered that extensive intercrystalline cracking occurred under creep conditions, the commencement being observable at relatively small elongation of the order of 1·5 - 2 per cent. All steels of high creep resistance of which the author has had experience fail by intercrystalline fracture with low ductility. Fig. 6 shows the nature of the cracking. Failure, however, over a wide range of temperature and stress, is determined very largely by the magnitude of the deformation. Since there is a possibility of fracture taking place at elongations as low as 3 or 4 per cent. and the microscope reveals the commencement of intercrystalline cracking at elongations of 1 - 2 per cent., it is clearly necessary in practice to limit deformations by creep to less than 1 per cent. For this reason the author would advise that a total creep of 0·003 inch per inch for the life of the plant should not be exceeded and if circumstances permit, it should preferably be less, a good figure being 0·001 inch per inch. From the standpoint of actual failure carbon steels could safely be permitted ten or more times the deformation allowable for the corresponding 0·5 per cent. molybdenum steel. Such large safe deformations in the case of carbon steels would of course be inadmissible on account of the dimensional changes involved.



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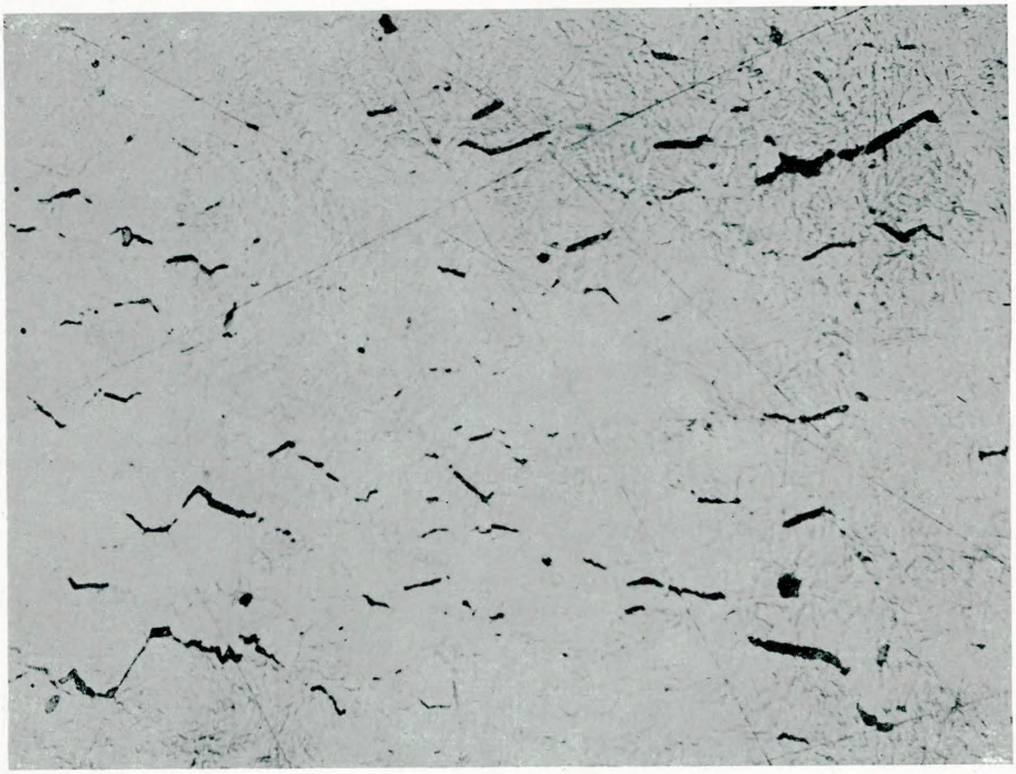
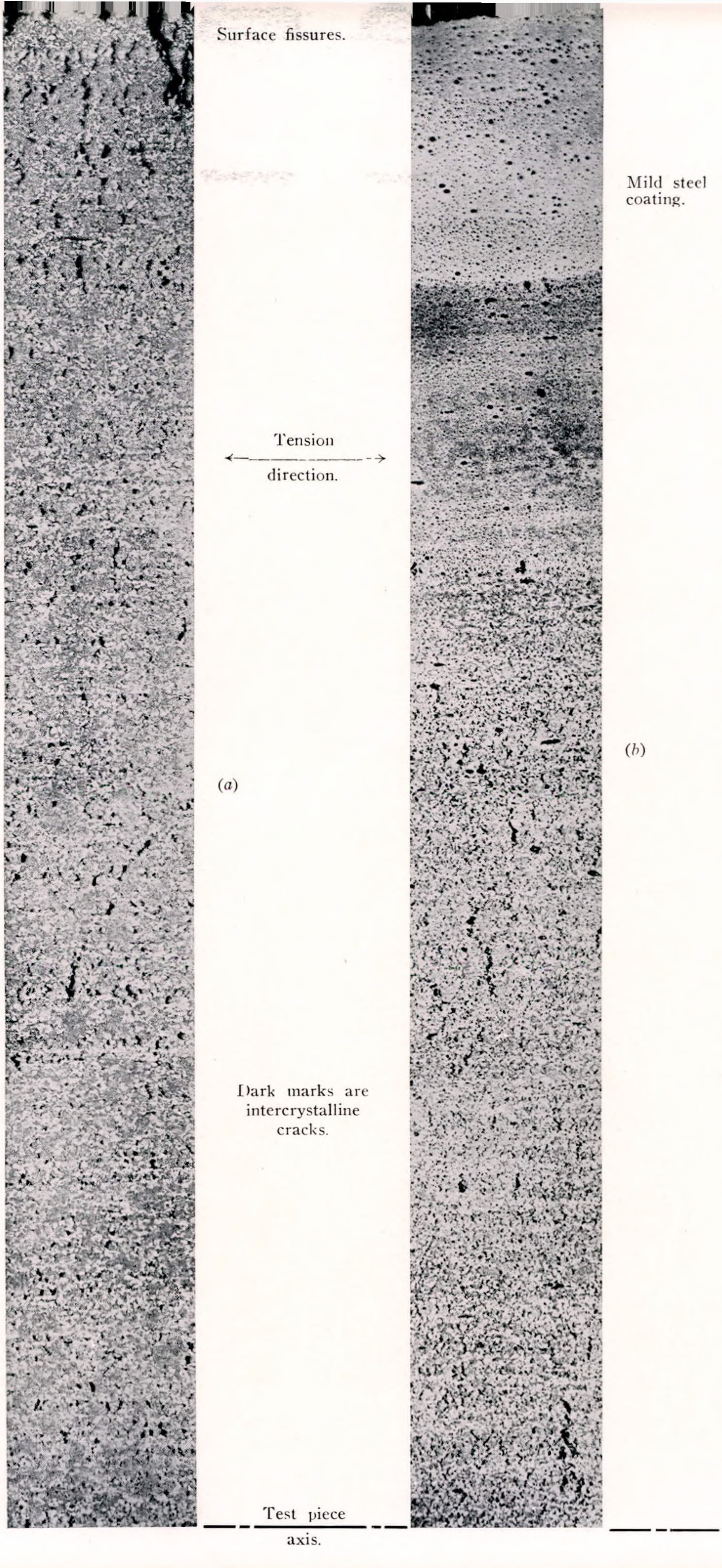


× 100.
FIG. 6.


Surface fissures.
Tension direction.
Dark marks are intercrystalline cracks.
Test piece axis.
Mild steel coating.

(a)

(b)

Comparing carbon steels and corresponding molybdenum and other high creep resistant steels, the permissible creep is determined in the former case by dimensional considerations, and in the latter it is set by inter-crystalline cracking independently of the nature of the part.

The subject of welding may be remarked upon here because the phenomenon of intercrystalline cracking under creep has important bearing upon the matter. Welding of mild steel has had extensive and successful application for many years and in recent years steam pipe joints in a number of installations in the U.S.A. have been made by welding. Because of the good ductility under creep of mild steel welds, electrically welded steam pipes for high temperatures and pressures can be fully justified, provided of course that the welded joint is sound and satisfactory. With 0·5 per cent. molybdenum steel however the weld electrode deposit fails under creep by intercrystalline cracking at a total elongation of perhaps no more than 1 per cent. The irregularity of a welded joint by possible notch effects, both at the inside and outside of a pipe may result in local deformations in excess of the average and so a practice which is safe for mild steel may be unsafe or in any case one which requires investigation and special safeguards in the case of molybdenum and other high creep resistant steels.

At present suppression of intercrystalline cracking under creep of high creep resistant steels appears to be a problem which may prove fundamental in character and inherently associated with high creep resistance. Its elimination at present therefore does not appear to be very hopeful. If elongation at failure could be increased, however, it would be an advantage. It was noticed that all our creep test specimens which fractured, failed from the outside. Fig. 7A, which is an etched section of a 0·3 per cent. carbon, 0·5 per cent. molybdenum steel test piece, embracing one half of the test piece, shows clearly the extensive distribution of intercrystalline cracks and their extension at the surface whereby fracture is initiated. A weld deposit of mild steel at the surface can prevent the development of intercrystalline cracks into fissures as is shown by Fig. 7B, and thereby extension at fracture may be increased by as much as 50 per cent. In the tests to which the figure refers, the mild steel coating actually caused fracture to start from the central region of the test piece. Similar tests upon weld deposits of 0·5 per cent. molybdenum steel showed no advantage was obtained from covering with mild steel for the reason that cracking started from small cavities and inclusions in the weld metal. Clearly the use of welded constructions in high creep resistant steels, where the operating temperature is such that creep considerations dominate design, requires special safeguards to ensure reliability.

Once more it is seen that, as a general rule, carbon steels should be used as far as their properties permit. Stress but not temperature is the determining consideration until scaling becomes the major factor.

Land experience and investigation has served to reduce alloy steels most suitable for high steam temperatures to one or two steels. Methods of short time creep tests, used extensively on the Continent and to some extent in the U.S.A. have suggested a general superiority of a chromium molybdenum steel, having about 1 per cent. chromium and 0·5 per cent. molybdenum over a corresponding 0·5 per cent. molybdenum steel. This is only true within certain limits of temperature and time. It is in fact an example of a general principle affecting the creep properties and utilisation of alloy steels. The addition of an alloy element to a steel will generally have two effects, namely it alters (1) the initial creep resistance, (2) the eventual effect of temperature in weakening creep resistance. If an element increases the initial creep resistance and also if it brings about a more rapid weakening under thermal action, the result will be as follows. Below a certain temperature the initial stiffening effect will preponderate over the thermal weakening and the addition of the element confers advantage. Above that temperature the initial stiffening would in time be more than offset by the weakening by thermal action, and the alloy addition would therefore in this case be a disadvantage. Evidently from this standpoint

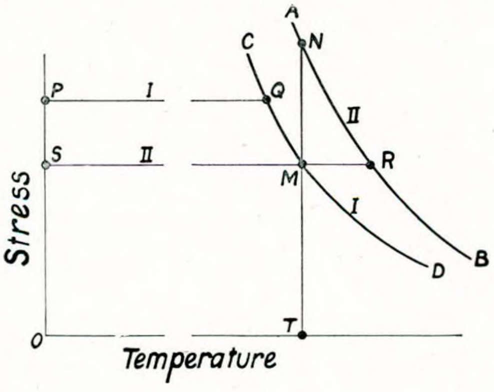


FIG. 8A.

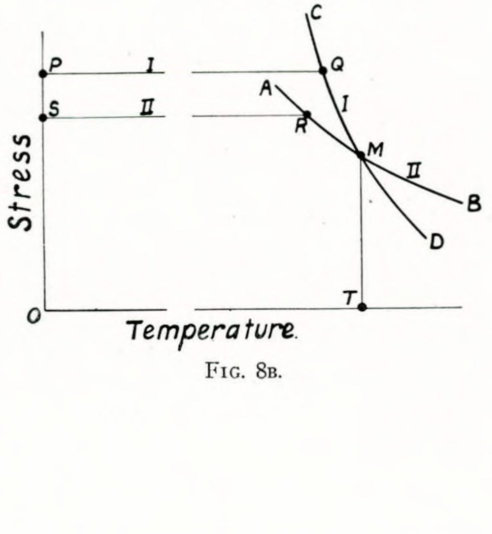


FIG. 8B.

length of service is also a factor influencing the temperature where the changeover occurs, and without reference to both operating temperature and life, no general statement can be made regarding the superiority of one steel over another. If for two steels, which differ by the addition of a stiffening element, there is a cross over temperature, it will be evident that for a shorter life this temperature is raised, and, conversely, for a longer life it is lowered. Addition of 1 per cent. chromium to a 0·5 per cent. molybdenum steel has an initial stiffening effect, but also it increases the rate of weakening produced by thermal action. For a life of 100,000 hours investigation indicates that the crossover temperature is less than 900° F. Consequently when for general construction carbon steels are utilised to the full extent of their possibilities under creep conditions, there are only restricted opportunities for the use of chromium molybdenum steels before the operating temperature reaches a magnitude where molybdenum steels are about equal or superior from a creep point of view. Creep, however, is not the only consideration and sometimes the properties at temperatures below the operating temperature are of importance. This may be the case at bolted joints where the maximum stress in the bolts and flange may occur during heating up. Another important case is where creep does not dominate the selection of working stress.

Because, for any temperature above atmospheric temperature, a working stress would never be chosen greater than the working stress permissible for atmospheric temperature, the ultimate strength at atmospheric temperature has a bearing upon the working stress at elevated temperatures. Logically the stress permissible for atmospheric temperature would generally also be permissible up to the temperature beyond which excessive creep would occur. Thus for example, if two steels had the same creep properties as are shown by Fig. 5 but in one a working stress at atmospheric temperature of 8 tons/in.^{2} were permissible, and in the other 6 tons/in.^{2}, the former would permit higher steady working stresses than the latter up to a temperature of 490° C. beyond which equal working stresses would occur. This is a point of importance in connection with boiler and steam drums for high steam pressures where saturation temperatures occur, i.e. where the temperature is not high enough for creep to take entire charge, and where a useful reduction in wall thickness and weight could result from the employment of a steel with superior ultimate strength at atmospheric temperature. One finds, for example, that nickel steels have been used for boiler drums although nickel in low alloy steels does not confer any advantage in creep resistance, but generally it has an opposite influence. Its use in preference to carbon steel can be justified, however, because of its superior strength and ductility at atmospheric temperature. There are other steels which can be employed with greater advantage such, for example, as chromium molybdenum steels because of a combination of good creep resistance with high ultimate strength at atmospheric temperature.

It is doubtful whether the point just referred to has been sufficiently appreciated. Figs. 8A and 8B illustrate the principles involved in the choice of a steel. Two steels I and II are represented in the figures of which I has superior ultimate strength at atmospheric temperature. The curves AB and CD represent the stress-temperature relationships for the two steels for a permissible amount of creep. In Fig. 8A steel II is superior under creep conditions to steel I at all temperatures, whereas in the case represented by Fig. 8B there is a crossover at the point M. The curve PQD represents permissible working stresses for steel I and similarly SRB refers to steel II. For lower temperatures than T represented by the point M steel I offers the higher working stress, whereas for higher temperatures than T steel II permits superior working stress. It will be observed in Fig. 8A that over the range MQ, where the working stress is determined by creep, steel I is actually superior to steel II, although over this same range of temperature it is inferior in creep resistance to steel II, as shown by NM at the temperature T, merely because steel I has superior strength at atmospheric temperature.

The place taken by nickel in low alloy steels for elevated temperatures is of interest. Its first use, where creep was recognised as important, was in nickel chromium molybdenum steels for joint bolts. Investigation showed such steels to have good creep resistance at temperatures up to about 450° C. (842° F.) but in the region of this temperature the stress for a given creep rate fell rapidly with increase in temperature. It was suspected that nickel was responsible for this falling away, due to the influence of this element in increasing the rate of weakening, under thermal action. Creep tests upon chromium molybdenum steels and nickel chromium molybdenum steels of similar chromium and molybdenum contents, confirmed this suspicion and showed that omitting the nickel gave improved creep resistance, and at the same time resulted in a steel free from embrittlement in service as shown by the Izod impact test at atmospheric temperature. To-day, therefore, for temperatures where creep is important nickel chromium molybdenum steels can be regarded as superseded by chromium molybdenum steels which are generally superior and cheaper. The author also investigated the influence of nickel up to 3 per cent. upon a 0·5 per cent. molybdenum steel. In all cases a reduction in creep resistance occurred with the addition of nickel. This reduction, however, was not large, and as the Brinell hardness increased regularly with the nickel percentage from 150 to 210 Brinell for 3 per cent. of nickel, or an increase in ultimate tensile strength of probably 13 tons/in.^{2} a nickel molybdenum steel would appear to be a possible steel for steam drums and like parts where temperatures are not so high that creep would entirely dominate the selection of working stress. It is possible that for such a steel a case could be made, in the direction suggested, for temperatures up to about 850° F.

Proportional Limit and Proof Stress.

Absence so far of reference to proportional limit or proof stress may have occasioned surprise to some, especially in connection with Figs. 8A and 8B. These quantities generally have either secondary or no importance at elevated temperatures as will be seen by referring to Fig. 5, which is typical of other steels and also to Fig. 9. It is seen that not only are proportional limit and proof stress values no indication of creep properties (generally, working stresses will be less than proportional limit stresses), but even when the proportional limit is exceeded by any reasonable amount the magnitude of the permanent deformation involved is insignificant compared with the permissible creep. Having admitted permanent deformation by creep, there is no logical objection to negligible deformation arising from a stress in excess of the proportional limit. In practice such excess stress would not often occur where any calculated stresses are concerned. It may arise, however, in parts such as bolted joints where the initial stresses due to tightening are high. Here proportional limit stresses can be and very frequently are exceeded, but without ill effect for the reasons given.

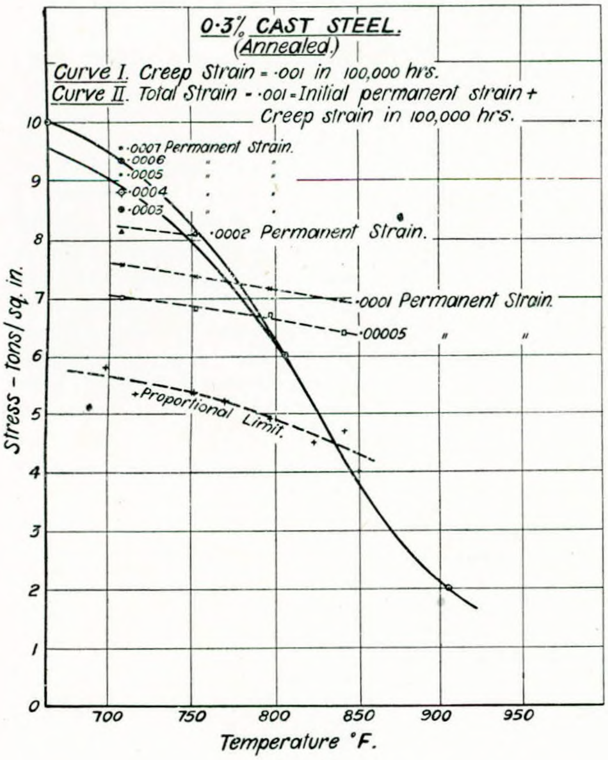


FIG. 9.

Scaling and Oxidation.

Wastage by scaling and oxidation is not likely to be a serious factor in marine development for some time, although steam temperatures on land are reaching levels where the phenomenon calls for attention. Even there, however, the problem will first be confined to the high temperature sections of the superheater, and it seems probable that some sacrifice in creep resistance may be made if substantial increase in resistance to scaling is obtainable. Steels containing 5 - 6 per cent. chromium and 0·5 per cent. molybdenum are regarded favourably in some quarters because of their resistance to scaling, although they are definitely inferior in creep resistance to a similar 0·5 per cent. molybdenum steel without chromium. One advantage of mild steel tubes where they are admissible from the standpoint of creep resistance is that owing to the substantial tube thickness obtained, the margin for permissible attack is increased over that of tubes of higher creep resistance material. Moreover the freedom from intercrystalline cracking of mild steel and the even character of attack (which does not penetrate grain boundaries, except at excessive temperatures, such as would only occur with accidental local overheating sufficient to destroy steels of higher creep resistance) places mild steel in a favourable position to meet immediate developments in marine practice.

High temperatures occur in certain constructional parts of steam boilers not cooled by steam which are subject to the action of furnace gases, such as superheater supports. These parts, however, do not present increased difficulty with higher steam pressures and temperatures and established practice is likely to meet any development in the marine field. Several steel makers supply castings and other parts suitable for the kind of service involved. These steels are usually of the austenitic kind, a common one being of the 22 Cr. 12 Ni. type with tungsten addition.

Design for Creep Conditions.

(a) *Pipes and tubes.*

Tubes and cylindrical vessels enter very largely into the construction of steam plant both when subjected only to internal pressure and when in addition there is heat transmission. This matter has been investigated by the author*, and for detail information consultation of the paper is suggested. For the present purpose Fig. 10 is reproduced from the paper showing permissible average hoop stresses for pipes, cylinders and tubes in carbon and most low alloy steels expressed in terms of the tensile stress in simple tension producing creep of a magnitude permissible at the bore as diametral creep strain (i.e. inch per inch of bore). From the value of ρ given by the figure, the permissible average hoop stress f_m is given by ρf, where f is the creep

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*Bailey, R. W. "Utilisation of Creep Test Data in Engineering Design". Proc. I. Mech. E., 1935, Vol. 131.

stress as given for example by Fig. 3. The wall thickness t would be given by the relationship

$$t = \frac{pd}{2f_m} \quad \text{where } p = \text{pressure}, \; d = \text{bore diameter.}$$

An addition to the thickness as calculated would of course be made to allow for variation in manufacture and also possible scaling as in the case of superheater tubes for example.

(b) *Pipes joined by welding.*

It is a fortunate circumstance, already referred to, that bending and torsional stresses in pipes and tubes due to thermal expansion effects quickly disappear at working temperature when there is creep, and appear in full effect when the system is cold as residual loading and stress. Such stresses therefore need not be considered when determining proportions for operating conditions, and at atmospheric temperature the proportions and physical properties are usually more than adequate to carry the residual loading. Another fortunate feature is that the axial stress is one-half the hoop stress, and therefore provided welding is sound and no serious notch effects occur, the weld is really under easy stress conditions. This and the reliability of mild steel no doubt account for the fact that welded mild steel steam pipes have been used extensively in the U.S.A. with success. Caution, however, is necessary in dealing with high creep resistant steels, the mode of failure under creep conditions of which differs so much from mild steel.

Seal welded pipe joints where the steam loading is transmitted by loose flanges and bolts, such as the Corwell and Vanstone types which are well known, have been extensively used on land, and the Dawson joint which employs a full pipe thickness circumferential weld, safeguarded by loose flanges and bolts, has also had important application. The ideal joint for really high temperatures and high pressures, which is both simple and unquestionable has yet to arrive.

(c) *Flanged joints.*

For high temperatures where creep is the determining factor, studs or bolts should have the full shank diameter as shown by Fig. 11A and not be reduced at the shank as shown by Fig. 11B. This is true if the bolts and flanges are of commensurate strength. Actually the present B.S.I. flanges of mild steel using alloy steel bolts of superior creep resistance are weak at the flanges, and bolts with reduced shanks, as Fig. 11B, do not involve a serious reduction in life. With heavier mild steel flanges however higher temperatures could be carried without change in bolt diameter if the shanks are not of reduced diameter.

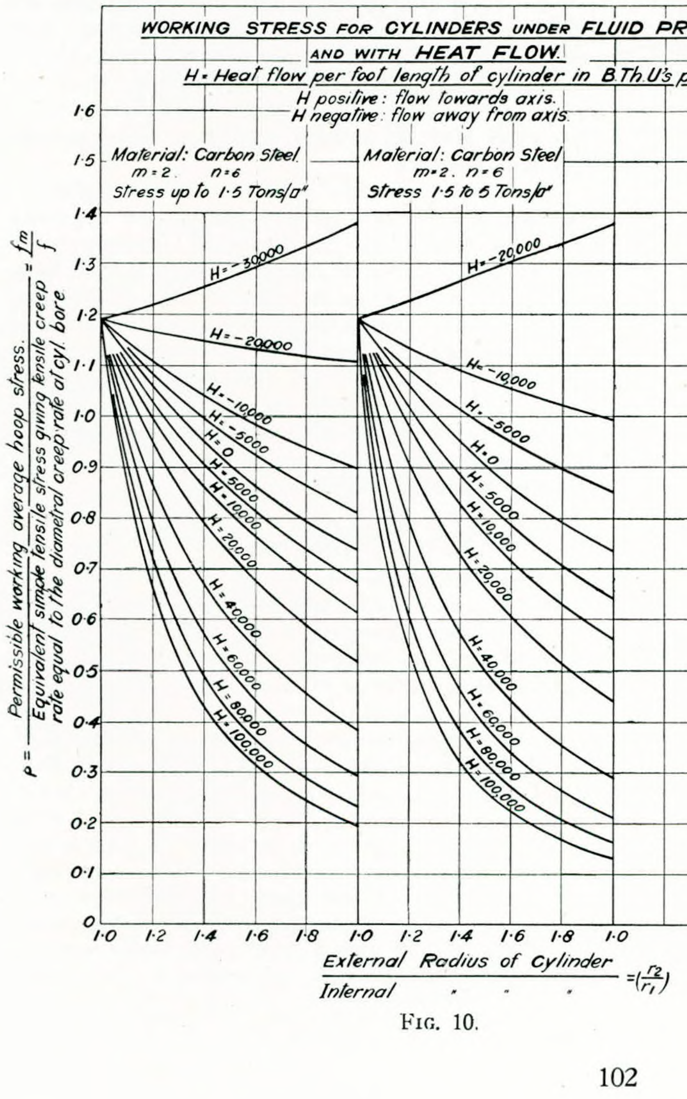

FIG. 10.

The loading of bolted joints for high temperatures has been examined by the author* and there is no need therefore to go into details here. The flange thickness L, for joints in which bolts and flanges are of commensurate proportions, may be calculated using the following relationship:—

$$L = \sqrt{\frac{2(W_1a_1+W_2a_2+W_3a_3}{\pi K(r_2-r_1)\,f_1}}$$

where:

a_1 a_2 and a_3 are as shown by Fig. 12, which also indi-

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*Bailey, R. W. "Flanged Pipe Joints for High Pressures and Temperatures". Engineering, October 1, 15, 29, November 12, December 3 and 17, 1937.

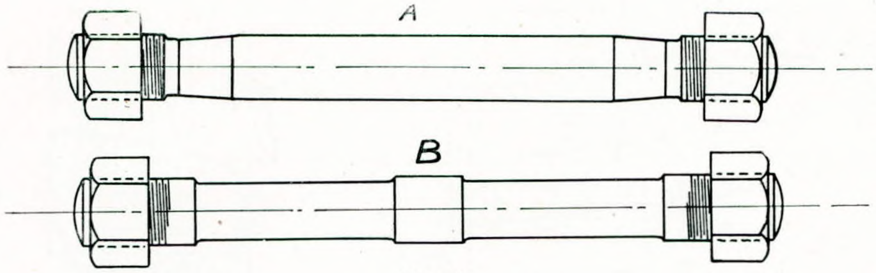

Fig. 11.

cates other symbols involved. Steam pressure $=p$.

W_1 = steam load on bore of pipe $=\pi r_1^2 p$.

W_2 = loading at joint face $= np \times$ area of joint face.

W_3 = loading necessary to provide for bending moment transmitted at joint. This is zero or negligible at operating temperature under creep conditions, but in this case it operates when the system cools down.

$$= \frac{\frac{\pi}{2} r^3 \left[1 - \left(\frac{r_1}{r}\right)^4\right]}{r' + 0{\cdot}8\, t''} f_b$$ where f_b = bending stress in pipe wall.

The factor n involved by W_2 is given by:—

$$n = 1 + \frac{(r_1 + t'')\,[(r_1 + t')^2 - r_1^2]}{(r_1 + t')\,[(r_1 + t'')^2 - r_1^2]}$$

f_1 = permissible hoop stress in flange for life period, and creep conditions. Values of f_1 are given by Fig. 13. The values of stress given for alloy steel may be taken to refer to average alloy steel bolts.

K = factor allowing for creep distribution of stress in flange and weakening effect of bolt holes. Values are given by Fig. 14.

(d) *Parts subjected to bending.*

There is no need here to analyse the behaviour of parts subject to bending under creep conditions. It may be taken that creep under tensile and compressive stress is similar but of course opposite in character. The distribution of stress is more favourable under creep than under elastic conditions, as indicated by Fig. 15. A simple rule applicable safely to most ordinary cases, is to assume uniform stress distribution as shown by the dotted line, express the moment of resistance upon this basis and to increase the stress so obtained by 10 per cent. to give the actual maximum stress f. For an I section girder the stress and moment of resistance under creep and elastic conditions will be nearly the same. For a rectangular cross section the maximum stress f is approximately 8·5 per cent. greater than the magnitude corresponding with uniform stress as shown dotted by Fig. 15. It will be obvious that with many sections creep is an advantage in the case of bending because of the more favourable stress distribution obtained than occurs under elastic conditions.

(e) *Rotating discs.*

For most rotating discs the maximum circumferential stress due to centrifugal force under general creep conditions can be obtained safely by finding the uniform stress which would balance centrifugal action and increasing this by 10 per cent.

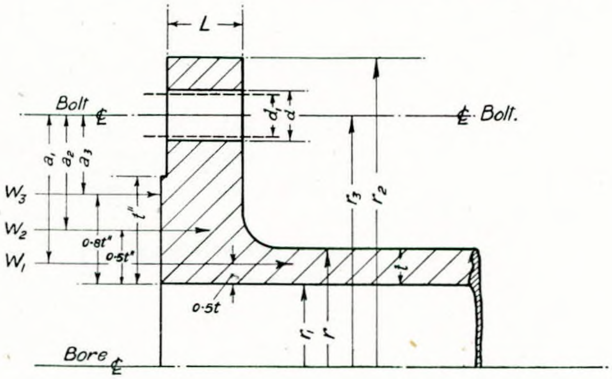

Fig. 12.

For a more detailed consideration of this subject and also of the earlier cases, the author's paper may be consulted. The foregoing, however, are simple rules sufficient in most cases for design.

Conclusion.

It is hoped that the brief survey made by the paper of the more important aspects of creep of metals and their utilisation for high temperature

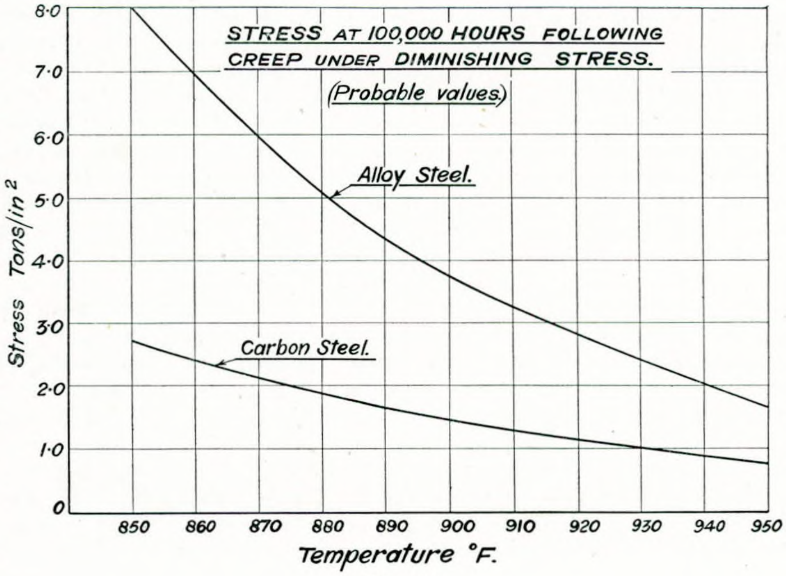

Fig. 13.

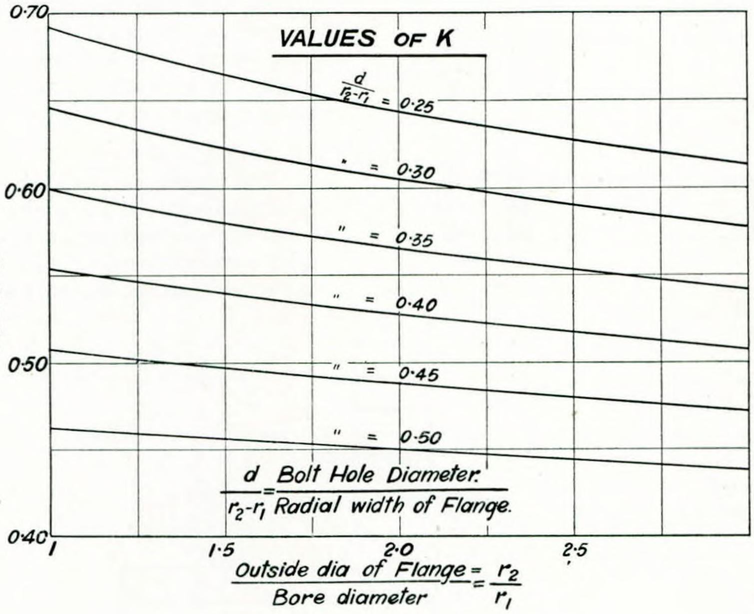

FIG. 14.

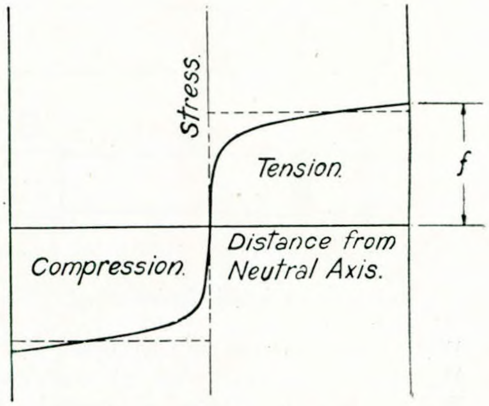

FIG. 15.

steam plant service, will show that a satisfactory basis has been established for reliable design which experience has confirmed. From the standpoint of materials, design and experience, there appears to be no reason why marine practice should not follow land practice in its advance to higher steam pressures and temperatures and likewise participate in higher thermal efficiencies.

Acknowledgment.

The author is indebted to the Directors of the Metropolitan-Vickers Electrical Company Limited, for permission to read this paper.

Discussion.

Dr. S. F. Dorey (Vice-President), opening the discussion, expressed the pleasure of the meeting at having Dr. Bailey present to give the members the benefit of his investigations on materials for use with high steam temperatures. In marine work they were now encountering high pressures and temperatures and the time had arrived when they should have information, such as was contained in the paper under discussion, from an authoritative source.

It had been his good fortune to be associated with Dr. Bailey on one or two Committees. The thick flanges shown on one of the slides were the result of work done by the Pipe Flanges Committee of the Institution of Mechanical Engineers on which Dr. Bailey and himself served. He (the speaker) also represented The Institute on the Committee of the British Electrical and Allied Industries Research Association, and he could assure the meeting that Dr. Bailey was one of the leading members of that Committee. Indeed, but for his assistance the work would have made little progress insofar as design was concerned.

There were several points he could discuss but he thought they had been well covered in the author's presentation of the subject. He felt that he should refrain from criticism to any great extent to avoid confusing their understanding of the problems.

He agreed with the author that marine engineers need only confine themselves to the behaviour of carbon steels at elevated temperatures. Nevertheless, it was worthy of mention to the author that a few marine boilers were working at pressures slightly higher than he appeared to think, e.g., a Loeffler boiler working at 2,000 lb. per sq. inch and 900/930° F., and of course for a number of years now a Benson boiler working at a pressure of 3,000 lb. There were also one or two other plants working at steam pressures greater than the 500 lb. which the author thought marine engineers were unlikely to exceed for some time.

In general a temperature of 850° F. could be considered high enough for marine work. Marine engineers must base their information on land practice, and that was where the author's experience could prove so useful to them. They had not only to consider the question of temperature as such, but the fact that a ship went right round the world and had to be catered for if a breakdown occurred. There were two points in regard to temperature, i.e., the temperature of the working parts and the temperature of the generator. So far as the working parts, i.e., the machinery, were concerned, 850° F. was a suitable temperature, but the difficulty which concerned them was the difference between the steam temperature and the temperature of the superheater tube from which it was generated. In marine work it was a little more difficult to get a satisfactory margin. To get 850° F. it was possible that 1,000° F. would be required, i.e., a difference in temperature of 150° F. This was brought about by conditions of manœuvring which did not necessarily apply to land work. There was also the possibility of longer periods of steaming at reduced speeds. In certain vessels, particularly vessels which were frequently stopping and starting, experience had shown they had been unable to work with very high temperatures and pressures on this account. It was therefore necessary to consider whether it would not be wise to go a little further than carbon steel and use a 0·5 per cent. molybdenum steel. By the curves shown in the paper it would be seen that for temperatures up to approximately 950° F. there was a considerable margin of safety in using 0·5 per cent. molybdenum steel. With a temperature of 900° F. there was a factor of safety four times as great as when using carbon steel. This low alloy steel would therefore appear to be a very satisfactory material for superheater tubes; for turbine rotor discs, however, a carbon steel was all that was required.

A special feature in the employment of molybdenum steel even for ranges suitable to carbon steel was its additional factor of safety should there be a likelihood of "hot spots".

Errata.

Page 105, left-hand column, 9th line from bottom—"3/100in." should read "6/100in.".
Page 105, left-hand column, 6th line from bottom—"four times" should read "twice".

molybdenum stiffened up the creep resistance in the early stages it had no superior claims in respect of oxidation. He mentioned these points to stress the need for care in choosing an expensive and stronger steel for use at the higher temperatures.

With regard to the thickness of tubes given by the curves in the author's formula Fig. 10, he had worked out the case of a superheater tube $1\frac{1}{4}$in. internal diameter, working pressure 500 lb. per sq. inch, H=20,000 and temperature 900° F., permissible stress 2 tons per sq. inch as given in Fig. 3, and he found that according to the author's theory, the thickness of that tube would only work out at about $^{3}/_{100}$in. That showed that while it would give a theoretical thickness the formula in this particular case was hardly practicable. The thickness given by Lloyd's Register's Rules came out at four times that figure. There were thus practical as well as theoretical considerations, and until the range of really high pressures and temperatures was reached the thickness of superheated tubes was governed more by practical considerations than by the theory advanced in the paper. Thus account must be taken of the question of the stiffness of the tubes, the amount of metal required for expanding tubes into headers and drains, and also an allowance for wastage due to oxidation.

It was only right to add that the author stated at the top of page 102 that "an addition to thickness as calculated would of course be made to allow for variation in manufacture and also possible scaling as in the case of superheater tubes, for example".

While Dr. Bailey's theory for tube scantlings did not apply to the conditions under consideration there was little doubt that the theory, which was a purely plastic one, was applicable to scantlings in the range of 950° F. temperature and say 2,000 lb. per sq. inch pressure. In this range it would give sizes fulfilling both practical and theoretical considerations if a plastic theory were accepted. In the case of bolts, however, Dr. Dorey had hoped that the author would have dealt with the embrittlement of steel because both with alloy and mild steel bolts this trouble had been commonly experienced in marine work.

Regarding Dr. Bailey's note on page 94 that creep might be advantageous in giving a more even distribution of stress, he would also like to add that the ordinary yield point in mild steel was also capable of giving similar stress relief, and was, in the
ker's opinion, one of the chief advantages of
steel.

As regards the formulæ given on page 95 for
time required for carbide spheroidisation to
place, it might be mentioned that one of the
f difficulties of applying the proposed formulæ
due to the large variation of the "A" value
rding to the previous thermal history and
ıanical condition of the material.

The curves given in Fig. 3 were of great
rest to engineers who had to deal with design of

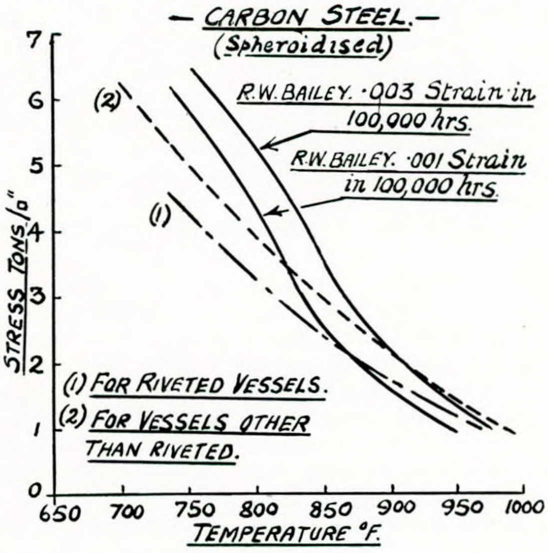

Fig. 16.

pressure vessels of carbon steel subjected to high temperatures, and Dr. Dorey stated that similar stress values had been used by Lloyd's Register for some years now. As a matter of interest Fig. 16 illustrated the curves used by Lloyd's Register for riveted and solid-forged pressure vessels and those given in the present paper were included for comparison.

In the case of riveted vessels it would be well to issue a word of warning that the stresses given by the curve should not be exceeded and the temperature should be the maximum to which the vessel was subjected, otherwise leaking rivets would result.

It might be added that the curve for riveted vessels should give total creep plus elastic strain divided by elastic strain ratio of 2 after about 11 years, and was based partly on results given in Bailey and Robert's paper before the Institution of Mechanical Engineers, Vol. 122, 1932, and the results obtained at the National Physical Laboratory for carbon steels.

With regard to the welding of 0.5 per cent. molybdenum steel, they would notice that unless special care was taken intercrystalline cracking was likely to ensue under creep for very low elongation. This was naturally a very important point to consider. In the Benson boiler which had now been in service for some years, these tubes were of 0·5 per cent. molybdenum steel and no difficulty was found in regard to welding or in subsequent service, while in Loeffler boilers (some of which had been in land service for over seven years) 0·5 or 0·4 per cent. molybdenum steel tubes were welded tc the headers and no difficulty had been experienced either in manufacture or in service. If special technique was employed the job could be made satisfactory.

Dr. Dorey had had his attention drawn elsewhere to the difficulties entailed in producing satisfactory electric welds in 0·5 per cent. molybdenum steel. Such welds had been found to be porous and to contain inclusions which could only accelerate failure if put into service under creep conditions. Dr. Bailey referred to the necessity for special safeguards to ensure reliability of electrically-welded constructions in high creep resistant steels, and it would be of considerable help if he would indicate the safeguards he had in mind.

On the other hand, in a recent high-pressure and high-temperature boiler installation (i.e., a Loeffler boiler) creep resisting steels had been satisfactorily welded by means of the oxy-acetylene process using filler rods of the same composition as the material being welded. Some of these welds had been X-rayed and were understood to be satisfactory. The welding was carried out by experienced operators employing a special technique and the welds were subsequently normalised. It might be inferred therefore that more reliable results might be obtained by the use of the oxy-acetylene process rather than the electric metallic arc process for the welding of high creep resistant steels.

Regarding scaling and oxidation, it was Dr. Dorey's opinion that this would occur more easily in marine installations than in land, assuming equal temperatures at the turbines, due to the varying steam demands of a marine installation. The author's remarks therefore regarding the 5-6 per cent. chromium 0·5 per cent. mo. steel were of special interest. Even with the moderate superheat temperatures at present in use, cases had been noted where dissociation of the steam had occurred followed by oxygen attack on the steel of the superheater tubes.

He would like to refer to one further point in regard to the change of structure. The author had brought out the question of creep and utilization of creep in design to a fine art, but it should not be forgotten that this was fraught with difficulties. The author had produced a mathematical calculation to show how the change of structure would develop in time. This might be quite suitable from an experimental point of view, but one must not overlook the practical significance. What happened in practice was that the change of structure could vary across the tube and between the inner and outer surfaces. There might be on the outer surface a carbon content originally of 0·25 per cent. which due to oxidation decreased to say 0·05 per cent., while the inside might remain at the value of 0·25 per cent. It was difficult to assess the value of a steel when the structure varied. To mention another case—oil cracking work—in a tube for oil cracking it was possible to get a double effect. Dr. Dorey had found in an actual case investigated that due to oxidation the carbon content of the outside of a tube had been reduced from 0·15 per cent. to 0·05 per cent., whereas on the inside the carbon content increased from 0·15 per cent. to 0·25 per cent. due to absorption from the coke layer. Further, on the outside of the tube the manganese had fallen from 0·4 per cent. to 0·15 per cent. and silicon from 0·2 per cent. to less than 0·1 per cent. Dr. Bailey's plastic theory as such was correct, but in superheater tubes both elastic and plastic theories had to be considered. In the speaker's opinion these tubes might work in an intermediate stage where both theories were applicable, i.e., the lower the creep resistance for stresses under consideration the more would the plastic theory apply, or, conversely, the higher the creep resistance the more would the elastic theory hold. These problems were sufficient to indicate the difficulties of producing materials and designing their scantlings to operate at high temperatures.

Finally he wished to emphasize, as the author had, how useful an alloy steel such as nickel-chromium-molybdenum could be if it was used for the right purpose. He (the author) had indicated that if the temperature rose the nickel had a detrimental effect, but when it came to boiler drums which were operated at the lower temperatures, a considerable reduction in the wall thickness was possible due to high tensile strength of the steel at working temperatures. That was important because it would reduce the complex stresses, arising in the drum, and might put it in the category of a thin cylinder instead of a thick cylinder in addition to the saving in weight. In this respect it might be mentioned that a steam pressure of 2,000 lb. per sq. inch was only of the order of 637° F., so that it would be apparent that these special-quality steels had a definite use at temperatures up to this degree, whereas if it was increased to superheat temperature these steels were certainly inferior to the molybdenum steels.

Mr. W. W. Marriner, B.Sc. (Member) said that in the development of the marine boiler various problems had from time to time presented themselves and it had always been the endeavour of the firm with which he was associated to make use of the latest advances in allied industries. The subject was such a wide one that he proposed to confine his remarks to the consideration of a water-tube boiler working at, say, 600lb. per sq. in. and 750° F. steam temperature. It would be evident that these remarks could be applied to higher pressures and temperatures.

They were so used to working with carbon steel, i.e. mild steel, that in considering steel alloys it was possible to lose sight of many qualities which had made the application of mild steel a success and Dr. Bailey was correct in suggesting that carbon steels were sufficient to meet the requirements of immediate developments. To illustrate this let them make a list of some of the qualities which were of more or less importance in their application to boilers, viz. (*a*) tensile strength at the working temperature, (*b*) ductility so as to be easily expanded and where necessary cold-worked as in bell-mouthing, (*c*) uniformity of the material, (*d*) conductivity for heat, (*e*) annealing temperature, (*f*) resistance to oxidization and to other chemical action, (*g*) Young's modulus, (*h*) creep, (*i*) coefficient of expansion, and (*j*) weldability. He would venture to make the following suggestions in connection with these qualities:—

(*a*) *Tensile strength.*—At the temperatures and pressures under consideration, for a tube 1in. internal diameter and $^1/_{10}$th in. thick the stress in the material was 3,000lb. per sq. in., so that mild steel was quite suitable in this respect and for much higher pressures. (Reference might here be made to the classical paper on "Tubes for High-Pressure Water-Tube Boilers" read before this Institute by Dr. Dorey in 1930).

(*b*) *Ductility.*—A modern mild steel tube in this respect was as near perfection as was required for bending, expanding or bell-mouthing.

(*c*) *Uniformity of the material.*—This was of importance to the boilermaker so that the expanders, jigs, tools, etc. could be used by the men and the same result obtained all over the structure and also with similar structures.

(*d*) *Conductivity for heat.*—Professor Mellanby in his *paper read before this Institute in February, 1938, said that it was rather unfortunate that this coefficient for alloy steels was much less than for plain carbon steels.

(*e*) *Annealing temperature.*—This might be defined as the temperature at which the internal stresses in the material were relieved. Rolled expanded joints or joints depending on the tension of bolts or rivets would leak if the temperature of the joint or bolts was raised above the annealing temperature. Mild steel was very favourably placed in a list of steel alloys in this respect.

(*f*) *Resistance to oxidization* which occurred in various forms. To-day, owing to the skill and attention of the operating engineers, the elimination of air from the feed-water and the general cleanliness of the furnace had reduced the corrosion both inside and outside the tubes to almost a negligible quantity with mild steel tubes. With reference to the action of steam at a high temperature on a steel tube, "The Engineer", in its metallurgical supplement "The Metallurgist", published a week or two ago the results of some recent tests. It was stated: "It will be noted that in the tabulated results of Potter, Solberg and Hawkins the carbon molybdenum steel differed little from the carbon steel in oxidation resistance" and "the general conclusion is reached that under fixed conditions of temperature and pressure steam attacks at about the same rate all the steels examined which include carbon and molybdenum types". Again, in striving for higher efficiencies the temperature of the flue gases had been reduced to an extent where with any reduction in the rate of working the dew point was reached and then they had to consider the sulphur gases, their absorption by the moisture in the uptake and the effect of the resulting sulphuric acid on the steel parts. It might be necessary seriously to consider some steel alloy which was more resistant to sulphuric acid than mild steel for uptakes and funnels.

(*g*) *Young's modulus.*—This played an important part in determining the stresses caused by the expansion due to unequal heating of

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* "Service Results with High Pressure Boilers", published in April, 1938, issue.

the parts of a boiler. Young's modulus was also an important factor in any deflection calculations. In the case of mild steel they knew what to expect from it in this respect and a useful feature was that the modulus fell with increase of temperature.

(*h*) *Creep.*—The author's remarks on creep were instructive and his remarks on the relief of internal stress by creep under working conditions were most illuminating.

(*i*) *Coefficient of expansion.*—This was of importance where two metals with different coefficients were working together. They all knew that a screwed brass plug in a steel boiler would leak. At present with mild steel tubes and mild steel drums they had no trouble from this cause.

(*j*) *Weldability.*—This was a property which was becoming of more importance and they might soon have to weld superheater tubes into the headers or superheater drums. At the moment mild steel was perhaps the best material known and the author had given some valuable information on the effect of welding on alloy steels.

They all knew that heat-resisting steels were of great use, for example, for superheater supports, for oil burner cones, for special baffles, etc., and again heat-resisting alloys had increased the life of parts of mechanical stokers when burning difficult varieties of coal. As regards stainless steels, they would be adopted for casings everywhere if they could be afforded.

What he wanted to draw attention to were the many varied characteristics which went to make a material suitable for the purpose for which it was used, and they should be careful not to pay too much attention to any one characteristic which might be obtained at the expense of other equally valuable qualities. In other words, let them always keep in close touch with the steelmaker and keep steel specifications flexible.

Mr. H. C. Walker (Member of Council) said that it was very gratifying to learn from such an authority as the author that the straight carbon steel should prove satisfactory for some time yet in the present trend towards higher temperatures in marine service, and his practical data gave a clear indication of the conditions where limitations would have to be considered.

Although the author's conclusions covered considerable ground the speaker proposed to confine his comments to the remarks on steam pipe arrangements. References were given on pages 96, 97 and 102 to the effect that at the higher steam temperatures creep effect tended to cancel out the stress in pipe work caused by the expansion when under steam, but would appear to full effect when the system was cold. It was also stated that "such stresses therefore need not be considered when determining proportions for operating conditions, and at atmospheric temperature the proportions and physical properties are usually more than adequate to carry the residual loading". The speaker felt that this conclusion might require qualifying and would appreciate the author's point of view. Marine design for steam pipe work as compared to land practice usually had to meet conditions of restricted space, and in certain circumstances it was difficult to avoid appreciable stress arising due to pipe expansion when under steam. Moreover, the alternate cycle in marine service of steaming and cold conditions was considerable, and long cold periods were usual where pipe wastage by corrosion at severely stressed parts was not uncommon. To minimize stress conditions it was customary to allow a gap when joining up pipe work, such that in the cold condition an initial strain was arranged of half the anticipated extension when hot, and he understood even higher allowances were customary in land practice. *Providing creep was not present* such an arrangement enabled designers to keep stresses in marine steam pipe work within reasonable limits under all conditions of service, whether under steam or cold conditions, and to ensure that the designed conditions would remain constant in service.

His point was that under higher temperature conditions, where creep effect would arise in service, it was important that the stresses that would eventually arise in service under cold conditions must be taken into account. With creep conditions present, pipe work designed on present-day methods would give satisfactory stresses in the initial stages of service but in time, as creep cancelled out the stresses under steaming conditions, the stresses under cold conditions would *increase* and in adverse circumstances exceed the safe limit. Experience in present-day practice showed that such adverse stresses did arise and trouble was not infrequently experienced by excessive wastage at highly-stressed parts, and by pipes cracking at the neck near flanged connections.

He would suggest therefore that while creep effect in steam pipe work might be all to the good in relieving stress under steaming conditions, the eventual additional stress thrown on the pipe work when cold was an important factor and must be given careful consideration in the design of steam pipe arrangements for the higher temperature ranges under discussion.

Mr. W. E. Bardgett, B.Sc. (Visitor) said that the author must have had considerable difficulty in dealing with the subject of creep in such a general manner on account of so many factors being involved which influenced the resistance to deformation at high temperatures, in particular the method of manufacture and small variations in composition. The author had made comparisons in a very precise manner between carbon steels, 0·50 per cent. molybdenum steels and 1 per cent. chromium 0·50 per cent. molybdenum steels which, in the light of present knowledge, hardly seemed justifiable. In a paper given by Jenkins, Tapsell, Mellor and Johnston to the Chemical Engineering Congress of the World Power Conference in 1936, the results of creep tests on carbon steels showed wide variations, though no explanation was given of the cause of the variations. Certain steels were classed as abnormal and others as normal with respect to creep resistance. In the research department of the Company with which the speaker was associated a considerable amount of work had been carried out on the effects of small variations in composition on the creep resistance of 1·0 per cent. chromium 0·50 per cent. molybdenum steels and they had found that certain small variations in composition could affect the creep resistance to a remarkable degree and that the creep resistance of these steels could be greatly increased by control of the elements normally present within certain well-defined limits. They had found that such steels of enhanced creep resistance were much superior to the normal 0·50 per cent. molybdenum steel and it followed that as a result of the enhanced creep resistance, the temperature range over which these steels were normally superior to the 0·50 per cent. molybdenum steels was considerably extended. While the results of their tests on the effect of variation in composition on creep resistance had been obtained by short period tests, full confirmation of the superiority of the low carbon chromium molybdenum steels over the 0·50 per cent. molybdenum steels up to high temperatures, actually from 400 to 700° C., was obtained from long time creep tests carried out in America. He mentioned this in order to show that the author's results referred only to steels manufactured by a particular process and of a definite composition and must not be accepted as applying generally to steels of the type referred to by the author.

Another factor of importance in the selection of the most suitable steel for high-temperature service was scaling, and in this respect the chromium-molybdenum steel was much superior to the 0·50 per cent. molybdenum steel. Since the useful range of service temperature of steels was limited by the effects of scaling, quite apart from consideration of stress, the chromium-molybdenum steel might be used at higher temperatures than the plain molybdenum steel.

The author referred to the method of artificial ageing by heating for a short period at a temperature higher than the working temperature, in order to determine the effect of thermal action on creep resistance at the service temperature. Had the author tested the creep resistance of specimens aged equally, according to micro examination, at different temperatures?

Eng. Rear-Admiral W. M. Whayman, C.B., C.B.E. (Vice-President) said that he had been very interested in the point that there was no disadvantage to the superheater tube due to the metal temperature creeping up slightly above the designed limit, provided it occurred only intermittently and not for a long period. This fact probably solved the problem of the surprising reliability of mild steel superheater tubes which were known to be in use at high temperature.

He had attended a meeting at the British Standards Institution that afternoon, and Sir Wm. Larke had mentioned that the number of specifications for different qualities of steel was about 380, but he understood that they were now reducing that number to something in the region of 25 or 30 for all the requirements of the engineer. This was very satisfactory and should be of great interest to the steel user.

The Chairman had invited him to propose a vote of thanks to the author for this valuable paper and he had very great pleasure in doing so, particularly thanking Dr. Bailey for the very lucid way in which he had delivered such an excellent contribution to the TRANSACTIONS.

Mr. James Carnaghan (Vice-President) seconded this proposal which was carried with applause.

By Correspondence.

Dr. W. H. Hatfield wrote that this paper did not really present any new data—this was mentioned by the author himself.

As regards spheroidising, the principle that times as well as temperatures were involved would be readily conceded, but it appeared to be rather presumptuous to attempt to express the time of spheroidising to a given degree in terms of a mathematical formula.

It was interesting to compare the stress values in Fig. 3, carbon steel, with his own Company's time yield values (*see* Fig. 17). For the author's

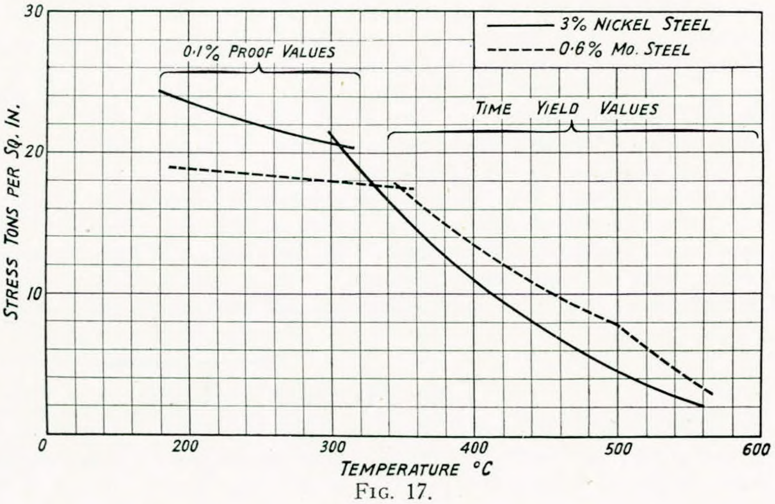

FIG. 17.

10^{-8} limit (average) he had 5·8 tons per sq. in. at 750° F. and just over 1 ton at 930° F. compared with the writer's values of 8 tons per sq. in. and 4 tons per sq. in. time yield at approximately the same temperatures. The author's values, however, referred to a spheroidised condition. His values for 0·003 strain in 100,000 hours were approximately ¾-ton higher.

The author drew attention to the fact that increased strength at atmospheric temperatures was in some cases an advantage. The writer would prefer to say that the increased strength at atmospheric temperatures was frequently retained in large measure at intermediate temperatures, i.e. at temperatures where the tendency to creep had not become sufficiently pronounced to be a determining factor.

In this way the addition of nickel or chromium as alloying materials could be taken advantage of for parts subject to steam temperatures all except the very excessive, and one might also here add that the higher carbon steels had also advantages over a limited range of temperature. Thus one could justify the use of 32/36 tons per sq. in. or 34/38 tons per sq. in. material for boiler drums as compared with the milder materials.

As regards the main principles of the author's thesis the writer was in agreement, e.g. his reference to proportional limit and proof stress and his reference to scaling and oxidation. As regards welding he would agree with the author that safeguards should be imposed and each individual item dealt with on its own merits. The advantages of molybdenum as an addition to alloy steel were very clearly brought out, and as regards welding of this steel improved technique might possibly extend its applications.

Mr. Harry Hunter (Member) wrote that attention might be drawn to some differences between marine and land operating conditions which had a bearing on the use of high temperatures.

In an ordinary case the marine engine would be started from a dead stop about 1,100 times per annum, so that a considerable number of fluctuations of steam temperature had to be provided for, and from experience it was found that for short periods when manœuvring the steam temperature might be considerably in excess of normal. This, of course, was due to the temperature at the superheater outlet being dependent on the relation between rate of combustion and rate at which steam was passing through the superheater. In the case of a boiler with a superheater designed for a steam temperature of 775° F. and assuming that the rate of combustion be left constant at 100 per cent. and that the quantity of steam through the superheater was reduced, the resultant temperatures would be somewhat as follows :—

Percentage of normal evaporation through superheater ...	100%	80%	60%	40%
Steam temperature at superheater outlet	775° F.	850° F.	960° F.	1,100° F.

Such troubles as had been experienced with marine high-temperature superheaters were in general due to the effects of short periods at unduly high temperatures rather than prolonged periods at more moderate temperatures. This could be expected from the formula (1) on page 95, as according to this, one hour at 1,200° F. would produce as much carbide spheroidisation as would 100,000 hours at 800° F.

Tube failure under above "breakdown" conditions was due to a combination of creep and scaling (both internal and external) and some workshop tests were carried out by the writer's company on tube life in the "breakdown" zone. The tubes were 1½in. outside diameter mild steel subjected to an internal air pressure of 800lb. per sq. in., the air being stagnant. The following data gave the life until burst occurred as deduced from these tests :—

Metal temperature	1,600° F.	1,400° F.	1,200° F.
Life	About 3 hrs.	About 80 hrs.	Approx. 3,000 hrs.

This all confirmed the necessity with mild steel of avoiding even short periods at abnormal temperatures and that in marine work it was essential at all times to ensure adequate circulation of steam through the superheaters.

In the section of the paper entitled "Cylinders, Pipes and Tubes" the author implied that at the higher temperatures creep could be relied on to assist in taking care of pipe expansion loads. According to the experience of the writer's firm, at temperatures of 750° to 800° F. this assistance was not apparent—or at any rate was too slow in acting to be of practical assistance. If at these temperatures inadequate provision for expansion was made, then the joints would give trouble before creep could relieve the expansion loads. However, it might well be that at higher temperatures the relief might take place soon enough to be of practical help.

On page 103 the author stated "It may be taken that creep under tensile and compressive stress is similar, etc.". Could he tell them where information as to compressive creep had been published as the writer had been unable to find any data on this subject? Lacking any information, the assumption as to similarity between tensile and compressive creep could hardly be accepted, particularly as in the case of certain materials the compressive elastic properties bore no relation to those under tension.

The Author's Reply to the Discussion.

The author, in reply, said that he was very interested in Dr. Dorey's remarks about the experience obtained in marine practice with high temperatures and pressures, referring to the Loeffler and Benson boilers. These cases, of course, employed temperatures and pressures which corresponded with those attained on land and he was glad to hear from Dr. Dorey that he agreed that 850° F. was a likely high temperature for marine practice for some time to come. Whereas these high pressures and temperatures were in use at sea only to a very limited extent, on land they were being used commercially, so that the use of similar pressures and temperatures at sea must be regarded more as an experiment.

Dr. Dorey referred to the difference in temperature between the steam and the tube, and mentioned that temperatures of 1,000° F. might be obtained during manœuvring. The author did not know what time was occupied manœuvring as compared with the full life of marine plant, but high temperatures could be tolerated for short periods without doing any real damage, and he was not afraid therefore of occasional short periods at temperatures in the region of 1,000° F. even with carbon steels. In this connection he might mention their own experience in the early days of testing high temperature steam turbines. The piping installation of the works' power plant was not then rated for the temperature required, although from investigation they were satisfied that occasional periods at the desired temperature could be safely employed if the total time at the higher temperatures was limited. The matter was discussed with the insurance company and, upon the basis of creep and its dependence upon temperature, agreement was reached to use higher temperatures provided the total annual times and temperatures did not exceed a proposed schedule covering temperatures 50° and 100° F. above the temperature at which the plant was previously insured. If, then, manœuvring only occupied a short period in the whole life of the plant, he did not think there need be any fear in getting up to temperatures of, say, 1,000° F.

Dr. Dorey referred to the fact that at 950° F. there was little advantage in the 0·5 per cent. molybdenum steel. He was quite right. One must bear in mind that molybdenum steel weakened considerably in time at the higher temperatures, so that much of the advantage which it offered in the region of 900 to 930° F. was lost 20 or 30° higher. It was one of the problems to find a steel which would maintain its properties for long periods above 932° F. There were indications that the solution would be found with a molybdenum-vanadium steel. Such a steel, however, would have only a limited useful range of temperature, but it looked as if the range would be above that of the usual 0·5 per cent. molybdenum steels.

He agreed with Dr. Dorey regarding calculating the thickness of steel tubes. One must choose a thickness which would stand up to constructional requirements and its work, and in making use of the formula which gave minimum thickness sufficient for creep, practical aspects must be considered. The thicknesses calculated upon the basis given by the paper sometimes caused one to consider whether, in the case of severe pressures and temperatures, a stronger steel should be used in order to reduce thickness to a practical magnitude.

The diagram shown by Dr. Dorey (Fig. 16) showed interesting agreement between the stresses used by Lloyd's Register and the stresses given by the paper for carbon steels, especially at the higher temperatures where creep conditions prevailed.

The author did not think he had made himself quite clear about welding. He pointed out that in the case of a weld, failure could occur by intercrystalline cracking starting from a small cavity if the stress were high enough. Failure of the kind would occur when the material had been under load and creep for some time. His experience of molybdenum steel welds was that as welds they were very good. He was speaking of electrically-deposited metal. The metal went down very solid and it seemed to be a very sound material for welding. But if an all-welded testpiece—a perfect specimen—were tested under creep until failure occurred, it might fail at 1 or 2 per cent. extension, whereas a similar testpiece tested at the same temperature as in an ordinary tensile test, an extension of 20 per cent. would probably be obtained. Under the prolonged stress action intercrystalline cracking developed in the material and it seemed to be associated with a specific deformation. It was, he thought, very necessary therefore that one should arrange to have the working stresses such that there was a good factor of safety on deformation. Whereas it was going to take 1 to 2 per cent. to develop these intercrystalline cracks, if in practice the deformation was limited to 0·1 - 0·3 per cent. there would be a fairly good margin of safety. He was interested to hear Dr. Dorey's good opinion of welds made in 0·5 per cent. molybdenum steel using the oxy-acetylene process.

Dr. Dorey in referring to carbide spheroidisation drew attention to the large variation that could occur in the value of "A". Actually this did not affect the practical utility of the relationship found which depended really upon the index of "e". The experiments carried out by the author's Company revealed the significant fact that for all the steels tested, which ranged from mild steel to steel with 0·9 per cent. carbon, the index of "e" was for practical purposes the same and was as represented by the figure 33,000 in the equation.

The practical problem was as follows: If a steel were required to operate in practice at say 500° C. for 100,000 hours, what period of thermal treatment could be given to say 650° C. (below the AC_1 point) equivalent to the service conditions in its influence upon structural change? This time did not involve "A" but in accordance with the equation was given by:—

$$100{,}000e^{33000\left(\frac{1}{650+273}-\frac{1}{500+273}\right)}$$

or, it was approximately 100 hours. This equivalence of 100 hours at 650° C. with 100,000 hours at

500° C. would apply to all carbon steels whatever their initial condition. Thereby a short laboratory treatment of material could be used to imitate the effect of prolonged service temperature.

Cases of steel tubes mentioned by Dr. Dorey where there might be decarburisation at one place, and even carburisation at another, presented difficulties, and without investigating such cases it would be unwise to attempt to forecast behaviour. However, both decarburisation and carburisation might be expected for physical reasons to be governed by the same kind of law as carbide spheroidisation and therefore a similar relationship, but probably with different constants would express the effect of temperature upon the kind of changes involved.

Mr. Bardgett asked whether he had made creep tests which justified the conclusions reached. Particulars were given in a *paper read by Mr. A. M. Roberts and the author, which indicated that their attitude was justified. Good agreement was found by the tests made on both a 0·15 per cent. carbon and a 0·4 per cent. carbon steel.

Dr. Dorey referred to the extent to which the elastic properties should be taken into account with plasticity. There was bound to be a point, as Dr. Dorey indicated, where the elastic and the plastic conditions were concerned and where both were important. When, however, plastic conditions were reached the amount of movement permitted under creep swamped completely the elastic deformation. Take, for example, a superheat of 900 to 1,000° F. and a stress of 1·25 tons/in.^{2}; the modulus of elasticity would be of the order of 8,000 tons per sq. in., so that the elastic deformation of the tube would be about 1/6,500 inch per inch and the amount of permissible creep would be not less than 6·5 times the amount of elastic deformation. With an elastic deformation of 3/1,000 inch it would be 20 times. In most cases the author considered that it could be taken that the initial elastic phase did not last long and the stress distribution changed from the elastic to the creep distribution. He thought it was reasonably safe with high temperatures where creep was the controlling factor to deal with the stresses as they were found by analysis under conditions associated with creep.

Dr. Hatfield characterised as presumptuous the attempt to express the time of spheroidising to a given degree in terms of a mathematical formula. The author believed that both the experimental evidence and the physical basis did justify the use of the formula. From the physical standpoint carbide spheroidisation involved a movement or immigration in the ferrite of iron carbide. Whether this movement was associated with iron carbon molecules having energy of heat motion above a particular level, or of a critical magnitude, the dependence of the number of such molecules present upon temperature would conform with a relationship of the same type giving the time t for a specific change in the form $t=Ae^{\frac{b}{T}}$ where T is absolute temperature. Thus the relationship was not empirical nor a guess, but rational, and they had themselves been surprised by the high accuracy of its application to the results of experiments upon carbon steels. Because of its rational character application of the formula to lower temperatures where very long times were involved was justified. Dr. Hatfield's data (Fig. 17) confirmed the views expressed in the paper.

There were one or two points in Mr. Marriner's remarks he would like to underline. The author was glad to note they were both in agreement on the wide usefulness of mild steel. Mr. Marriner referred to the question of oxidation and mentioned that in a recent article evidence had been given to show that there was equal attack in the series of steels examined. The author thought that the amount of the attack was about equal, but there was a tendency for a difference in the character of the attack and the advantage was on the side of mild steel. If one examined the film of oxide on mild steel it would be seen that the attack was very even over the metal. In the case of molybdenum steel there was a tendency for the oxide to enter at the grain boundaries, although it was not an extensive penetration. He had tried nickel plating on the surface of creep test specimens to counter oxidation and found evidence of oxidation below the nickel.

The coefficient of expansion was an important property. It was an unfortunate circumstance that the steels which resisted corrosion and oxidation best had a coefficient of expansion greater than mild steel and other low alloy steels, which made it difficult to incorporate these steels in design.

Mr. Walker drew attention specifically to the question of stress in steam pipes associated with thermal expansion and gave a warning that although creep resulted in an easier set of conditions at high temperatures there was the fact that thermal stresses came in with their full effect when the system was cold. The author thoroughly agreed that one must not overlook that fact. There could be cases where the stresses cold could be sufficient to cause an open joint and one must therefore be on the lookout; but generally speaking by alterations in proportions advantages could be ensured both cold and at working temperatures.

Mr. Bardgett mentioned that as the result of his Company's researches they had found that certain small variations in composition could affect the creep resistance of 1·0 chromium and 0·5 per cent. molybdenum steels, and that short-time tests showed that the creep resistance could be greatly increased. He agreed with Mr. Bardgett that under certain

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* Testing of Materials for Service in High Temperature Steam Plant". Proc. I. Mech. E. 1932, Vol. 122, pages 224-227.

conditions of temperature and duration the presence of chromium with 0·5 per cent. molybdenum could show lower creep than a similar 0·5 per cent. molybdenum steel. But the author's own evidence all showed that the permissible stresses for the two steels crossed over at a particularly temperature depending upon the time of service required, and above this temperature the presence of chromium was detrimental.

It was a serious disadvantage of short-time tests at the intended working temperature that one did not discover the cross over. He agreed that there was an opinion in America and in Germany that one had an all-round advantage by adding the chromium to molybdenum steel. He had noticed recently, however, that an American firm which was running high-temperature plants now used. chromium steel up to a certain temperature, and they were using molybdenum steel above that temperature.

Dr. Hatfield in his comments compared the results which were given in the paper with figures which he had obtained for his time yield and noted the difference. There again the difference might be explained by the comparatively short time of the time yield test. If they could only find a short-time test which would give them the answer for long-time service!

It took a tremendous time to explore a steel in order to fix design stresses. The author's experience was that they always had steels waiting to go on the testing machines. A fully satisfactory short-time test would help them out of that difficulty. The author considered that short-time tests were valuable as comparative tests, but one should not interpret the results much beyond that. A short-time test meant an accelerated test by increasing the stress or the temperature. Of the two he considered increase in temperature gave the better picture of the relative properties of two steels, but the problem was how much to push up the temperature so as to obtain stresses which could be used at the working temperature for a long time.

Mr. Hunter in giving a quantitative idea of the influence of manœuvring conditions upon steam temperature, provided some of the data which was necessary for an estimate to be made of the resulting effect. Equally important was the total duration of these conditions, and this one would think must vary widely with different classes of shipping and routes. In any case Mr. Hunter's statement that "such troubles as had been experienced with marine high temperature superheaters were in general due to the effects of short periods at unduly high temperatures rather than prolonged periods at more moderate temperatures" must be given very considerable weight. It was necessary to enquire whether such failures were due to "hot spot" conditions, as these would become more severe in common with general conditions when manœuvring, and if so whether improvement in steam flow and design could offer improvement in this respect as had been notably the case on land. Mr. Hunter drew attention to this most important point when he stated that "it was essential at all times to ensure adequate circulation of steam through the superheaters".

If one assumed the average time for starting from a dead stop as five minutes, this would correspond with a total time of 46 hours per year or under 1 per cent. of the operating time. The matter of interest was what would this correspond with in permissible temperature rise, for what Mr. Hunter had referred to as "breakdown" conditions. Without much data one could only speculate and Mr. Hunter's very interesting tests upon the point might be used to obtain an idea. Assuming that a tube was only just able to ensure normal service without the contingency of abnormal temperature rise and that one was prepared under more severe conditions to sacrifice, say, 25 per cent. of the life to enable abnormal temperature rises to be carried for 1 per cent. of the life, i.e. this 1 per cent. under intense conditions was to be equivalent to 30 times the period for normal conditions, Mr. Hunter's figures suggested that the temperature might be allowed abnormal increases of about 200° F. Would this not meet the conditions of extra severity in the marine case, and be handsomely paid for by the resulting steam economy associated with increased rated steam temperature? If it became necessary design might even provide for the easy replacement of elements in the most vulnerable positions, such replacements being a matter of routine and not necessitated by failure. Should it be necessary in especially difficult cases some arrangement could probably be made for desuperheating to operate automatically when starting.

Mr. Hunter's experience that no substantial changes in pipe expansion loads occurred at temperatures of 750-800° F. agreed with what would be expected. The degree of relaxation of thermal expansion loading was related to the amount of corresponding diametral creep of the pipe, and under normal design for the temperature mentioned this would be insufficient to cause appreciable relaxation. At higher temperatures, however, e.g. 850° F. and above, in cases where creep determined design, the position was different and effective relaxation would occur.

Similarity of creep of steel under tensile and compressive stresses was very difficult to demonstrate directly by tests under simple compression, only because of the difficulty of making satisfactory creep tests under simple compression. The existence of similarity, however, could be deduced with certainty from the results of creep tests under compound stress. Work of this kind had been done and *published, which showed conclusively that behaviour under tensile and compressive stresses was similar.

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*R. W. Bailey. "Utilization of Creep Test Data in Engineering Design". Proc. I. Mech. E., Vol. 131, 1935.

INSTITUTE NOTES.

[*]Discussion on "Service Results with High Pressure Boilers" *(Continued).*

Dr. Gleichmann wrote: "I hasten to take the opportunity of meeting the wish expressed by Professor Mellanby by sending the accompanying diagram and the following remarks based on practical knowledge of the subject.

The interesting table which illustrated Mr. Roylands Cooper's contribution to the discussion (*see* April, 1938 TRANSACTIONS, page 69, Fig. 19) gave specific figures for the hourly production of steam on a basis of total boiler weight and space occupied, and showed the development from the large cylindrical boiler to the forced-circulation pressure-tube boiler. During the past ten years it had been possible to reduce the boiler weight in the proportion of 6 to 1, and the necessary floor area and boiler-room space in the proportion of 8 to 1; this important reduction of the boiler dimensions naturally had an important effect upon the entire layout of the ship. While, for example, the boiler space previously required was twice that of the machinery space, to-day in a ship fitted with Benson boilers the boiler space required is only half that of the machinery space. Moreover, the use of steam at high pressure, for the production of which the Benson boiler is peculiarly adapted, gives an economy of fuel which becomes noticeable either in the diminution of the bunker space or in an increase in the range of the voyage.

The following notes may serve as an example. The steamship 'Uckermark', the first ship with a Benson boiler, is at present completely driven by super-pressure steam. The original steam generating plant consisted of one double- and two single-ended boilers. The machinery is also a new installation, and as a result of these alterations the cargo capacity of the ship is increased to the extent of about 900 tons.

In all high-pressure boilers the question of feed-water supply requires more attention; this problem has been specially considered during many years of experience with the Benson boiler in land and marine plants. The result of this experience has proved the necessity of feeding the Benson boiler with nothing but pure condensate. It has become apparent that to overlook this necessity in either a land or marine plant leads to difficulties in the operation of the boilers and to corrosion of the turbines. The realisation of this necessity, namely the feeding of the boiler with condensate, especially simplifies the design of the Benson boiler as opposed to the construction of other high-pressure boilers. In the Benson boiler no separate circulating pumps, no additional consumption of fuel for the indirect heating of a secondary circuit, and no drum are needed; instead there are the quite considerably important advantages of a

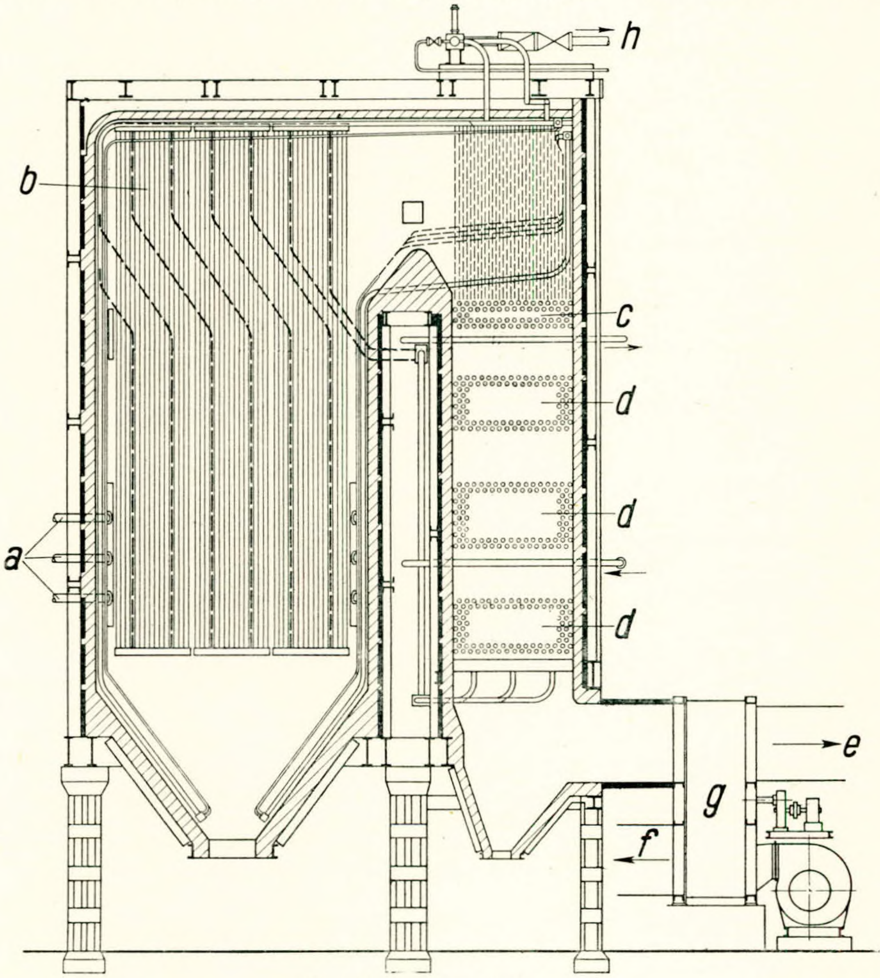

FIG. 24.—Benson boiler.

(*a*) powdered coal burner
(*b*) radiation element
(*c*) superheater
(*d*) generator element
(*e*) outlet to electro-filter
(*f*) air inlet to boiler
(*g*) air preheater
(*h*) superheated steam outlet

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[*] Published in April, 1938 TRANSACTIONS, Vol, L, Part. 3.

forced-circulation pressure-tube boiler, namely high overload capacity, freedom in choice of shape as it is no longer necessary to pay attention to the natural circulation of the water, safety from explosion, and the possibility of working the boiler at any required superheat and temperature. The advantages of the high overload capacity, of the small space occupied, and especially of the safety from explosion are very important features in favour of the use of the Benson boiler in warships.

The principle of forced circulation has also strongly influenced the design of the boiler for use on land, and the publicity which the Benson boiler has received in Germany during the last few years has led to the adoption of a standard method of construction (*see* Fig. 24). In Germany there are in construction and in use 43 land Benson boilers with an aggregate steam capacity of more than 3,800 tons per hour, of which 11 boilers with a total of 800 tons per hour steam capacity have been working for several years to the satisfaction of their owners".

Professor Mellanby, in reply to Dr. Gleichmann, wrote: "The Members of The Institute would be pleased to have the additional information on the Benson boiler which had been supplied by Dr. Gleichmann. Especially interesting were his figures of steam raising capacity, while the fact that there would soon be 43 land Benson boilers in use in Germany was further confirmation of the statement in the paper that the controlled circulation boilers were now becoming accepted practice. I would especially ask the Members to give careful consideration to Dr. Gleichmann's figures on the possibilities of reducing weight and space by the adoption of the new types of steam generator, and to the resulting effects upon cargo accommodation".

ELECTION OF MEMBERS.

List of those elected at Council Meeting held on Monday, 2nd May, 1938.

Members.

John Edward Bish, Suva, Fiji.
Gavin Jarvie Brown, 152, Cathedral St., Glasgow.
Frank Stanley Davies, 68, Highbury New Park, N.5.
James Rigby, Takuapa Valley Tin Dredging Co., Ban Pru, Haad Yai, South Siam.
Kenneth Charles Thorburn, 85, Harden Road, Leamore, Walsall.
William Heslop Woolnough, 4, Clements Inn, W.C.2.

Associates.

Joseph Norman Galley, Allendale, Greta Avenue, West Hartlepool.
Robert Humble Lowes, 22, Peel Street, Sunderland.
Norman Carse Marr, Woolston, East Herrington, Sunderland.
Alfred Menhennet, 7, Barfillan Drive, Craigton, Glasgow, S.W.2.
Noel Leslie Seager, School House, Frensham, Farnham, Surrey.
Godfrey Hunt Thomas, 11, Park View, Port Talbot, Glam.
Herbert George Thompson, 126, Albert Road, South Melbourne, S.C.5, Victoria.
Richard Edward Witty, 46, Albany Street, Hull, E. Yorks.

Transfer from Associate to Member.

Francis Anthony Aloysius Whitehead, 7, Chord Road, Drogheda, I.F.S.

Transfer from Probationer Student to Student.

Ernest Harold Duncan, 52, Moorgate, E.C.2.

ADDITIONS TO THE LIBRARY.

Purchased.

Report for the Year 1937 of the National Physical Laboratory. H.M. Stationery Office, 2s. 6d. net.

Welding of Steel Structures (Report of the Welding Panel of the Steel Structures Research Committee, Department of Scientific and Industrial Research). H.M. Stationery Office, 6s. net.

Very Low Temperatures, Book II. By T. C. Crawhall, M.Sc. and O. Kantorowicz, Dr. Phil. H.M. Stationery Office, 2s. net.

Lloyd's Register of Yachts, 1938. Lloyd's Register of Shipping, 42s. net.

Presented by the Publishers.

Report of the Research Committee of The Institution of Civil Engineers for the years 1935-36 and 1936-7.

The British Engineers' Association. Classified Handbook of Members and their Manufactures.

Handbook for Oxy-Acetylene Welders. British Oxygen Co., Ltd., 3s. 6d. net.

Ignition Quality of Diesel Fuels. The Institution of Petroleum Technologists.

British Standard Specification No. 122-1938. Milling Cutters and Reamers.

Proceedings of the Institution of Mechanical Engineers, Vol. 137, containing the following papers:—

- "The Mechanics of Flame and Air Jets", by Davis.
- "Recent Developments in High-speed Reciprocating Pumps", by Towler.
- "Diesel Traction on Railways", by Ambady.
- "Friction and Heat Transmission Coefficients", by Cope.
- "Heat Loss from Gilled Metal Pipes", by Griffiths and Awbery.
- "Impact Stresses in a Freely Supported Beam", by Arnold.
- "Overhead Electric Travelling Cranes", by Ellis.
- "The Distortion of Metals by Cold Working", by Wainwright.
- "British Engineering Societies and Their Aims", by Mowat.
- "Modern Developments in Tractor-drawn Excavator Equipment", by Bone.

Discussion on Notched Bar Impact Testing. Reprinted from the Transactions of The Manchester Association of Engineers, St. John Street Chambers, Deansgate, Manchester, 3. (Copies bound in stiff paper covers are available on application to the Association at 3s. 6d., post free).

The first meeting promoted by the Joint Committee on Materials and Their Testing was held in Manchester on the 29th October, 1937, when the following papers were presented:—

- "Impact Testing from a Physical Standpoint", by Professor R. V. Southwell, M.A., F.R.S.

"Some Aspects of the Notched Bar Test", by L. W. Schuster, M.A.

"The Development and Present Position of Continental Research on the Notched Bar Test", by Dr.-Ing. Max Moser.

"Discussion of the Impact Test", by Captain R. K. Haskell and H. C. Mann.

A most useful and interesting discussion resulted, both spoken and written, and all the contributions as well as the papers have been bound in one volume. It will be realized that this work contains a most valuable survey of the state of knowledge of the subject and current opinions.

Elastic Properties of Non-Ferrous Metals and Alloys: Collected Data. By J. McKeown and E. D. Ward. (Research Report R.R.A. 473 of the British Non-Ferrous Metals Research Association). Published by the Association, Regnart Buildings, Euston Street, London, N.W.1, 35 pp. (29 of which are tables of data), 6s. post free.

The need for the collection and survey of data on the elastic properties of non-ferrous metals and alloys is evident to anyone who has searched the literature of this subject. A great supply of information exists for most materials, but it is spread over a wide range of technical literature and is not always easily traced. In addition, when a critical survey is made it is found that much of the information is incomplete and quite unsuitable for purposes of comparison, owing to the omission of details regarding such important factors as the limits of accuracy and sensitivity of the determinations.

For the selection of the results given in this report a large mass of published information was collected, and as a first step this was critically examined and all information which failed to reach a high standard set was discarded. In arriving at this standard, the primary condition laid down was the inclusion of the fullest details on *(a)* the composition of the material; *(b)* its condition as tested—this includes its nature, whether wire, sheet, rod, etc.; *(c)* where relevant, the method of production of the material; and *(d)* the sensitivity of the strain-measuring apparatus used. In addition to information from published sources, some determinations recorded in the Association's own research reports are included.

By far the greater part of the data given have been obtained from tensile tests, and elastic data obtained in torsion tests; bending tests or more complex tests have not been included.

Most of the data are given in the form of tables, but occasionally, where space is saved thereby, graphical representation is used. In addition to data on elastic properties, the tables in a large number of cases contain information on the ultimate tensile strength and elongation of the materials. The metals and alloys included in this report have been divided into groups as follows: Copper and its alloys (further divided under six sub-headings); nickel, cupro-nickels and nickel alloys (five sub-headings); light metals (aluminium; aluminium alloys; magnesium and alloys); gold, silver and platinum group metals. Altogether 219 metals and alloys are tabulated. A list of literature references from which the data were obtained is provided, together with an index.

Motorshipping in 1937. By A. C. Hardy, B.Sc., F.R.G.S. Charles Birchall & Sons, Ltd., 208 pp., copiously illus.; unpriced, and copies only obtainable on application to the author or publishers.

This publication comprises in bound form the articles by the author which have appeared week by week during the year 1937 in "The Journal of Commerce" (Shipbuilding & Engineering Edition) under the title of "Motorshipping". It should not be confused with the author's other annual work "Motorships of the World and Motorshipping Register", which is due to appear very shortly.

The volume contains a most exhaustive commentary on the current state of that large portion of world shipping which depends upon internal combustion engines for propulsion. It is complete with an index, and those who are favoured with a copy of this volume will find it extremely useful for reference purposes.

Steam Propulsion Developments. By C. R. Ferris, B.Sc. Charles Birchall & Sons, Ltd., 166 pp., 79 illus., 5s. net.

The fact that the first edition of this work was rapidly sold out and the second has been unavailable for some time now seems to indicate that it supplied a need. As even in the few years since the first edition was published fresh developments have taken place, the whole book has been revised and brought up to date. Two entirely new sections have been added and also an appendix giving the names of ships in which the machinery described has been fitted. The contents of this new edition include exhaust turbines, improved reciprocating engines, improved turbines, boilers, super-pressure boilers, mechanical stokers, electric propulsion, ship forms and appendages.

The value of having in one handy book up-to-date descriptions of all these modern developments seems to ensure that the new edition will have as happy a reception as its predecessor.

Experimental Electrical Engineering. By E. T. A. Rapson, M.Sc., A.C.G.I., D.I.C. Sir Isaac Pitman & Sons, Ltd., 2nd edn., 181 pp., 202 illus., 3s. 6d. net.

This is a type of book difficult to write and in many cases difficult to apply generally to existing conditions in the laboratory. It is one, however, which can be recommended to teachers who are drawing up or extending laboratory courses in electrical engineering. Thus adopted as a guide, it could then be recommended without reserve as being of great utility to their students.

The book contains descriptions, diagrams, etc. of 105 grouped experiments dealing with resistance, heating, illumination, instruments, and testing of d.c. and a.c. generators and motors, transformers, rectifiers and valves. One is glad to see so clearly set out and illustrated the conclusions to be drawn from each experiment. If a student is thus directed he is far more likely to learn what is intended than if such guidance is withheld and he is left to his own conclusions, which in many cases are nil and even worse than useless. In the teaching of electrical engineering, and especially in the higher grades of the subject, it is impossible for the lectures in theory to keep pace with the requirements of the practical work; hence students are often called upon to work out experiments of which they have not the slightest idea of the "why" or the "wherefore". For this reason alone, the reviewer believes it would be a great advantage if the author included a brief yet complete digest of the principles underlying each experiment. This would of course enlarge the book somewhat, but it would make it entirely self-contained and the reviewer believes the advantages to be gained far outweigh the disadvantages.

The procedure or method of each experiment is clearly set out and as stated before the conclusions are indicated and illustrated. The diagrams of connections are as clear and complete as possible, and the respective contributions of the author and publishers to the general production are to be highly commended.

Materials and Structures: Vol. II—The Theory and Design of Structures. By E. H. Salmon, D.Sc. Longmans, Green & Co., 796 pp., 516 illus., 32s. net.

This is a comprehensive, up-to-date and clearly written text book, complete with numerous excellent diagrams and drawings.

Dealing first with forces and deflections in framed structures and the use of influence lines, it includes sections on strain-energy theory, columns, beams, girder-bridges, roofs, arches, reinforced concrete, earth pressure, foundations, etc., with a short account of electric welding methods. Application of theory to practical design is shown throughout the text in worked examples which include, among others, the designs of a girder bridge, roof truss and reinforced-concrete arch.

The many examples (with answers) at the end of each chapter should prove of great value to the student, while the very comprehensive classified lists of original sources enhance the value of the book as a work of reference.

Statistical Survey of Engineering Exports. British Engineers' Export Journal, Dorset House, Stamford Street, London, S.E.1, 10s. 6d. post free.

The "British Engineers' Export Journal" has just produced a very comprehensive survey of British engineering exports to the principal countries of the world. Engineering exports to 112 countries are tabulated under about 80 different headings. The value of the classified exports reaches the enormous total of £36,075,000, electrical machinery leading with a total of £8,673,000, the largest customers being South Africa. A layman, scanning the pages, cannot help but be impressed by the wealth of detail given in the survey, but manufacturers and exporters will find it an exhaustive and reliable guide to the many categories of engineering exports upon which to base their plans for future development. This is a pioneer effort to provide reliable statistical data for the exporter and is produced in handy folder form.

Engineering Metallurgy. By Bradley Stoughton, Ph.B., B.S. and A. Buts, A.B., B.S. McGraw Hill Publishing Co., Ltd., 3rd edn., 525 pp., illus., 24s. net.

This useful manual is now in its third edition. It has been revised in places but the scheme remains practically the same as before. In the foreword the authors explain that, what to include in a moderate-sized book of so broad a scope and what portions of the subject to treat very briefly or at greater length, can be the basis of much divergence of view. Before beginning this revision they invited the views of users of the book, as to how it might be made to serve their purpose better. The preponderance of opinion appeared to favour the expansion of the material on alloys, utilization of materials and alloys, and the relations between composition, properties and utilization.

Although most subjects must of necessity be treated briefly, the very wide scope of this well-planned textbook recommends itself not only to students but to metallurgical engineers and users of metals generally. At the end of each chapter is given a most valuable summary which gives a clear and concise general interpretation of the detailed matter comprising the chapter.

JUNIOR SECTION.

Progress in Steam Engine Design.

On Thursday evening, April 7th, 1938, the last of the 1937/38 series of joint meetings of the Junior Section with students of technical colleges in the London area was held at Leyton Technical College, when Mr. G. R. Hutchinson (Member) delivered a highly interesting and instructive lecture under the above title to a crowded audience. Mr. R. W. Jukes, B.Sc., F.C.S., F.R.S.A. (Acting Principal of the College) occupied the Chair.

A remarkably complete grasp of the subject enabled the lecturer to discourse fluently without recourse to a manuscript, and the excellent set of slides with which he illustrated his remarks formed a valuable additional feature of the lecture. The many questions subsequently asked by the audience indicated the keen interest aroused.

On the proposal of Mr. S. H. Flood (a Member of the College Staff and an Associate Member of The Institute) a cordial vote of thanks was accorded to the lecturer, while the chairman was warmly thanked for his welcome of the visitors and able chairmanship on the proposal of The Institute Secretary (Mr. B. C. Curling).

The Centenary of Trans-Atlantic Steam Navigation.

In the course of an exceedingly interesting lecture under the above title delivered at the Science Museum, South Kensington, on March 16th, 1938, the author, Engineer-Captain Edgar C. Smith, O.B.E., R.N.(ret.), President of the Newcomen Society and the well-known historian of marine engineering, paid a moving tribute to George Pearne, the chief engineer of the "Great Western" who was fatally injured on St. George's Day, 23rd April, 1838, just as the ship was proceeding to her moorings at New York on the completion of her epoch-making voyage from Bristol. Of Pearne, a man of inestimable character, it was recorded:—"In him the Company has lost a valuable servant, and science, in regard to the engineering department, an able chronicler of one of the most interesting experiments of modern times".

In concluding his tribute to the man and the part he played in the momentous undertaking, Engineer-Captain Smith said:—

"On the banks of the Mersey at Liverpool stands a fine granite obelisk with carvings representing the contending nature of the elements Fire and Water. It was erected as a memorial to the engine-room staff of the "Titanic", and to all other men who have died in the performance of their duty in the engine-rooms of ships. Besides its symbolic carvings it bears two inscriptions, one of which runs:

THE BRAVE DO NOT DIE
THEIR DEEDS LIVE FOR EVER
AND CALL UPON US
TO EMULATE THEIR COURAGE
AND DEVOTION TO DUTY.

Such it seems to me to be the message of George Pearne, the chief engineer of the first Atlantic steamship".

Inspired by this moving reference the Newcomen Society, The Institute of Marine Engineers and the Marine Engineers Association jointly decided to hold a ceremony to the memory of Pearne at the Memorial at Liverpool on St. George's Day, 1938, the centenary of the completion of the "Great Western's" voyage.

The ceremony took place at 11.0 a.m. on the appointed date in the presence of many distinguished engineers, wreaths being laid on the memorial by Mr. Robert Gladstone for the Newcomen Society, by Engineer-Captain W. J. Willett Bruce, R.N.R. (Retd.), O.B.E., M.Eng., former superintendent engineer of the White Star Line, for the Institute of Marine Engineers, and by Mr. Walter Jones for the Marine Engineers' Association.

The Institute of Marine Engineers was also represented by the two Liverpool Vice-Presidents, Mr. Sterry B. Freeman, C.B.E., M.Eng., superintendent engineer of Messrs. Alfred Holt and Co. (the Blue Funnel Line), and Mr. Lee Wood, of Messrs. Esplen and Sons, consulting engineers. The Liverpool Engineering Society was represented by the president, Colonel F. Hibbert, and the North-Western branch of the Institution of Mechanical Engineers by Mr. George E. Windeler.

Tragedy and Triumph.

Mr. Gladstone said that prior to 1836 several vessels had crossed the Atlantic using steam as an auxiliary, but none had attempted a regular passenger service. In that year, however, two companies were formed with the purpose of making a regular Atlantic ferry. The British and North American Steam Navigation Company, under the American, Julius Smith, and Macgregor Laird, a member of the Birkenhead Laird family, ordered the building of the "British Queen"; and another company in Bristol under Brunel, the engineering genius of the Great Western Railway, who designed and ordered the steamer "Great Western".

When the London company found the "British Queen" could not be finished before the "Great Western", in a panic they chartered the "Sirius", which had never been intended for such a voyage. The "Sirius" was the first vessel to cross the Atlantic entirely under steam, but it was a scramble, even the spars finally being used for fuel. The "Great Western" started four days later but reached New York in the afternoon of the same day as the "Sirius". Then, in New York Harbour, Pearne was "blowing off the boilers" when he was fatally scalded, a colleague named Roberts also being scalded but less seriously. Pearne's death in the very moment of his triumph was a tragedy indeed, after a very satisfactory voyage in which the engines had worked satisfactorily from first to last. He was certainly a brave man; for four days before the ship sailed he had risked his life to suppress a

Facing camera, left to right: Mr. Robert Gladstone, Col. Hibbert, Mr. S. B. Freeman, Eng.-Capt. W. J. Willett Bruce, Mr. R. Hall (Bibby Line) and Mr. Walter Jones.
Facing left in centre foreground: Mr. G. E. Windeler.
The ceremony on St. George's Day at the Liverpool Marine Engineroom Heroes' Memorial, in commemoration of the centenary of the death of George Pearne, chief engineer of the steamship "Great Western".

fire which broke out round the boilers, taking "several deep breaths of air and then making a rush through the smoke and flames".

Marine Engineers' Heroism.

Engineer Captain Willett Bruce said that he would like to preface his remarks by stating how gratified he felt in the honour the Institute of Marine Engineers had done him, through their local Vice-Presidents, Mr. Sterry Freeman and Mr. Lee Wood, by requesting him, now one of their oldest members, on their behalf to place their chaplet on this, the Engine Room Heroes Memorial, which for all time significantly but silently testified to those who were indeed "faithful unto death".

The centenary of the "Great Western's" first crossing of the Atlantic Ocean had resuscitated the event to public notice, and with it the great devotion to duty and sacrifice made by George Pearne, her chief engineer, which finally resulted in his untimely death, thereby depriving him of the honour due and congratulations awaiting him, while engineering science lost a pioneer, also the company he was serving a most efficient, devoted and valuable servant.

Coming to more recent events during, say, the last fifty years or more, they found not a repetition so much of individual heroism and sacrifice, but of collective action by engineer officers with their staffs, who verily paid the full penalty of their unequalled devotion to the main objective of saving others before themselves; consequently that act of laying their tributes on that memorial to George Pearne's memory simultaneously marked both their acknowledgment and deepest appreciation of those engineers' magnificent heroism.

Of such instances he would like to refer to some which stood out with special prominence, and in doing so, he trusted not to hurt anyone's feelings.

In the early days of the American Line steamer "St. Paul", several engineer officers, raising steam preparatory to sailing, met their deaths by scalding through fractured steam pipes, one of them being a fellow apprentice of his and son of a much respected chief engineer of the Inman Line.

It was with intense pride, mingled with some sadness, that he now referred to those super-courageous engineer officers of the "Titanic" who so brilliantly and effectively upheld the very highest and noblest traditions of the sea, never to be excelled, all remaining at their posts and carrying out their duties, until overwhelmed by the inrush of water, the whole of them being swept away, not one of them saved to testify as to how stubbornly they had had to contend to maintain steam and to direct their every effort to preventing increased calamity, which otherwise would have occurred had the electric generating plant ceased operating, resulting in darkness and no power supply to either wireless or boat winches.

The engineering staff of the ill-fated "Titanic" were the pick of the company—no finer body could be procured, more devoted to their duty and more loyal to their chief engineer, Joseph Bell, who undoubtedly on that terrible occasion inspired all about him with confidence and determination to give unsparingly of their very best.

Joseph Bell, known to some of them there present, held the highest professional attainments, coupled with many years of the very highest experience, proving himself a very valu-

Mr. Robert Gladstone laying the Newcomen Society's wreath.

able asset to the company he served so faithfully, while independently of this, he was a man of wonderful personality with a transparently sincere character, loved and esteemed by all.

It would be a serious omission on that occasion if he did not allude to that other brilliant example of super-human fortitude and self-control, who stood out so prominently on that fatal occasion, facing death calmly so that others might be saved. He referred to Thomas Andrews, managing director of Harland & Wolff, and their representative on this maiden voyage, who was most intimately associated with all the then recent construction of White Star Line tonnage. Up to the very last he rendered magnificent service, and it is recorded that he was last seen lashing together deck chairs and throwing them to the aid of those who were visibly struggling for life. So passed "Tommie", as he was affectionately called and known to many of them, for truly he had endeared himself to all with whom he came in contact, and who in their lives had genuinely paid tribute to his many sterling and manly qualities.

Following this great calamity, some three years afterwards came the loss of the "Lusitania" by enemy action, resulting in the engineering staff suffering most severely to the extent of 20 engineer officers, including the chief engineer, Archibald Bryce, together with 176 of the engine-room crew, all of whom in their passing fully maintained the highest traditions of the British Mercantile Marine.

Finally it would be an oversight on his part if he failed to speak of an act of heroism which took place some eight years ago in a South American port, when the Donaldson Line s.s. "Tortonia" took fire; all efforts to extinguish it failed miserably, and owing to the nature of the cargo—petrol and dynamite—an explosion became inevitable. It was suggested in the interests of the surrounding shipping that by flooding the steamer the consequences might be minimised; this resulted in Chief Engineer Alexander Johnson and 2nd Engineer William Hall voluntarily returning with the intention of opening the sea connections, yet to meet death facing them. They indeed paid the full penalty of their courageous action and made the supreme sacrifice, for the explosion took place while they were on board.

In conclusion, he maintained that such glorious instances of valour spoke for themselves with no uncertainty, thereby requiring no human effort to extol that wonderful courage and devotion to duty which he said was the characteristic inheritance of the peoples of these sea-girt islands, who in the past had never been found wanting, hence he was convinced that such a function as that for which they were gathered that day would serve a useful purpose for the future—"lest we forget".

Mr. Walter Jones also made a moving address.

ABSTRACTS OF THE TECHNICAL PRESS.

The First Producer Gas Tugs of the German State Towing Service.

The authors give a detailed description of the first of three 250 b.h.p. producer gas-driven tugs completed in summer, 1937, for the German State Towing Service, in which the gas is produced from anthracite. The principal dimensions of the vessel are: length b.p. 22·65 m. (73ft. 4in.), breadth mld. 5·75 m. (18ft. 10in.), depth amidships 2·65 m. (8ft. 8in.), draught with bunkers filled and full crew, 2·00 m. (6ft. 6¾in.), greatest height above waterline of fixed structure with tanks and bunkers empty, 3·90 m. (12ft. 9½in.). The vessel's hull is made of steel, while iron was used for the erections and electric welding was extensively employed. The main engine seating is of sufficient strength to enable the gas engine to be run as a Diesel engine. In order to improve the directional stability two streamlined fins are fitted above the stern tube, and two balanced rudders, which can be rotated through an angle of 180°, are arranged so as to prevent the propeller from touching the sides of the canal. The stern has been designed so as to maintain the flow of the screw race in an axial direction, thus minimizing damage to the sides and to the bottom of the canal, and the slow-running propeller is fitted in a tunnel ending below the waterline at the stern. The ends of the vessel are ice strengthened, and to allow for ice-breaking conditions the rudders are so arranged as not to emerge. The crew consists of a skipper, an engineer, a boatswain and a boy. The main engine is a non-reversible six-cylinder four-cycle Humboldt-Deutz gas engine which normally develops 250 b.h.p. at 350 r.p.m., the maximum overload, which can be maintained for one hour, being 280 b.h.p. at 375 r.p.m., while the lowest speed at which the engine can be operated in the no-load condition is about 175 r.p.m. The speed of the four-bladed propeller of 2,100 mm. (6ft. 10½in.) diameter and 1,817 mm. (5ft. 11¾in.) pitch is reduced to 170 r.p.m., i.e., in the ratio 2·05 to 1, by an oil-governed Renk speed reducing and reversing gear; between the gear and the main engine a Renk spring coupling of the sleeve type is inserted. Starting is effected by means of compressed air in the engine room. The remaining manœuvring operations on the engine, changes in the rate of revolution, stopping and the manœuvres on the reducing gear can be effected alternatively from the bridge or from the engine-room platform. The auxiliary set consists of an 18 b.h.p. gas engine coupled to a d.c. generator, a compressor and a bilge and cooling-water pump. When starting, before gas is being produced, the motor of this set is run on benzol, and for emergency purposes a small paraffin motor is provided. The generator supplies current at 110 volts to the various electric driving motors through a bus bar. In further new vessels the d.c. generator is to be driven directly off the main engine, a small Diesel engine being provided for the auxiliary set. The revolving grate gas producer installation is also of Humboldt-Deutz design, the anthracite, which is of nut grade No. 4, having a calorific value of 7,800 kcal/kg. (14,000 B.Th.U. per lb.), being hand fed. The fuel consumption is about 350 gr. (·77 lb.) per b.h.p. per hour. Discussing the performance of the tug, the authors state that at a quay trial a standing pull of 20 kg./b.h.p. (44 lb. b.h.p.) was obtained. They also give particulars of towing tests made with a train of up to six barges in a canal having a cross sectional area equal to 4·47 times the mid area of the barges and a depth of water below the bottom of the barges of 1·2 m. (3ft. 11in.). In these tests the speeds obtained ranged from 7·05 km./hr. (3·80 knots) towing one barge of 1,511 tons met. (1,480 tons av.) displacement to 4·35 km./hr. (2·35 knots) when towing six barges of an aggregate displacement of 8,271 tons met. (8,147 tons av.). The corresponding values of the towrope pull per b.h.p. ranged from 14·4 kg. (31·8 lb.) to 17·4 kg. (38·3 lb.) and those of the propeller efficiency from 37·63 per cent. to 28·07 per cent. Discussing the operation of gas producer tugs in its economic aspects, the authors state that these are well able to compete with modern steam and Diesel tugs, although in the first case the reduced fuel consumption per b.h.p. per hour is partly offset by the higher cost of the anthracite, while in the second comparison the reduced cost of the fuel is almost entirely balanced by the increased capital and maintenance charges of the producer gas installation. The principal economic advantage thus consists in the utilisation of the national fuel supply.—*Ebelt, Roth and Machtens, "Werft, Reederei, Hafen", Vol. 19, No. 8, p. 107, 15th April, 1938.*

A Chemist's View of Metallurgy.

A survey is made of metallurgical science from its earliest empirical beginnings. Metallography is becoming more and more a specialised branch of physics, and the author pleads for its inclusion *ad hoc* as a post-graduate course, quite apart from the strictly technical training necessary for the control of works operations. Chemistry is *par excellence* an experimental subject built up with astonishing success on a minimum of hypotheses, and new physical conceptions like wave-mechanics are only now beginning to be used in the study of alloy phases. Microscopical examination is based essentially on the chemistry of etching; the different effects obtainable by controlled etching of the same alloy under varied conditions, and the essential difference in the etching-mechanisms for single phases and for duplex structures, are discussed. The well-known phenomenon of etching-figures lends striking support to the mosaic theory of crystals recently developed to explain physical and mechanical properties. Small percentages of alloying elements (including oxygen) have marked effects on the properties of "pure" metals; this explains the increasing popularity of quantitative spectroscopic analysis. Other recent advances are in the fields of micro-chemical methods, contact printing for special elements, intercrystalline corrosion, and various improved technical processes. He concludes with a survey of the conservation of matter and the cultural importance of metals, with special reference to surprising industrial interchangeability of unlike metals which the pursuit of self-sufficiency has shown to be practicable.—*C. H. Desch, Presidential Address, Institute of Metals; "The Engineer", 11th March, 1938, pp. 270-271.*

Steam Turbines for Marine Propulsion.

Recent high-pressure marine installations include 1,850lb. Loeffler boilers in "Conte Rosso", 1,150lb. Benson boilers in "Potsdam", 880lb. Sulzer boilers in "Kertosono" and 685lb. Velox boilers in "Athos II", these being made partly to obtain service data under the severe conditions of marine service. The 710lb. Wagner boilers in "Scharnhorst" with turbo-electric drive and in "Gneisenau" with geared turbines, consume 0·668lb. oil and 0·623lb. oil per s.h.p. hour, respectively. General limits in British practice are about 400lb./in.^{2} at 750° F., the mean consumption being about 0·61lb. oil. The super-pressures mentioned, therefore, seem to show little advantage in fuel economy, although they have the important advantages of being flexible, very rapid in starting and save weight and space; nevertheless there is a strong body of expert opinion opposed to the forced boiler circulation which they necessitate. The Holland-America vessel "Nieuw Amsterdam", shortly to enter trans-Atlantic service is fitted with single-reduction geared turbines, supplied with steam at 600lb./in.^{2}, superheated to 750° F., from six Yarrow double-flow water-tube boilers; hitherto the limit for this design was about 450lb. It is understood that C.P.R. tonnage with 28,000lb. h.p. geared turbines working at 525lb. and 825° F., supplied from Babcock-Johnson two-drum boilers of improved design, will shortly be begun. The Atlantic Refining Co. has recently completed a 5,000 h.p. tanker "J. W. van Dyke", with turbo-electric drive, using steam at 650lb./in.^{2} and 835° F. from natural-draft boilers. The author concludes that steam initially at 500lb. and 850° F., will require reheating at intermediate stages if much improvement in efficiency is to be obtained, and in view of the complication and difficulties attending the necessary machinery, he advocates the use of moderate pressure increases only.—*"Times Trade and Engineering", April, 1938, p. 32.*

Recent Progress in Motor Ship Design.

Very recently three two-stroke twin-screw motor cargo liners, of deadweight 12,000 tons and capable of 17 knots, have been ordered. The "Capetown Castle" of 27,000 tons, with length 734ft. 3in. and beam 82ft., is larger than earlier ships of the Union Castle Line. Her machinery comprises two double-acting two-stroke engines each rated at 12,000 but capable of 14,000-15,000 b.h.p., with 10 cylinders 600 mm. (23·6in.) in diameter with 1,500mm. (59in. stroke), the upper piston exhaust valves being operated by eccentric rods. Normally three of the four 600 b.h.p., 2,200-2,800 r.p.m. electrically-driven blowers will suffice to supply the 30,000ft.^{3} of air needed per minute. The new Nazi cruising liner "Wilhelm Gustloff" has overall length of 683ft., beam 77ft. and the moderate draft of 22ft., and was completed in 19 months. She has geared-Diesel engines but two 15½ knot sister ships now under construction will use two-stroke single-acting trunk-piston Diesel-electric drive, an arrangement which is popular in Germany just now. Four units with seven cylinders of diameter 520 mm. (20·5in.) and stroke 700 mm. (27·6in.) develop 9,500 b.h.p. at 230 r.p.m., driving two propellers at 125 r.p.m. via Vulcan couplings and reduction gear. The author states in regard to cylinder wear that this action, always varied and erratic, is much increased where a vessel uses oil of various grades in the course of a voyage, instead of consistently good quality. It is generally attributable to cylinder corrosion, not, as in the case of vehicle motors, to wall erosion in the first few revolutions after starting, when lubricant is absent. Since the motor runs continuously while at sea the corrosion from low grade bunkers will clearly be very important. Chrome-hardening of liners decreases wear, apparently because of the resistance to chemical attack, and not mechanically. In some double-acting two-stroke 4,000 h.p. motors treated by the process, wear was found to be less than 0·01 mm. (0·0004in.) per thousand hours after a year's service. Reduced wear of piston rings, and lower lubricant consumption are also reported, but against these must be set the cost of plating. It has also been used in Diesel injection nozzles in Germany, with the object of preventing carbon deposition when poor fuels are used.—*"Times Trade and Engineering", April, 1938, p. 32.*

The Reheated Reciprocating Marine Steam Engine.

From its increasing use in large power stations, reheating is obviously advantageous economically;

it was introduced in 1870 in H.M.S. "Briton" leading to a 5 per cent. fuel saving. Since 1931 about 50 Götaverken equipments have been installed, the present type was tried out in 1934 in "Hazelwood" and there are now seven such at sea; its object is to avoid cylinder condensation and the resulting efficiency drop, in the simplest way. Scotch cylindrical boilers are retained on account of suitability for general cargo vessel conditions; steam, usually at 2,200lb. is expanded 13 - 14 volumes giving a mean pressure of 34lb., comparable with normal practice. With full superheating 750° F. would be required against 600 - 620° F. usual to-day; instead of this the high-pressure exhaust is reheated from 425° to 575° F., giving a theoretical gain of 1½ - 2 per cent., in practice 13½ per cent. is reached. Dry exhaust necessarily rejects about 10 per cent. more heat than a wet exhaust, but 32 per cent. less steam per i.h.p. is rejected to the condenser. Wetness reduces cylinder efficiency through heat absorption and leakage. A three-crank triple-expansion engine developing 2,200 i.h.p. at 70 r.p.m., with cylinder diameters 23½in., 38in. and 66in., is described, with four photographs and four scale drawings. In general, double-beat poppet valves are fitted, and with the thoroughly dry steam special attention must be paid to cylinder liner lubrication. The U-tube all-steel self-draining reheater transfers 5,000 B.Th.U./ft.^{2} with negligible pressure drop. Heat distribution is as follows: feed water heating 8 per cent., evaporation 74 per cent., superheating 18 per cent.; since superheat temperature is rather sensitive, feed conditions must be kept constant. Performance data are given for voyages loaded and in ballast for each of two 10-11 knot, 9,000 ton deadweight, sister ships, and a test result for one of these is compared with an oil-fired ship similarly equipped.—*H. Hunter, "Engineering", 15th April, 1938; pp 427-430.*

Heat-resisting Steels and Alloys.

Eleven steels (C. 0·12 - 0·49) and three heat-resisting alloys are investigated at thermostatic high temperatures. The range of non-ferrous elements is: Si 0·21 - 3·88 per cent., Mn 0·21 - 1·42 per cent., Ni 0·15 - 78·55 per cent., Cr 0 - 33·52 per cent., W 0·68 - 4·07 per cent., Mo 0·66 per cent., Ti 0·56 per cent. To simulate industrial conditions in scaling tests, the specimens, mainly in the air-cooled state, were maintained at temperatures up to 1,200° C. in an atmosphere obtained from burning a 1 : 6 town-gas/air mixture, and cooled to room temperature between each six-hour heating, the cycle being repeated seven times. The *shape* of the scaling index/temperature curve indicates whether an alloy becomes useless gradually or suddenly. The apparatus used in creep investigation is described. In deciding tolerances for high-temperature work, due regard must be paid to creep, even at low loads, and to thermal lag of adjacent parts; as a general rule two thirds of the creep limit (say 10^{-7} in 1,000 or 10,000 hr.) is a safe working stress for the particular temperature, but exceptions may occur in both directions. The author deprecates the practice of adding 50° C. to allow for doubts regarding the actual operating temperature; where not really required, this may entail a very substantial reduction in the permissible stress. Chromium alone confers oxidation resistance; nickel and chromium together confer oxidation resistance and high strength; tungsten additions also accentuate the latter. The special alloys (with 77·1 - 97·6 per cent. of non-ferrous metals and low carbon) show a time yield of 1½ tons at 700° C. (against 400lb. for mild steel), but at 800° C. this has fallen to half a ton, at 900° C. to 250lb. and at 1,000° C. to below 100lb./in.^{2}. He emphasises the economic factor in the use of these alloys and pleads for more exact knowledge regarding their mechanical properties and actual working conditions.—*W. H. Hatfield, "Engineering", 1st April and 22nd April, 1938; pp. 372-374, 455-457.*

Flanged Pipe Joints for High Pressures and Temperatures.

Tests on plain and drilled light steel rings of rectangular cross section are reported from Trondheim Technical University. For rings the ratio of deflexions is found to be 1·32; for bend test-pieces supported on knife edges 14in. apart, the central load and the supports being midway between the drill-holes, 1·29 and 1·27 was found. Neglecting strains from radial and shear stresses, and considering one half of the ring, a distributed couple Wa applies a bending moment $Wa/2\pi$ to a single cross section. For a beam, $\rho = (Y.M. \times M.I.)/$applied bending moment $=$ E.I. $2\pi/Wa$, constant along the periphery; $\rho = r_m/\sin\theta = r_m/\theta$ approx., so that $\theta = War_m/2\pi$ E.I. $= 1{\cdot}65 \times 10^{-6}$ W for a plain ring, against $1{\cdot}66 \times 10^{-6}$ found experimentally. The effect of the holes is less than that suggested by R. W. Bailey.—(*"Engineering", 15th October, 1937; p. 419*). *L. Sölsnoes, "Engineering", 22nd April, 1938; p. 443.*

Continuous Reading Power Meters.

Two types of torsionmeters, one electrical and one mechanical, giving the value of the shaft horse-power by direct indication on a dial, as well as the total horse-power-hours by means of a counter, and intended primarily for marine use, are described. In the electrical type, a generator geared to the shaft supplies a voltage which is proportional to the shaft speed. Two shaft-driven contact breakers, at different positions along the shaft, are so arranged that the time lag between the two is zero when no torque is being transmitted, but when the shaft twists there is a lag proportional to the angle of twist, and this determines the length of time during which current passes through the meter, so that the two factors of torque and revolutions per minute are combined. About 25 current impulses per second are generated, and the power is indicated by a standard electrical instrument reading the quantity of electricity per unit time. A second instrument gives the total quantity and hence the horse-power-hours. The mechanical type has two countershafts, geared to the screw shaft at different points, and to a differential gear. A spherical dome mounted on the casing of the latter is tilted through an angle proportional to the torque, and is rotated at a speed proportional to the shaft speed, so that a tracking wheel in contact with it rotates at a speed proportional to the power.—*"The Engineer", 29th April, 1938, p. 485.*

The "Capetown Castle".

The "Capetown Castle" is a twin-screw motorship of 27,000 tons gross, 685 ft. b.p., and 82ft. moulded breadth, carrying about 800 passengers; part of the hold space is insulated for the carriage of fruit, and there is also refrigerated stowage. The engines are 10-cylinder double-acting two-stroke airless-injection units of 660 mm. piston diameter, and 1,500 mm. stroke. The exhaust valves are of the piston type, driven by eccentrics on the main shaft, and scavenging is on the uniflow principle, with "tuned" exhaust pipes. The cylinder covers and jackets are cooled by fresh water in a closed circuit, which is in turn cooled by salt water, and the pistons similarly by oil. The exhaust gases pass through thimble-tube boilers. The scavenge-air blowers and most of the auxiliaries are electrically-driven, the total generator capacity being 3,500 kW.—*"Engineering", 29th April, 1938, p. 471.*

The Deutsche Lufthansa Seaplane Catapult Motorship "Friesenland".

The vessel has length 461ft., beam 54ft., draft 19ft. 8in. and displacement 6,813 metric tons. Primarily a wireless and meteorological station, her speed of 16 knots will enable rescue work to be carried out over the 1,600 mile ocean route, if necessary. Planes are launched over the stern so that a craft can be placed directly on the launching rails after lifting, without reversing. The hull, mainly of welded construction, is divided by six bulkheads and collision bulkhead, and a double bottom protects the wing fuel tankage. Storage for oil, fresh water and plane fuel, workshops, machinery, food storage, living accommodation and navigating equipment, are described in detail. In the original design there were three turntables but one was omitted in construction. In the revolving crane, with triangular jib, two motors drive the same drum via clutches and gearing. The motors are 50 h.p. and 8 h.p. respectively for hoisting the hook loaded at 40ft. per minute and light at 600ft. per minute. The luffing 50 h.p. motor is mounted on the central column and revolves with it; slewing through the full circle in one minute, is effected by two geared vertical-spindle 30 h.p. motors. All units are 200 v., d.c., 1,000 r.p.m., with Ward-Leonard control, the jib being rated at 15 tons for 20-53ft. The 95 ton catapult, 136ft. long, launches craft up to 18 tons at 94 m.p.h. in 1·52 sec. by means of a cylinder of 27in. diameter and 17·7ft. stroke, multiplied six-fold, acceleration being 3·5 g. Braking distance for the carriage is 19ft. Twin propellers are driven at 230 r.p.m. by two single-acting, two-stroke 2,500 b.h.p. Diesel motors, each with 9 cylinders of diameter 20·5in., stroke 27·6in. Independent auxiliaries include three six-cylinder non-reversible four-stroke single-acting Diesels, which drive either 140 kW. d.c. generators or air compressors. The paper is illustrated with 17 scale drawings and a photograph of the engines.—*"Engineering", 25th March and 15th April, 1938; pp. 321-323, 414-415.*

Recent Developments in High-Speed Oil Engines.

For the fuel, bulk modulus and density, which determine compressibility and injection lag, are the most important physical characteristics; viscosity is of minor importance in injection but may be important within the cylinder and in the supply pump. The author surveys the field of modern development with the aid of 10 diagrams, starting from the following general conclusions for an idealised pump:—(1) Residual pipe pressures between injections are very important; with pintle nozzles these are higher; (2) opening and closing pressures are proportional to effective valve area; (3) the pressure diagram calculated from simple reflexion is modified by (*a*) pump oil which slows down delivery, (*b*) nozzle oil which modifies injection; (4) injection lag is due to (*a*) passage of a disturbance along the pipe, (*b*) rising nozzle pressure, (*c*) rising pressure for operating the valve (with higher residual pressures the second and third are higher); (5) leakage causes a fall in residual pressure and thus affects nozzle lag; (6) increase in pump speed increases injection angle, maximum nozzle pressure and valve lift, modifies total injection lag and gives sharper cut off; (7) rough running from alternating injection is common and settings for normal running should avoid this; eight-stroking when idling should also be avoided; (8) increased nozzle opening pressure leads to increased lag, higher pressure throughout injection, smaller needle lifts, greater liability to needle chatter and cyclic variation at low speeds, smoother pressure curves at high speeds, earlier closing of the valve and generally better atomisation and penetration; (9) "nozzle-valve bounce" seems to be associated with special pressure variations; (10) valve weight and friction are minor factors; (11) increased pipe diameter causes flatter pressure waves, leading to greater nozzle lag at low speed; at high speed this is offset by higher residual pipe resistances; small diameters increase frictional resistances, causing excessive pressure loss; steepness of the initial waves and smaller nozzle pressure after flow begins, may lead to intermittent action; (12) large nozzle diameters give low residual pressures and greater nozzle lag; too small a diameter prolongs injection, especially with high speeds and high opening pressures; (13) very long pipes cause lower pressures after opening, owing to late arrival of reflected waves. Pipe lag increases with speed and pipes should be made as short as possible.—Two possible improvements are (*a*) better utilization of the air, (*b*) increase of the air input; to increase the output per litre, two-stroke working and supercharging should be considered. The author discusses the scope for scavenging developments as in the Kadenacy engine, with wide speed range, high output, and high thermal efficiency.—*S. J. Davies, "Engineering", 25th March and 8th April, 1938; pp. 342-344 and 400-404.*

The Engineering Outlook—Marine Engineering.

Apart from naval work, marine engineering depends ultimately on shipping earnings; in 1937 these were very satisfactory except in the Pacific. Rates for time-charter and freight reached peaks of 250 and 144 (1924=100) in the late summer, but fell back to 120 and 99 by December. The tramp subsidy and voluntary-rate scheme approved by 14 European countries and Canada in London in December, 1937, is discussed; recent declines in the freight index due to the poor Argentine harvest have caused a laying-up scheme to be mooted in view of the surplus consistently shown by the International Tanker Pool since its inception in 1934. In May, 1937, this amounted to £355,657 despite progressive reductions in the levy from 15 per cent. of voyage freights and 18 per cent. of time charters, to three-quarter per cent. and one per cent. For 1938 the tanker outlook is satisfactory. A decrease on the year of 40,000 tons of shipping laid up in British ports at 1st January, 1938, occurred, a record low level of 61,000 tons being touched in July, 1937. A marked increase in new construction in the first half of 1937 has faded out, owing to high cost. Part of this is due to improvements in design, crew's quarters, etc. In view of the steady flow of naval orders, no reduction in price can be expected for a few years. Striking examples of the re-sale of old and new vessels at a profit are quoted. Statistics of launching show the proportion of tonnage for foreign registration to be: U.K. 13 per cent., Germany 53 per cent., Sweden 56 per cent., Denmark 87 per cent.; a decline of the British share of world tonnage from 40 per cent. to 34 per cent. is attributable to the launch of 451,121 tons by Japan, now the world's biggest builders, Germany taking second place. Naval and merchant engineering are discussed, as well as the allocation of naval construction. In 1937 there was an increase in exports of marine engines from £403,000 to £500,000, but an estimated decrease in exports of ship's engines installed.—*Leader, "Engineering, 8th April, 1938, pp. 391-392.*

Experimental Tests for Ascertaining the Effect of Reinforcing Bulkhead Plating in Way of the Stiffeners.

The object of the experiment was to ascertain the effect of increased thickness of plating in way of bulkhead stiffeners. It was assumed that by reinforcing one of the flanges of stiffeners (by local increase in the thickness of plating) an increase in the rigidity of the stiffener would be attained, with the possibility of increasing the spacing of such reinforced stiffeners and at the same time reducing the thickness of the bulkhead plating between them, as compared with the thickness in way of the stiffeners.

The experimental bulkhead was constructed at a Leningrad shipyard, of plates 4 mm. thick, with a vertical strip of plate, 250 mm. × 8 mm. thick, in way of a single web stiffener 250 mm. × 8 mm., welded to the strip and to a flange on top 154 mm. × 13 mm. The stiffener was supported by tripping brackets spaced 1,000 mm. apart and 500 mm. from the top and bottom of bulkhead. The vertical stiffeners were spaced 1,500 mm. apart as against the usual rule spacing of 750 mm. On account of the experimental tank being only about 3 m. wide, only one stiffener was fitted, at the centre. This construction was adopted for comparison with a bulkhead of ordinary construction with plating 6 to 7 mm. thick, the saving in weight being about 40 per cent.

The plating was butt-welded to the boundary bars and to the strip of plate in way of the stiffener; the lower end of the stiffener was fillet-welded on each side to the bottom of the tank, the upper part being attached by double lugs riveted to the top of tank. Coated electrodes were employed for carrying out the welding. The bulkhead was tested by a gradual increase of water pressure; the welded lower end of the stiffener was torn away from the bottom of the tank and the stiffener buckled under a head of water of about 29 m. above the bottom of the tank. The bulkhead remained practically water tight under the maximum pressure applied, i.e. about 50 m. above bottom of tank, the riveted attachment at top of stiffener was not disturbed.

Conclusions.

The reinforcing of the plating in way of the stiffeners increasing the spacing of the stiffeners and reducing the thickness of plating in the space between the stiffeners, was considered satisfactory, provided a great rigidity of the bulkhead is not required. The economy in the weight of bulkheads of similar construction to the experimental one, would be from 27 per cent. to 40 per cent. The technological process of the electric welding employed, proved to be of the highest quality. It was considered that both methods of attaching the ends of the stiffeners were sufficiently reliable since the pressure which resulted in the damage to the attachments was considerably above the calculated load; at the same time, the riveted connection being flexible proved more reliable than the welded end; as a matter of fact it was not disturbed by the testing. Therefore it follows that in some methods of ship construction, the connection of certain welded parts should be riveted, thus disregarding the principle of entirely welded construction.

Notes.

Strength calculations are also given for the bulkhead stiffener. Suitable instruments were arranged for measuring the deformation and tension of the bulkhead under pressure. Seven views are shown of the bulkhead during and after the test. Two tables are given showing the condition of the bulkhead under the different heads of water, which varied from 3 to 50 m. A table is also furnished giving the deflection at the various points of measurement.—*Fillippov, Trans. of Scientific Technical Society of Shipbuilding and Marine Engineering, U.S.S.R., Vol. I, 1936.*

Experimental Tests on the Hull of an All-welded Tug.

The results are given of experimental tests on the hull of an all-welded tug, carried out by the Scientific Research Institute of Shipbuilding at the Sormov shipyard. The dimensions of the tug are 42·57 × 6·1 × 2·13m.; draft fully equipped 0·6m. At the time of the tests the vessel was without engines, boilers, deck houses, woodwork and equipment. The experiment was carried out when the hull was afloat in still water, water being pumped into the vessel alternately in the midship portion of the hull (machinery space) and in the fore and after peaks. The preliminary examination of the hull showed that the welding was not of the highest quality, the shell plating being wavy between the frames, due no doubt to the difficulty of welding thin plating; the thickness of the shell plating varied from 3 to 4 mm. and the upper part of bulkheads was 2½ mm. thick. For obtaining the general and local stresses reliable measuring instruments and devices were placed in position at various parts of the vessel, viz.: frames, keelsons, deck stringer plate and ties, bulkheads and on the side and bottom plating. The bending moment obtained from the deflection associated with an average value of E with 50 tons of water in the machinery space was 132·5 t/m. as compared with 106·5 t/m. calculated; the actual bending moment with water in both peaks was 144·5 t/m.

Conclusions.

The strength of the tug was considered to be satisfactory, the hull resisted without damage a bending moment 25 per cent. above the maximum calculated moment at a draft of 0·7 m.; at the normal loaded draft of 0·6 m. no permanent set was observed. The welding withstood the tests satisfactorily, notwithstanding that the workmanship was not of a first-class quality. The actual stresses as measured compared very favourably in the majority of cases with those as calculated, which confirms that the usual calculations carried out in practice, although not taking all the factors into account, give stresses very close to the actual. The bulkheads withstood the tests in a reliable manner, the measured tension on the stiffeners was less than the calculated. On the basis of the examination of the hull before the tests were commenced, it may be stated that the welding caused quite a large number of undulations in the shell and bulkhead plating; part of the welding separated in two places, which showed faulty technological process in the construction of the vessel. The experiment showed that the non-fitting of the continuous steel deck caused an unequal distribution of the stresses on the longitudinal deck ties. Similar results to the foregoing experiments were obtained by M. Paton, when carrying out experimental tests on a tug at Kiev.

Notes.

Plans are given of midship section and after hold with scantlings; various views are shown of different parts of the hull illustrating the positions of the measuring devices. Tables are given of the tension and deflection of the various parts of the vessel as actually observed and are compared with the calculated stresses. Curves showing the deflection of the keelsons, web frames and bulkhead stiffeners are also furnished.—*Rousanov, Trans. of Scientific Technical Society of Shipbuilding and Marine Engineering, U.S.S.R., Vol. I, 1936.*

Non-destructive Testing of Welds—The Stethoscope Method.

The principle is that of striking a metallic article to see whether it "rings true", a common stethoscope with rubber cap being placed against the welded plate. In the U.S.A. it has been claimed that if the weld is weak a high-pitched reedy note is distinguishable in the early part of the sound; obviously the method would be highly suitable for commercial examination of welded structural steel in buildings. N.P.L. statistical examination of 5,076 welds showed that the sound is very complex, consisting of a deep note and a more persistent high pitched singing note. In transverse fillet-welds the high pitch was absent near the middle, increasing towards the ends; in longitudinal fillets the sounds were more complex, a metallic harshness increasing towards the ends. Correlation with subsequent tensile tests showed that sound irregularities cannot be taken as indicating low tensile strength, and no special defects were found in the welds in question; further, stethoscopic examination failed to indicate obvious cracks and discontinuities. The author concludes that even with wave analysis the test is valueless, although in one case it did indicate a definite flaw in an otherwise good butt-weld.—*A. J. Fenner, Report on Welding of Steel Structures, D.S.I.R.; "The Engineer", 8th April, 1938, pp. 400-401.*

Researches on Cavitation.

An apparatus like that of H. Schröter (*V.D.I., 1934, 78, p. 349*) is used, but two plates 101·6 × 31·5 × 6·4mm. are tested simultaneously; to obtain a sufficiently rapid current (265ft./sec. at the narrowest portion) a high pressure pump was used;

with this velocity a testing time of 16 hrs. was found to be sufficient. The author quotes results of Schumb, Peters and Milligan (*Metals and Alloys, 1937, 8, p. 126*) showing that attack increases with rising temperature, but reaches a peak at 50° C. The plot—mass lost/vapour pressure of water—is approximately linear, so that the special precaution which practice has shown to be necessary in tropical waters and in warm water pumps is understandable. Addition of 1 per cent. or more of dissolved air (introduced under pressure) has a marked inhibiting effect; under ordinary conditions the solubility is less at higher temperatures so that the two effects reinforce one another in increasing the cavitation loss. He quotes experiments carried out in an American power station on the addition of air under pressure which led to an increased output of over 1,000 kW. per turbine. Cavitation is affected by a number of properties, e.g. strength, elastic limit, time yield, workability, inherent hardness, effect of water hammer in decreasing porosity, crystal form and size, arrangement of constituents, chemical composition, presence of non-metallic inclusions. Owing to the presence of free graphite, cavitation in cast iron is worse than in steel; it is reduced by Cr. which causes rapid work-hardening and refining of the coarse graphite flakes, and increased by S, P and slag inclusions. In steel 3½ per cent. Ni. markedly reduces cavitation in the ratio 1 : 11 but a fine grain is essential, and to this end alloying additions of Mo. and V. are recommended. In general, specimens give better results when rolled or forged than when cast, but great care is necessary to avoid a stratified structure, which is particularly objectionable when accompanied by large grains. Test pieces built up by electric welding were superior to those by gas welding. Stainless steel with 12 - 14 per cent. Cr. and 1 - 2 per cent. Ni. was far better than the usual 18 per cent. Cr., 8 per cent. Ni. composition, but a steel with 16 per cent. Cr. and 6 per cent. Ni. excelled both; this is attributed to the greater hardness of the latter when welded, and to its greater harderability under cold-work. No results for bronzes are reported.—*J. M. Mousson, V.D.I., Zeitschrift des Vereines Deutscher Ingenieure, 2nd April, 1938, pp. 397-400.*

Diesel-engine Progress.

Attention is drawn to the 1937 report of the Diesel Engine Users Association issued April, 1938. The bulletin reviews research work at the universities, and reports progress in the road-transport, industrial and agricultural fields, the first having far outstripped the others. Rival manufacturers in Britain and Germany have alike had difficulty in obtaining skilled labour. The most powerful British land engine yet built is a 3,800 h.p. Fullagar airless-injection type, fuel consumption being 0·365lb. per b.h.p., against 0·440 for an air-injection type in 1924. Lack of a "shop window" like the Leipzig Fair, or the former Birmingham B.I.F., is deprecated, and attention is called to the wide diversity in marine types and to the increasing use of high speeds and reduction gearing; standardisation is rendering superfluous a new design for each ship. In aeronautics, heavy oil is inferior to petrol for short flights, but above 9½ hrs., oil has the advantage. Recent demand for greatly improved performance in civil and military craft alike has militated against increasing use of Diesel motors, except for long distance routes.—*Leader, "Engineering", 22nd April, 1938, pp. 450-451.*

The Mechanism of Wear.

From a technical standpoint, wear covers not only abrasion but also distortion without loss of substance; obviously in the absence of friction wear would disappear. Recent Cambridge work suggests that contact friction represents the force required to shear through the bridges at the few points where two metals are within molecular range. Actual motion is discontinuous and the force required fluctuates widely from one slip to the next, accompanied by very brief sharp rises of temperature which may even exceed 1,000° C. The article suggests phenomena which cannot be explained exclusively on the bridge-breaking theory, *e.g.* non-metallic wear, turbine blade erosion, sand blasting; corrosion and electrolysis often play a part. Certain lubricant dopes reduce friction at the expense of increased wear. X-ray examination of the actual product removed, at Glasgow, shows that a highly damped "surface fatigue" action also occurs, in steel, leading to a breakdown of the crystalline structure. In conclusion the article pictures the technical *Utopia* resulting from the disappearance either of corrosion or of abrasion.—*Leader, "The Engineer", 22nd April, 1938, p. 449.*

Diesel Supercharging.

Supercharging raises output with a minimum of new problems, which are considered from the standpoint of compression ratio and thermal efficiency, combustion shock, scavenging and valve timing. Types of blower, crankshaft vibration, gear loadings and lubrication of blower timing gear are discussed. Bearing load diagrams are reproduced to show the effect of a 50 per cent. increase in b.m.e.p. for two extreme types; reference is made to a high-speed railway engine of 9in. bore and 12in. stroke with aluminium pistons running at 1,800 ft./min. at 900 r.p.m., and a stationary engine of 14in. bore and 22in. stroke with cast iron pistons running at 1,100ft./min. at 300 r.p.m. Increases in maximum load were 18 per cent. and 20 per cent. respectively, and in mean load 16 per cent. and 4 per cent. The effect of speed and gas pressure on the maximum connecting-rod-bearing loads are shown in curves for an 8in. diameter, 10½in. stroke Diesel engine with cast iron pistons. Polar diagrams for the centre main bearing loads for the above-mentioned pair of engines are also reproduced. The greatest change is in the connecting-rod peak load and it may even be necessary to reduce reciprocating weight or increase speed or improve the bearing metal. For the centre main bearing the effect is small, load per b.h.p. is actually lowered, and lubricating oil consumption increased by 5 per cent. Crankshaft and flywheel problems are discussed; theory and test data both indicate greater torsional vibration amplitudes at the sixth order critical speed. About 15 per cent. additional load on piston and pin is to be expected; a 40° F. temperature rise at the crown edge and 25° F. at the skirt of an aluminium piston was found, but no clearance difficulties occurred. Comparative graphs for fuel consumption for a 12in. 12-cylinder motor are given. The author concludes that brake mean effective pressures may be raised by 50 per cent. with only minor changes of design on the points—(1) Compression rates to be lowered. (2) Clearance volume to be scavenged completely. (3) Blower location to be chosen so as to have a minimum effect on frequency. (4) Connecting-rod bearing to be improved. (5) Stresses at critical speeds due to increase in harmonic torque.—*R. Pyles*, *"The Automobile Engineer", March, 1938, pp. 101-105.*

The Centenary of Trans-Atlantic Steam Navigation.

By 1820 the paddle-boat was common for river work in U.S.A. and Britain, and in 1821 mails were carried to Ireland and France by steam. By 1822 the "James Watt", of 448 tons and 100 h.p., was the largest steamship afloat; in 1827 steam was introduced in the Navy. In 1836 an American formed a transatlantic company after some difficulty, and placed a contract for the "British Queen" of no less than 1,800 tons and 500 h.p., but building delays occurred. Meanwhile a Bristol firm associated with Brunel had launched the "Great Western" in 1837, and the London company, unwilling to be beaten, chartered the "Sirius", a new Leith-built packet of 703 tons and 320 h.p. She stole a march on the "Great Western", leaving Cork on April 4th, 1938, a few days before the advertised sailing date of the latter, and arrived at New York on April 23rd, amid great rejoicing. After two double-crossings the little "Sirius" returned to her owners and was eventually wrecked in 1847. The "Great Western" continued to cross till 1846, when she was sold to the R.M.S.P. Company, and finally broken up in 1856. Two other steam vessels sailed in 1836 from Liverpool—the "Royal William" and the "Liverpool". In those days vessels were constructed of heavy wooden beams with elaborate internal diagonal trussing fastened with iron and copper, and carried sail in order to take advantage of any favouring wind. Equipment was standardized as a two-cylinder side-lever engine at 5lb./in.^{2}, driving cranks at right angles to the paddle wheel, this being simple, robust and trustworthy. The author gives many interesting details of construction and concludes with a vivid appreciation of the difficulties of technique and operation facing those early pioneers, which in no degree minimized their own pride of accomplishment.—*Edgar C. Smith, "Engineering", March 18th and April 8th, 1938; pp. 320-321 and 398-399.*

Non-destructive Testing of Welds—Magnetic and Electrical Methods.

The principle is comparison of the potential gradient in the weld and its neighbourhood on passing magnetic flux or electric current through the joint. Since a mere ratio is required, galvanometer deflections under comparable conditions may be read off directly. In the magnetic method, which appears theoretically better, the authors report the effects of (1) field strength, (2) shape and position of poles, (3) size of weld, (4) edge effect, (5) position of search coil. Curves for 12 butt-welds showed fair correlation with welders' estimates and X-ray evidence, but tensile tests were inconclusive, since most of the specimens, even those indicated as "defective", broke in the unwelded plate. The ratio found was about 3, even for joints with unit tensile ratio. Machining away of the surplus weld metal did not affect the curves markedly, and again correlation with the tensile test results was inconclusive; welds with lack of fusion can scarcely be regarded as defective mechanically. Conclusions reached are: (1) The electrical method is valueless in discriminating between good and bad welds; (2) the magnetic method gives a fair indication of general quality for welds of identical size and shape, but cannot satisfactorily be used to detect local defects, especially near the edge. Where the magnetisation can be rigidly controlled and a highly uniform product is being tested (*e.g.* for wire ropes) magnetic analysis may be applied successfully; in other conditions it is inconclusive and untrustworthy.—*C. E. Webb and L. H. Ford, Report on Welding of Steel Structures, D.S.I.R., "The Engineer", 8th April, 1938, p. 400.*

Non-destructive Examination of Steel.

The author describes a method for the non-destructive examination of steel developed at the U.S. Naval Research Laboratory, in which the electrical conductivity is the property utilized for the exploration of the physical continuity and homogeneity of the metal and which is used more particularly for the detection of laminations. These the author states have become a serious source of trouble, more especially in ship construction, with the advent of welding owing to the thermal stresses set up, which act in such a manner as to shear a plate along any plane of weakness, and their main physical effect which can be determined without the destruction of the steel is the effect on the electrical and thermal conductivity measured at right angles to the lamination. The most practical scheme is to set an alternating magnetic field in the body of the plate and to utilize the eddy currents thereby set up in the material to detect any lack of continuity in its structure. For this purpose the plate is surrounded by a magnetising coil and close to it, where the field is the strongest, a yoke made of laminated magnetic material carrying a large number of coils is fitted. This yoke forms a magnetic shunt or side track for the lines of force traversing the plate, thus giving them a "choice" as to the path to follow. If then an exciting current is at its peak, all the lines of force traverse the body of the plate as well as the exciting coil, but as the exciting current dies away to zero, there are new lines of force set up which only traverse the magnetic shunt and the portion of the plate immediately beneath it, and owing to their localised nature these are surrounded by eddy currents which are more or less independent of the current in the main coil. The magnetic flux in the yoke can be resolved into two components, one in phase with and the other 90 degrees out of phase with the main flux in the plate. The latter is purely due to the eddy currents and vanishes if none of these exist. Its magnitude is measured by the voltage set up in the coils surrounding the yoke and the subsequent cutting-up of a large number of test plates has shown that, in general, any drop in this voltage of as much as 25 per cent. over an area covering more than one foot in any direction is strongly indicative of lamination. The author gives particulars of a full-size testing apparatus designed on these lines and states that further investigations are being carried out to discover the most practical method of recording the voltage variations, e.g. visually by means of a vacuum tube oscillograph or graphically.—*Dr. R. H. Canfield, Trans. of American Society of Naval Architects and Marine Engineers, 17th May, 1938.*

Thermodynamics of the Petrol Engine.

Efficiency defect is due to (1) heat loss in the working fluid, (2) incomplete combustion at the peak pressures, even when the indicator diagram is pointed. A small loss also occurs from early ignition, early release, and excess pressure in early stages of the exhaust, due to restricted valve passages. Completeness of combustion rises with improved mixing; in a non-homogeneous "correct" coal-gas/air mixture, combustion may still be as incomplete as in a 70 per cent. "correct" mixture. In a petrol engine running on the "maximum efficiency mixture" (85 - 90 per cent. of "correct" fuel), combustion is abnormally incomplete, but on the "maximum power mixture" (120 per cent.) very high efficiency is obtained, and on an oxygen basis, combustion is practically complete. If temperatures could be evened out, slightly higher pressures would result. Heat loss during explosion and expansion varies inversely as speed, *i.e.* is proportional to time of contact between hot gases and cylinder walls; this appears to hold for losses due both to radiation and to convection. Turbulence is caused by (1) entry of gas, (2) rapid combustion, (3) detonation. In slow burning mixtures, the first factor is most important, but in rapid burning is overwhelmed by combustion turbulence. Sudden expansion of detonated gas into the already burnt gas, and skin friction, usually cause a large increase in turbulence. Large pressure waves are reflected back and forward within the cylinder, but the completeness of combustion resulting does not compensate for radiation loss. Heat loss for a compact E.35 engine of bore 4·5in. and stroke 8in., running at 1,500 r.p.m. on strong mixtures, is about 25 per cent. in the water jacket, and 12 per cent. in the exhaust ports and passages, against 16 per cent. for a poppet valve engine. Measured efficiencies are usually too high; for a 120 per cent. "correct" petrol-air mixture, and compression ratio 5, the author calculates a 32 per cent. efficiency referred to air, against Ricardo's experimental value of 32·8 per cent. He discusses critically the effect of mixture strength on efficiency, power, and exhaust valve temperature. For an 85 per cent. "correct" mixture, the efficiency at a given composition is much the same under widely varying conditions, *i.e.* bad mixing has a minimum effect at this composition, for petrol, benzol and ethyl alcohol. This holds for a wide range of speeds, if the compression ratio is low. For a given mixture, efficiency increases with compression ratio; very rapidly with 90 - 85 per cent. "correct" liquid fuel mixtures. The influence of detonation on heat loss, and of detonation, speed and size on efficiency, are treated in detail; obviously it varies from one engine to another, apart altogether from the efficiency of mixing. The author concludes that there is a possibility of considerable further economy—of great importance in aviation.—*W. T. David, "The Engineer", 22nd and 29th April, 1938, pp. 438-441 and 464-466.*

The Essential Elements of Naval Research.

One distinguishing feature of naval research is the comparative unimportance of the economic factor in regard to certain problems of great military importance. As regards training of research workers, men who are both engineers and physicists are preferred. Development, as distinct from research, probably requires a similar number of personnel in a research organisation. Only those new ideas which will bear quantitative investigation are worth pursuing, and a great deal of theoretical work usually requires to be done before the first rough model can be made. Then follows the period of development and gradual perfecting of the apparatus by the development engineers, with the advice of the scientific workers. Contact with other research workers and with the industry, as well as sea experience, are very valuable. It is suggested that, apart from the direct value of research, an organization benefits by the gradual diffusion of the scientific method. Attention should not be confined to immediate problems, but should also be directed to more remote studies which may be expected to bear fruit in the future.—*R. Gunn, Trans. of American Society of Naval Architects and Marine Engineers, 17th May, 1938.*

Two-cylinder High-pressure Radial Steam Turbine For Small Steam Consumption.

For reasonably efficient working a sufficiently large input volume must be maintained, but since volume diminishes with rising pressure, for high pressure operation either the quantity of steam passed or the running speed must increase. The latter solution entails the use of gearing. The authors describe very careful measurements carried out in March, 1936, on a *Meininghaus* turbine installed in a works power house in 1935, having run to the end of January, 1938, for 13,725 hours with one overhaul. At 3,000 r.p.m. it develops 5,000kVA./3,700kW. at 6·3kV., working with entering steam at 450° - 480° C. (842° - 896° F.) at 50 - 125 atm., with back pressure 7 - 11 atm. High and low pressure cylinders are placed at the ends, with the generator between them; the latter housing is sprung on the Ljungström principle. special arrangements for carrying the weight being described. The considerations underlying the internal design are discussed; both in the high and in the low pressure housing there are four pressure stages giving 81 steps in all. Within the housing, thin-wall construction is used with the object of reducing temperature fluctuations; extremely accurate workmanship, small clearances and robust radial construction have been aimed at. Steam pressure at entry is regulated by steam consumption. To obtain a fair comparison with turbines of other design, the equivalent coupling load is stated, since the present turbine utilizes a solid coupling; 32kW. is deducted for frictional loss in the bearings, which are intentionally designed on a generous scale and 60kg./hr. is allowed for leakage at 0·2 atm. positive pressure. Curves are plotted giving the consumption/pressure and heat/work relations; these are approximately linear. A table of performance and thermodynamic efficiency is also given, the latter varying between 47 and 74 per cent. Tabular comparison with published data for a single-cylinder back-pressure radial turbine shows a notable difference in the steam volume required for reasonably efficient working.—*O. Schöne and C. Kraft, "V.D.I., Zeitschrift des Vereines deutscher Ingenieure", 82, No. 16, 16th April, 1938, pp. 465 - 470.*

A Theoretical Method of Constructing Drawings of "Guiding Nozzles" for Propellers (Kort Nozzles).

The construction of a theoretical drawing of the nozzle should be looked upon as one of the most important parts of the work in designing a Kort Nozzle installation, for the purpose of acquiring those characteristics of the nozzle which may be determined by calculations. The present available method of hydro-dynamic calculations for the installation of Kort Nozzle propellers does not permit the possibility of obtaining direct from the calculation very important elements such as the length of the nozzle and the outline of its axial sections. Thus, the problem of a rational method of forming the contour and length of the nozzle must be solved by the designer when preparing the theoretical drawing so as to give the nozzle an absolute definite form. The only guiding consideration is that the shape of the contour should be based on the condition of an even acceleration of all speeds of flow to the propeller and guarantee the necessary coefficient of the opening F_e/F_p (the ratio of the area of the entrance opening to the propeller disc) and the increase in width F_a/F_p (the ratio of the exit opening to the propeller disc). This leaves considerable freedom, but at the same time presents great difficulty in choosing a suitable contour for the axial sections of the nozzle. The question of deciding on a rational length of nozzle is the first problem which arises in the construction of a theoretical drawing. The solution of this problem is directly dependent on fixing the value of the coefficients of the opening and its increase in width. If that part of the nozzle up to the plane of the propeller disc is designated the fore part, and that from the disc plane to the end, the after part, then the length of the after part should be arranged so that the angle at the centre of the opening, in accordance with the given coefficient F_a/F_p, should on no account exceed 10°, since otherwise the danger arises of a break in the flow. The minimum length of the after part of the nozzle will be determined by this angle. In general, this angle should be fixed less than the above limit and the maximum length of the after part determined by the opportunity offered for its elongation by the construction of the vessel's stern (the form of the sternpost, position of the rudder), always provided that the total length of the nozzle should not exceed 90 per cent. of the diameter of the propeller. The length of the fore part may be determined as follows:—With a coefficient of opening $F_e/F_p \leqq 1{\cdot}4$, the length should be 25 per cent. of the diameter of the propeller; with a coefficient from 1·4 to 1·9 the length may be taken as corresponding with from 25 per cent. to 45 per cent. of the propeller diameter. Such length of the fore part with a suitable curvature of the nozzle profile guarantees an even acceleration of the speed of flow in front of the propeller. The question of a suitable curvature in the axial direction of the nozzle to the vessel's hull may be approached by the examination of a rational profile of a circular nozzle working in open water, i.e. a nozzle the cross sections of which are in the form of co-axial circles and the axial profile of which therefore does not change along the circumference. The curvature of the inside shape of the nozzle in order to ensure a steady acceleration in the speed of flow must also change smoothly and without interruption. This condition is easily fulfilled if the inner line of curvature is formed by a suitable combination of sections of an elliptical form at the fore part of the nozzle, and of a hyperbole at the after part. The position of the joining of the elliptic and hyperbolic curves in forming the inner line of curvature of the nozzle is shown in Fig. 1 (not reproduced), which also shows the method of obtaining the outline of a section of the nozzle. Fig. 2 (not reproduced) shows the method of forming the toe of the section. Various equations and formulæ (eight in all) are given for drawing the curvature of the nozzle sections. For the purpose of illustrating the character of nozzle sections obtained by the method of construction as fully described in the article, Figs. 3 and 4 (not reproduced) show two forms of a series of sections in connection with models intended for testing in an experimental tank. The drawings clearly point out the change in the contours of the nozzle sections with the same coefficients of F_e/F_p and F_a/F_p, but with an alteration in the length of the after part of the nozzle. The most favourable form of a nozzle installation is one where the shape of the after part of the vessel and the draught permit fitting a circular nozzle; in the majority of cases this is not possible to achieve along the whole length of the nozzle, owing to the smallness of the ship's draught. The values of the ordinates to the curves shown in Figs. 3 and 4 are given in their respective tables. The fore part of the nozzle is flattened out at the top and bottom in order to prevent the nozzle projecting above the waterline or below the keel. The method of constructing a theoretical drawing of a guiding nozzle in relation to the vessel's hull is shown in Fig. 5 (not reproduced), and a full description of the method of procedure together with the necessary tables are also furnished.—*"Soudostroienie", No. 10, 1937.*

The Development of Water-tube Boilers with Natural Circulation.

The adoption of superheaters.

The transition to superheated steam in marine practice necessitated the employment of supplementary elements. Insufficient study of the fluctuation of superheating due to modifications in the types of boilers, and the problem of preserving the superheater when the main engines were not working and the auxiliary machinery was being supplied with saturated steam, led to the adoption of non-symmetrical superheaters. The pioneer in this field was the firm of Yarrow (Fig. 2). The main consideration in producing a boiler with non-symmetrical superheaters was that it presented the possibility of regulating the working of the superheater by fitting a baffle at the sides of the superheater for distributing the flow of the gases. The increased temperature of the steam causes the flue gases to pass away at relatively high temperature, thus decreasing the efficiency of the boiler. The way out of the difficulty is to place the superheater in the centre of the convection parts. For this purpose Yarrow fitted a supplementary water drum above the superheater drum (Fig. 3). The cumbersome arrangement of five drums called forth a

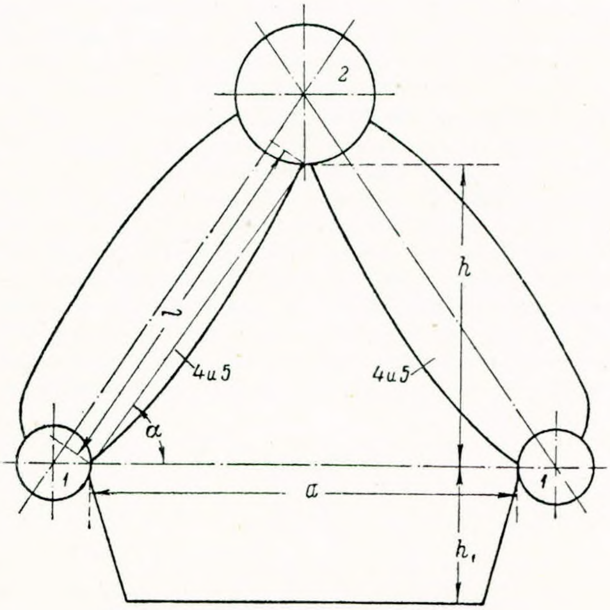

*FIG. 1.—Boiler of the triangular type.

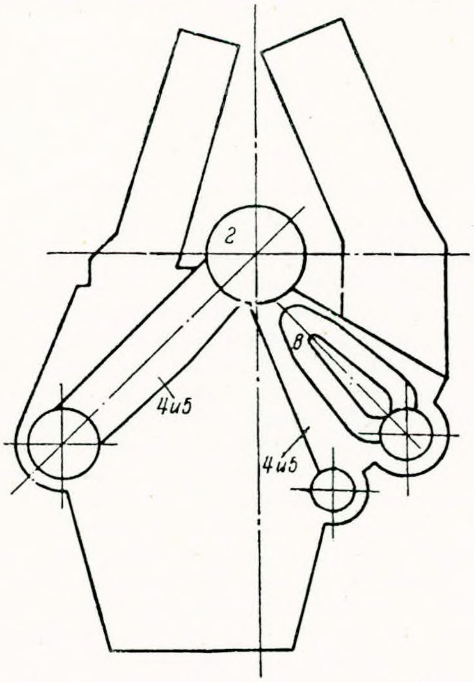

FIG. 2.—Yarrow boiler with three drums.

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*The key to the numbers designating the various parts of the boiler in this and the other figures is: 1=water drum; 2=steam drum; 3=steam collector; 4=fire-row tubes; 5=convection nests; 6=superheater; 7=supplementary water drum; 8=economiser; 9=air heater.

proposal to place the superheater header at the front of the boiler, and the fitting of the superheater tubes horizontally along the length of the boiler (Fig. 4). The latter method gave a large space for the passage of the gases and reduced the number of drums at the expense of fitting the header, but at the same time made it difficult to drain the superheater. The non-symmetrical working of the two halves of the boiler (with and without a superheater) showed a serious deficiency, which involved the reliability of the proposal; therefore, after experience had been gained in installing superheaters by altering the type of boilers, and designing the auxiliary machinery for working with superheated steam, there emerged a design of boiler with symmetrically disposed superheaters (Fig. 5). In addition to the change in the form of superheaters, the following facts are of not less importance. Radiation superheaters by decreasing the output of the boiler increase the superheating, but convection superheaters decrease it, and in a greater degree the further they are placed away from the furnace. The maximum decrease in superheating takes place when the superheaters are placed at the end of the boiler. In the past few years, due to the more complete study of the question of circulation, a widespread opinion prevails that superheaters should be placed at the centre of the generating nest of tubes, for the reason that it is more reliable for separating the upflow and downflow rows of tubes. This has the effect that all rows of tubes up to the superheater are considered as upflows in all types of boilers.

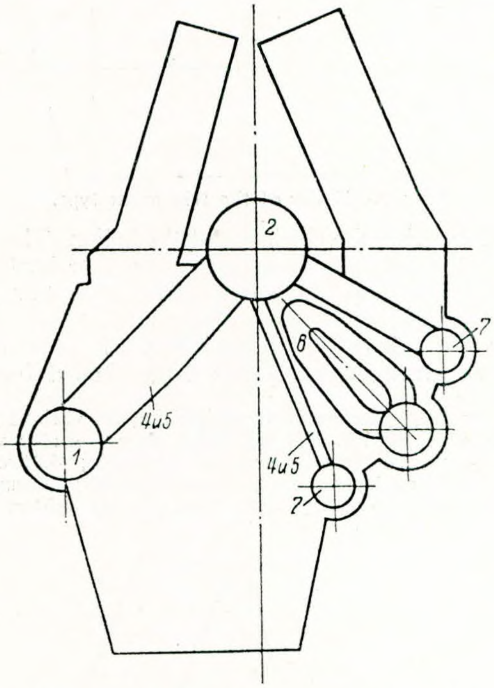

Fig. 3.—Yarrow boiler with five drums.

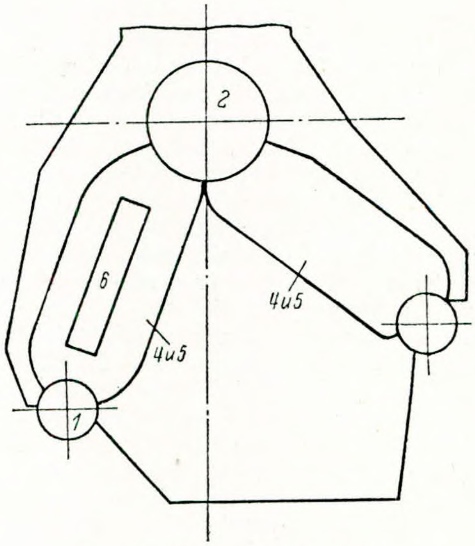

Fig. 4.—An American boiler.

Increasing the radiation surface.

The fundamental problem in designing marine boilers, in addition to generating steam, appears to be the question of economy, weight, and space occupied. The latter is bound up closely with the desire to increase the power of each separate group. Reduction of the space occupied and weight of a boiler may be effected at the expense of reducing the volume of the furnace and increasing the efficiency of the general heating surface. The volume of the furnace is determined by the consumption of fuel, which at the present day is taken at about 200 kg./m.^{3} p.h.; this value may be considerably increased by improvements in the fuel and air supply to say 300 and 500 kg./m.^{3} p.h. Increas-

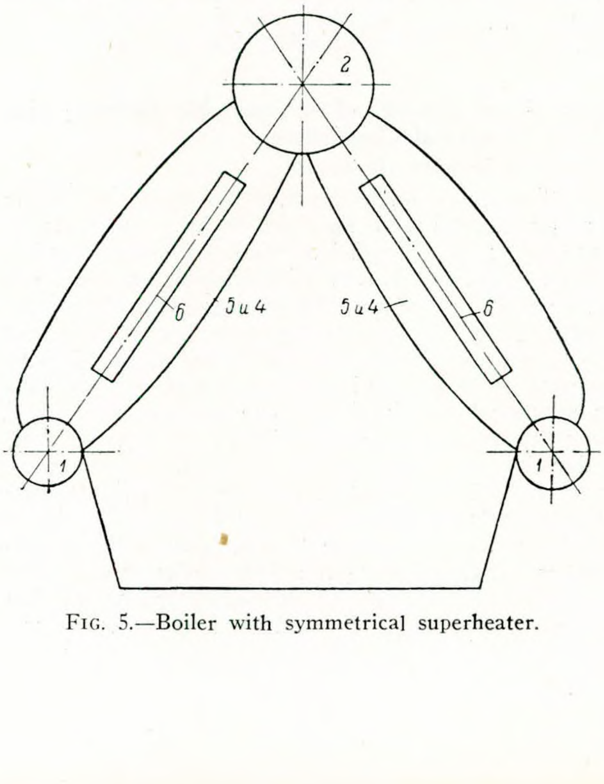

Fig. 5.—Boiler with symmetrical superheater.

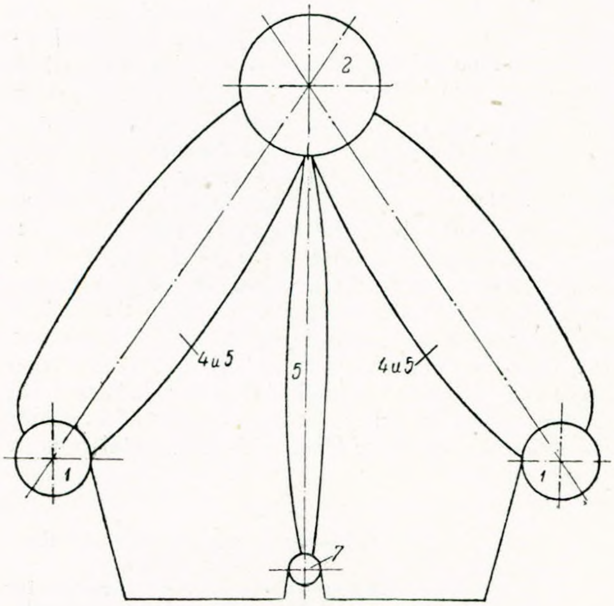

FIG. 6.—Schultz boiler.

ing the efficiency of the general heating surface may be effected at the expense of the relative increase in the radiation surface and raising the heat transmission coefficient of the convection surface by increasing the velocity of the gases. When deciding the question of the type and dimensions of a proposed boiler, it is necessary to consider that the volume of the furnace is proportional to the cube of the linear dimensions and the radiation surface proportional to the square; therefore if in small boilers a narrow space provides insufficient volume, then in large boilers the radiating surface may play the principal part where the space is narrow. The tendency to increase the relative value of the radiation heating surface produced a number of different types of boilers; the principal ones are shown by Figs. 6, 7, 8, and 9. In all types the load on the volume of the furnace (consumption of fuel per unit of volume of furnace) depends on the oil firing system adopted, so that an approximate comparison from the point of view of compactness may be obtained from the ratio of the radiation surface to the furnace volume. Since the volume of a furnace is the product of its cross-sectional area by its length, and the radiation surface is approximately the product of the furnace length by the length of tubes in the fire rows of each nest, then for comparison we may with sufficient accuracy take the sum of the inner rows of tubes of each nest (the convection part of the perimeter), assuming similar cross section areas. If the length of the inclined side tubes is designated by l, the full height of the furnace by $h+h_1$, the depth of the lower part of the furnace by h_1, width of the furnace by a and assuming the usual value of the angle at the base α to be 55°, then the following particulars are obtained as set forth in Table 1.

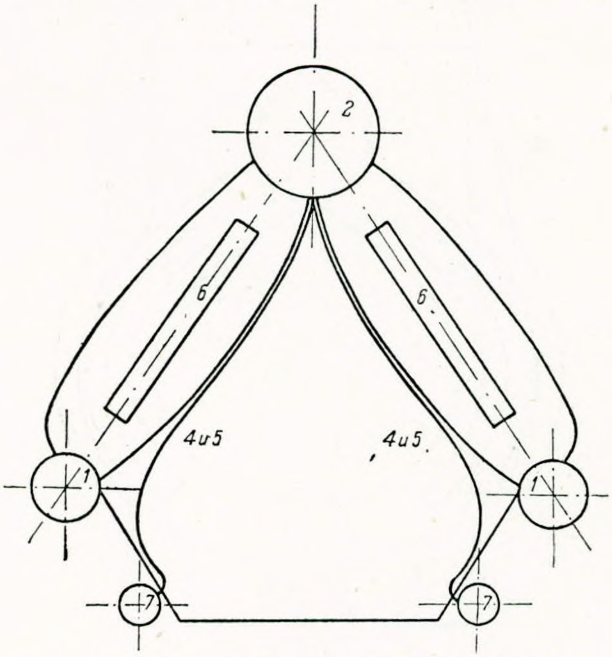

FIG. 7.—Boiler s.s. "St Paula" (Forster-Wheeler).

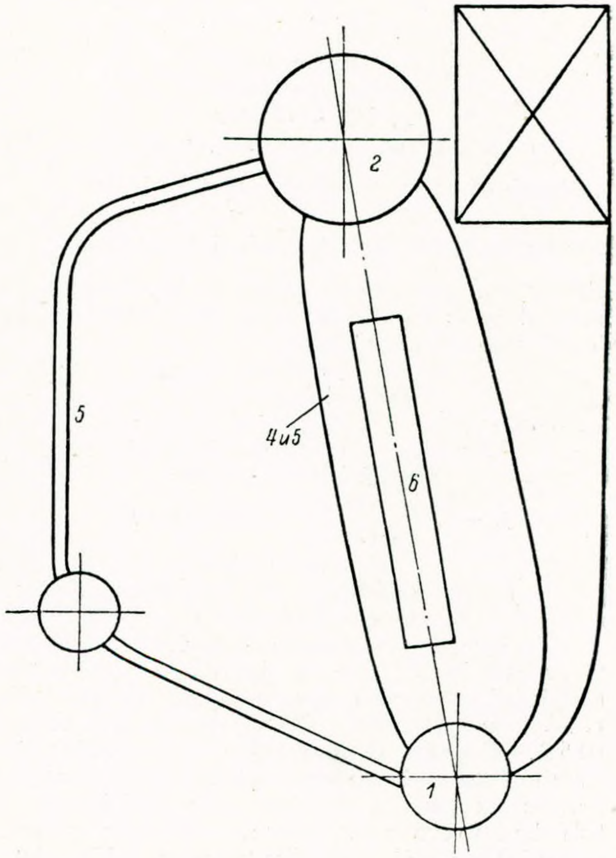

FIG. 8.—Wagner boiler with two drums.

TABLE 1.

Type of boiler.	Sketch No.	Portion of perimeter covered by tubes. l	h	h_1	a	Sum of lengths reduced to l
Ordinary triangular	1	2	—	—	—	$2\,l$
Schultz	6	2	2	2	—	$(2{\cdot}0+1{\cdot}8)\,l=3{\cdot}8\,l$
Forster-Wheeler ...	7	2	—	2	—	$(2{\cdot}0+0{\cdot}16)\,l=2{\cdot}16\,l$
Wagner	8	1	1	1	1·5	$(1{\cdot}0+0{\cdot}9+1{\cdot}43)=3{\cdot}33\,l$
Johnson	9	—	—	—	3·04	$2{\cdot}9\,l$

In the above table the following proportions are assumed for triangular boilers :—

$$\frac{h}{0{\cdot}5\,a}=\tan 55^\circ=0{\cdot}428$$

$$\frac{h}{l}=\sin 55^\circ=0{\cdot}819$$

$$h=0{\cdot}856\,a=0{\cdot}819\,l.$$

$$a=1{\cdot}17\,h=0{\cdot}955\,l.$$

$$l=1{\cdot}22\,h=1{\cdot}04\,a$$

If the consumption of fuel in relation to the volume of the furnace is taken as $\frac{B}{V_T}=$ 200 kg./m.^{3} p.h. and the radiation surface $\frac{B}{H_P}=$ 200 kg./m.^{2} p.h. and the length of the furnace expressed by L then (neglecting the corners of the lower part of the furnace) :—

$$V_T=L\,(0{\cdot}5\,ha+h_1a),\ H_P=2al;$$

$$0{\cdot}5\,ha+h_1a=2{\cdot}0\,l.$$

we obtain :—

$$0{\cdot}5\times1{\cdot}17\,h^2+1{\cdot}17\,h_1h=2{\cdot}0\times1{\cdot}22\,h;$$

$$0{\cdot}585\,h+1{\cdot}17\,h_1=2{\cdot}44;$$

$$h_1=\frac{2{\cdot}44\,l-0{\cdot}585\,h}{1{\cdot}17}=2{\cdot}08\,l-0{\cdot}5\,h;$$

$$\text{by } 3{\cdot}5<h<4{\cdot}0\text{m.}$$

$$h_1=0{\cdot}1\,h=0{\cdot}082\,l=0{\cdot}085\,a\simeq400\text{mm.},$$

$$h+h'=0{\cdot}9\,l=0{\cdot}94\,a.$$

To obtain a comparative result it is necessary to assume in the case of the Wagner boiler the length of a portion corresponding to one side ($l+h_1$), and the other (h), grate (a) and ceiling ($0{\cdot}5a$). For the Johnson boiler, in expressing the length of the circumference, taking into account the portion occupied by the drum, the total length of half the convection perimeter may be taken as equal to $\pi a-0{\cdot}1a=2{\cdot}9\,l$. In like manner, taking into consideration the maximum value of the radiation surface, we obtain with the same volume of furnace the different types of boilers arranged in the following order: (1) Schultz boiler, (2) Wagner, (3) Johnson, (4) Forster-Wheeler (s.s. "St. Paula"), (5) the ordinary triangular boiler. Not all arrangements of radiation surfaces give the same final effect, since when considering the value of the heating effect on the surface, circulation at the upper part of the furnace is assumed to be less (for the velocity of steam and water mixture, Reynolds number is more reliable); for instance, in a number of cases of natural circulation, the load permitted on the lower horizontal surface is assumed to be 50 per cent. and on slightly inclined surfaces 60 - 70 per cent. of the usual. The heating effect may be reduced by either lowering the total intensity on the whole radiating surface, or by additional protection of the dangerous parts by covering them with fire-bricks or fire-clay. It is evident that the second method is the more rational, because covering with fire-bricks lowers the effectiveness of only the protected parts. If a correction is made to the base of the furnace a by multiplying it by the coefficient 0·5, then we obtain as seen in Table 2, by the same sequence, a more defined difference between the various types of boilers at the expense of lowering the efficiency of those fitted with horizontal convection tubes.

TABLE 2.

Efficiency based on values of the radiating surface.

Type of boiler.	Without correction for horizontal part.	With correction for horizontal and circular parts.
Ordinary	2·0	2·0
Schultz	3·8	3·8
Forster-Wheeler ...	2·16	2·16
Wagner	3·33	2·86
Johnson	2·9	2·44

The advantages of the Schultz boiler are clearly not only as regards the heating, but also on the side of productiveness, if one takes into account the

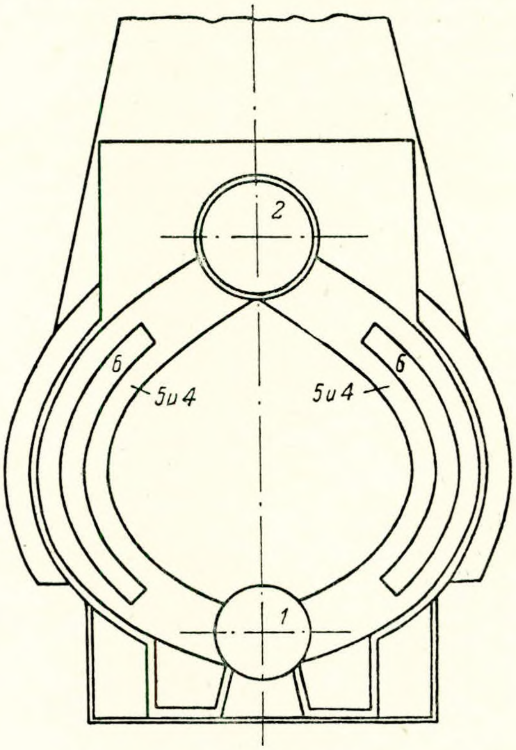

FIG. 9.—Johnson boiler.

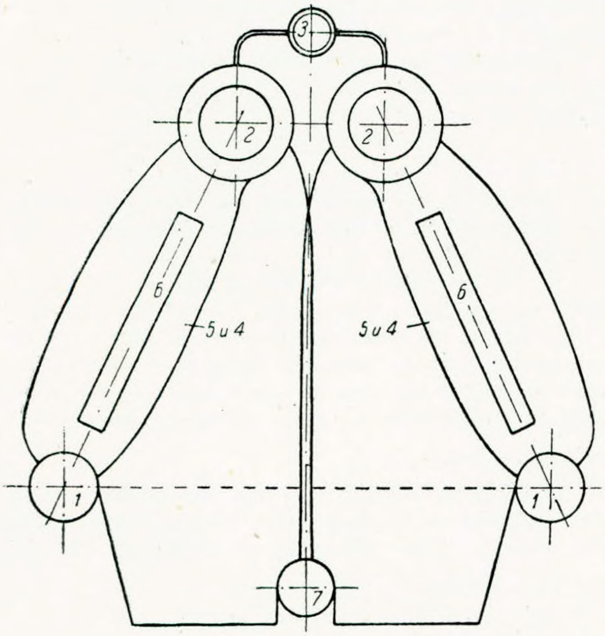

FIG. 10.—Schultz-Wagner boiler.

absence of intricate bent tubes of large diameter and the fitting of same. If in special types of Schultz boilers it is desired to make them wider for the purpose of simplifying the fitting of the oil burners, and in the case of the Wagner boiler to make them narrower for decreasing the horizontal part, then in cases where a large number of narrow boilers are required to be installed in the boiler room, from the point of view of radiation surface an installation of Wagner boilers may prove more advantageous. In order to facilitate the overcoming of the second difficulty several modifications of the basic type are proposed, such as: (1) For slightly widening the upper part of the Schultz boiler and reducing the size of the steam drum, Wagner proposed a boiler with two steam drums (Fig. 10). The endeavour to realize the idea of designing a boiler with two steam drums has been carried out in the U.S.A. (Fig. 11). (2) To decrease the length of tubes in the convection nest, Wagner suggested a type of boiler with a supplementary drum (Fig. 12).

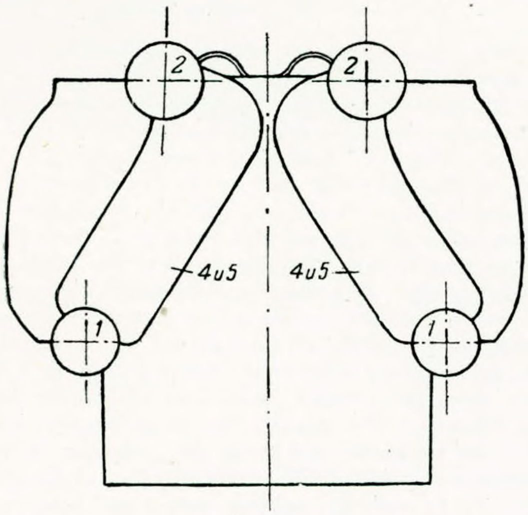

FIG. 11.—A double American boiler.

When comparing the efficiency of fitting additional fire rows, as in the La Mont boiler (Fig. 14), the following calculation may be suggested, assuming that the necessary velocity (Reynolds numbers) in the tubes guarantees the safety of a load on the fire rows of 200 kg./m.^{3} :—

The length of the perimeter of the cross section of triangular boilers is equal to $2l+a+2h_1$. Reducing this value to l we get :—

$$2l+a+2h_1=2l+0{\cdot}955\,l+0{\cdot}328\,l\simeq 3{\cdot}3\,l.$$

In this manner the boiler is more efficient from the point of view of the development of the radiation surface than the Wagner and the s.s. "Boser" boilers, but less efficient than the Schultz boiler.

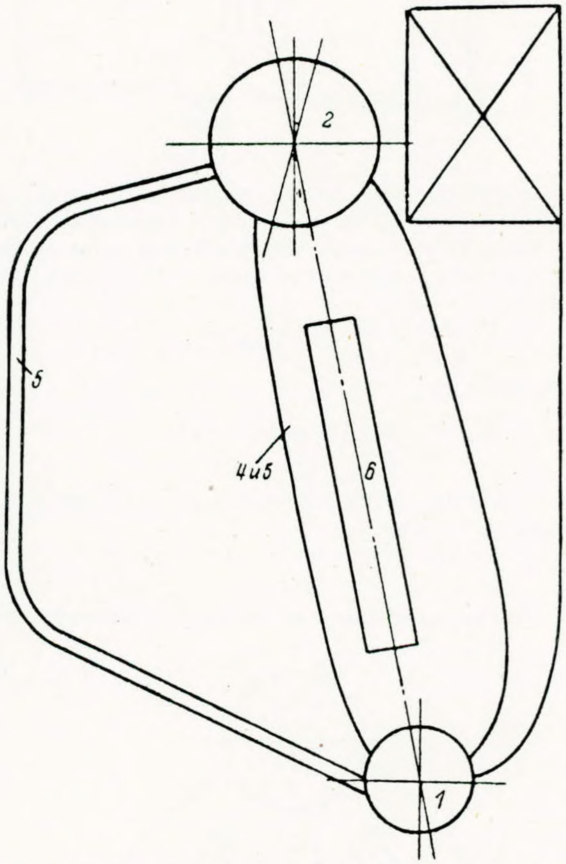

FIG. 12.—Wagner boiler with supplementary drum.

If one takes into account the intricate fitting of the fire rows in the La Mont boiler, it is obvious that these fire rows should be adopted only for modernizing and increasing the efficiency of triangular boilers previously constructed.

It is possible to increase the fire rows in the furnace of triangular boilers, by placing the oil

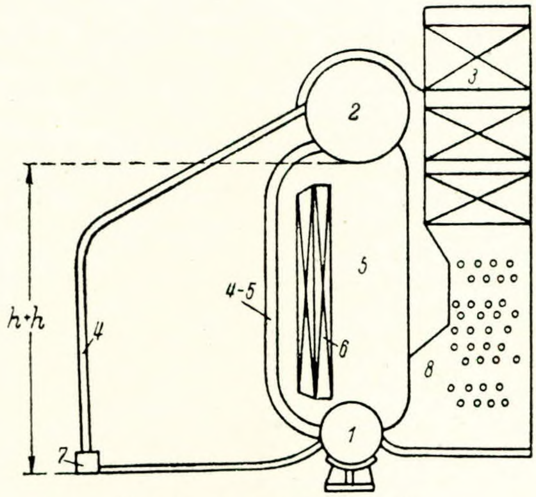

FIG. 13.—Boiler s.s. "Boser".

burners at the sides, at the expense of the end convection surfaces. In cases where convection tubes are fitted at both ends, the additional value of the fire rows in a boiler with a single row of tubes, with a pitch of $r=1{\cdot}5$:

$$\frac{2\,(0{\cdot}5\,ah+ah_1)}{1{\cdot}5}=0{\cdot}67\,a\,(h+h_1);$$

with the ratio

$$\frac{L}{l}=1{\cdot}5 \text{ and } a=0{\cdot}955\,l.$$

$$h+h_1=0{\cdot}9\,l.$$

The value of the additional fire rows per metre length of furnace is:—

$$\frac{0{\cdot}67\,a\,(h+h_1)}{L}=\frac{0{\cdot}67\times0{\cdot}955\times0{\cdot}9l^2}{1{\cdot}5}=\frac{0{\cdot}575\,l^2}{1{\cdot}5\,l}=0{\cdot}384\,l$$

At the same time the fitting of additional vertical fire rows gives an additional value per metre length of furnace of $2\,l$.

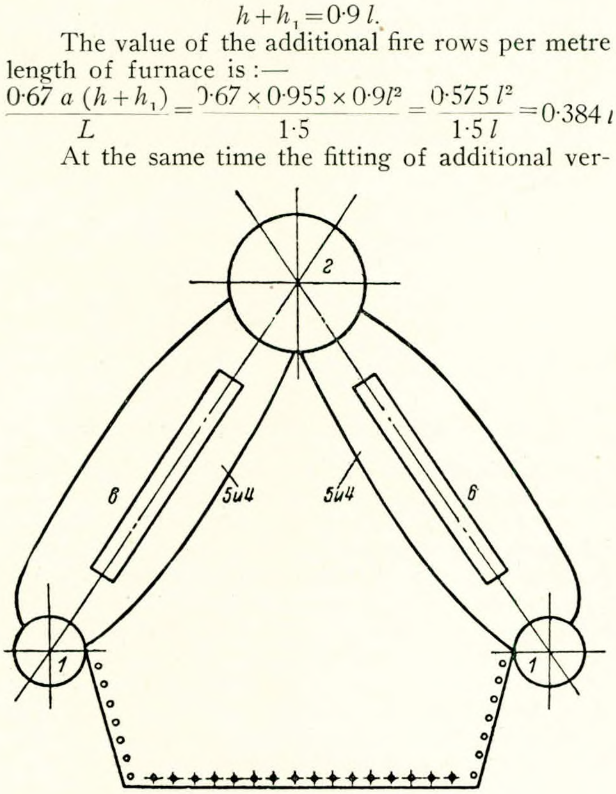

FIG. 14.—La Mont boiler.

By fitting fire rows at the base of the furnace the additional value (by $r=1{\cdot}5$) equals for one metre length of furnace:

$$a=\frac{0{\cdot}955\,l}{1{\cdot}5}=0{\cdot}637\,l.$$

By fitting fire rows over the whole surface of the ends and bottom, the additional convection value will be:—

$$0{\cdot}384\,l+0{\cdot}637\,l=1{\cdot}02\,l$$

and this is without taking into account the necessary reduction of the load on the bottom part. If the complicated construction of fitting fire rows on the bottom and at the ends is taken into consideration, then the unsuitability of this method is apparent.

Dimensions of furnaces.

Analogical with coal firing, the oil burners on the adoption of oil fuel were fitted at the front of the boiler. The difficulty of arranging the oil burners on account of the configuration of triangular boilers, caused the bottom part of the furnace to be increased in the form of a space lined with firebricks. The insufficient study of circulation in water-tube boilers did not permit the heat load on the radiating surface to be utilized to the limiting value guaranteed by natural circulation. On this account the load on the volume of the furnace was necessarily low, and the depth of the lower part of the furnace (h_1) was fundamentally determined by the requirements of installing a sufficiently large number of low-powered oil-burners, at a maintained spacing between centres of 800mm. and at a distance from the furnace sides and tubes of not less than 600mm. The installation of oil burners in the past year in connection with the adoption of non-symmetrical boilers with superheaters (as shown in Figs. 2, 3, and 4), taking into consideration a rational arrangement of the boiler room and the

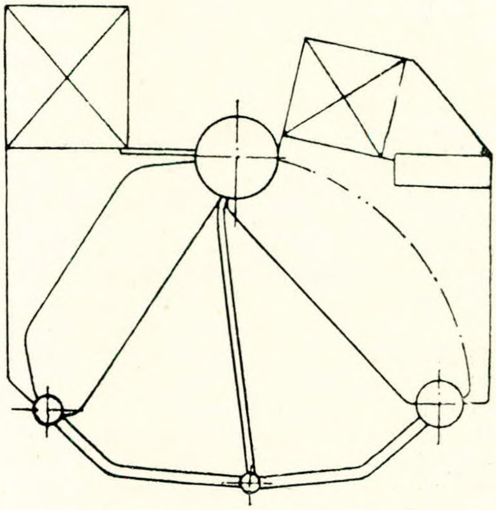

FIG. 15.—An American boiler.

TABLE 3.

No. in order.	No. of burners.	Power of burners.	Consumption of fuel kg./p.h.	Approximate productiveness by evaporation $\frac{D}{B}=12$	Required length of furnace L in metres.
1	3	500	1,500	18·0	1·31
2	3	1,000	3,000	36·0	2·62
3	3	1,500	4,500	54·0	3·93
4	3	3,000	9,000	108·0	7·85
5	6	1,500	9,000	108·0	7·85
6	6	3,000	18,000	216·0	15·70

length of furnaces, led to the adoption of side firing, the oil burners being disposed above one of the water drums on the side of the superheater in the case of the Yarrow boiler (Fig. 3) and in American boilers (Fig. 4) on the side opposite the superheater. Such an arrangement of oil burners, apart from all other considerations, permits the best arrangement of burners in the furnace. The adoption of oil burners of greater power permitted the reduction in their number, simplified their arrangement in the boiler, and at the same time the improvement in the fuel and air supply installations permitted increase of the firing load on the furnace in kg./m.^{3} p.h. and the introduction of boilers with very small lower parts of the furnace (Fig. 15). It would appear that by increasing the power of the boiler that the specific load on the furnace was relatively less than on the radiation surface. At the same time, permitting a greater load on the radiation surface (based on the example of the amassed experience and the advancement in the study of heat transmission in furnaces and the circulation in the tubes) showed the necessity for increasing the relative value of the furnace capacity at the expense of increasing the height (h_1).

With the value of $\frac{B}{H_P}$ $=200$ kg./m.^{3} it is necessary in ordinary triangular boilers to fix the depth of h_1 as follows :—

$$\text{Where } \frac{B}{V_T}=200 \text{ kg./m.}^3 \text{ p.h.} - h_1=2{\cdot}08-0{\cdot}5h.$$

$$\frac{B}{V_T}=250 \text{ kg./m.}^3 \text{ p.h.} - h_1=1{\cdot}66-0{\cdot}5h.$$

$$\frac{B}{V_T}=300 \text{ kg./m.}^3 \text{ p.h.} - h_1=1{\cdot}39-0{\cdot}5h.$$

That is to say, by decreasing the size of the boiler and load on the volume of the furnace, a less value of h_1 may be taken, and by $h_1 > 2{\cdot}16$ it may be determined only by constructional considerations. It may therefore be observed that when considering the rational utilization of the space occupied by a boiler, when designing the heating surface it is desirable that the lower part of the furnace should be kept at small as possible. The present constructive value of h_1 corresponds approximately with the diameter of the lower drum.

If a perspective limitation is taken of the values :—

$$h_1=800\text{mm.}$$

$$\frac{B}{H_T}=250 \text{ kg./m.}^2 \text{ p.h.}$$

$$\frac{B}{V_T}=300 \text{ kg./m.}^2 \text{ p.h.}$$

then the following optimum dimensions may be obtained for ordinary triangular boilers (from the point of view of the relative dimensions of the volume of the furnace and the radiation surface) taking the ratios as previously given :—

$$\frac{B}{L\ (0{\cdot}5ha+ah_1)}=300 \text{ kg./m.}^3 \text{ p.h.}$$

$$\frac{B}{2\,Ll}=250 \text{ kg./m.}^2 \text{ p.h.}$$

$$\text{whence } 1{\cdot}5\,ha+3\,ah_1=5\,l$$

$$1{\cdot}75\,h+3{\cdot}51\,h_1=6{\cdot}1$$

$$h=\frac{6{\cdot}1-2{\cdot}8}{1{\cdot}75}=1{\cdot}88\text{m.}$$

$$a=1{\cdot}17\,h=2{\cdot}2\text{m.}$$

$$l=2{\cdot}29 \text{ metres.}$$

Fitting three oil burners in the front, the boiler may have the following output corresponding to the lengths given in Table 3 above.

By the adoption of boilers with well-developed radiation surfaces the problem again arises of the furnace volume. Low values of the permissible load on the volume of the furnace do not permit the possibility of decreasing the space occupied or the weight of the boiler, with all the advantages of well-developed radiating surface. By employing the conditions as previously accepted, the optimum dimensions of the cross section for a Schultz boiler are obtained by the ratios :—

$$B=300\,V_T=250\,H_P$$

$$1{\cdot}5\,ha+3\,ah_1=2{\cdot}5\ (2\,l+2\,h+2\,h_1)\,;$$

$$1{\cdot}75\,h^2+3{\cdot}51\,hh_1=5\,l+5\,h+5\,h_1\,;$$

$$1{\cdot}75\,h^2+2{\cdot}81\,h=6{\cdot}1\,h+5\,h+4{\cdot}0\,;$$

$$1{\cdot}75\,h^2-8{\cdot}3\,h-4{\cdot}0=0\,;$$

$$h=\frac{8{\cdot}3\pm\sqrt{69+28}}{3{\cdot}5}=\frac{8{\cdot}3\pm9{\cdot}85}{3{\cdot}5}\,;$$

$$h=5{\cdot}2\text{ m}\,;\ l=6{\cdot}35\text{ m}\,;\ a=6{\cdot}07\text{ m}\,;\ h_1=0{\cdot}8.$$

The length of the furnace (L) is determined by the total quantity of fuel consumed, i.e., the amount required for the productivity of the boiler. If four 3-ton oil burners are fitted in each half of each front, it is possible to obtain the probable dimensions of a double-ended Schultz boiler of the following characteristics :—

$$B=2\times2\times4\times3{,}000=48{,}000 \text{ kg./p.h.}$$

$$D=48{,}000\times12=576{,}000 \text{ kg./p.h.}$$

$$\text{(assuming the evaporation}=\frac{D}{B}=\ 12).$$

$$L=\frac{B}{300\ (0{\cdot}5\,a+h_1\,a)}=\frac{48{,}000}{300\ (15{\cdot}8+4{\cdot}86)}$$

$$=7{\cdot}74 \text{ metres.}$$

It is therefore apparent that when constructing such a boiler in cases where required, the heating and constructive calculations should be verified.

By assuming the usual load on the heating surface of the Schultz boiler, $\frac{B}{H_P}=200$ kg./m.² p.h. and using the conditions previously stated, the following proportions are obtained :—

$$1\cdot75\,h^2+2\cdot81\,h=4\cdot88\,h+4\,h+3\cdot2\,;$$
$$1\cdot75\,h^2-6\cdot07\,h-3\cdot2-0,$$
$$h=\frac{6\cdot07\pm\sqrt{36\cdot9+22\cdot4}}{3\cdot5}=\frac{6\cdot07\pm7\cdot7}{3\cdot5}\,;$$

where $h=3\cdot94$m. ; $l=4\cdot8$m. ; $a=4\cdot6$ metres.
The length of furnace depending on the output of the boiler is set forth in Table 4.

TABLE 4.

Approximate dimensions of a Schultz boiler.

No. in order.	Consumption of fuel kg./p.h.	Output tons/p.h.	Length of furnace required in metres.
1	6,000	72·0	1·57
2	9,000	108·0	2·36
3	12,000	144·0	3·14
4	18,000	216·0	4·71
5	24,000	288·0	6·28

By reducing the optimum dimensions when fixing the basic space required for the furnace of a Schultz boiler, the load on the furnace appears to be the limitation of the values.

The angle α at the base, taking into consideration the best circulation, should not be taken at less than 45° ; the angle recommended is 55°. If the permissible load on the furnace is assumed to be $\frac{B}{V_T}=C$ kg./m.³ p.h., and the permissible load on the radiation surface $\frac{B}{H_P}=A$ kg./m.² p.h. where B= the quantity of fuel consumed in the furnace in kilogrammes per hour, V_T=the volume of the furnace in cubic metres and H_P=the radiating surface in square metres, we get :—

$$\frac{A}{C}=\frac{V_T}{H_P}=\frac{L(0\cdot5\,ah+h_1a)}{2Ll}=\frac{ha}{4l}+\frac{h_1a}{2l}\,;$$

whence $\cos\alpha=\dfrac{\frac{A}{C}}{0\cdot5\,h+h_1}$

when $A=C$ and $h_1=0\cdot1\,h$

$$\cos\alpha=\frac{1}{0\cdot6\,h}$$

The value of the angle at the base depending on the height of the boiler is shown in Table 5.

TABLE 5.

Height of boiler in metres $h+h_1=1\cdot1h$	Height of the upper part of furnace h in m.	$\cos\alpha$	angle α
2·2	2·0	0·835	33°20′
3·3	3·0	0·557	56°20′
4·4	4·0	0·417	65°20′
5·5	5·0	0·337	70°20′

In this manner it is seen that by increasing the load on the furnace in relation to the tension on the radiation surface and increasing the height of the boiler, the angle at the base is increased.

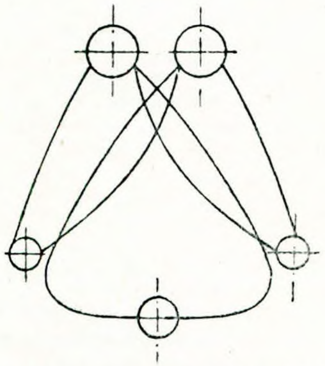

FIG. 16.—Wagner one-and-a-half boiler.

It is often the case that on account of the measurements of the vessel's hull, the proportion between the height and breadth of the boiler room is such that it is difficult to take advantage of the cross section required for the ordinary triangular boiler; in small vessels there remains a surplus breadth of boiler room where a single boiler is fitted, and insufficient breadth for installing two boilers. It is suggested that in such cases the Wagner "one-and-a-half" boiler be fitted (Fig. 16). The Wagner boiler with two drums, although narrow, is not suitable for adoption in high boiler rooms, as it requires a very large size of convection tubes with the increased difficulty of fitting them.

Conclusions.

(1) In the development of the water-tube boiler of the triangular type, the symmetrical arrangement of the superheater appears to be the most rational method; the non-symmetrical arrangement is only justified in small boilers and boilers of special construction.

(2) The tendency to utilise as far as possible the space occupied by the boiler, caused by the problem of the load on the volume of oil burning furnaces (200 to 300 kg./m³ p.h.), compelled the adoption of supplementary radiation surface in small and medium sized boilers even for a given boiler of original form and cross section.

(3) The adoption of fire-row tubes of the La Mont type in triangular boilers is only suitable when modernizing an existing boiler.

(4) In order to reduce the space occupied by a group of boilers, by utilizing the advantages of an elaboration in the development of the radiation surface, it is necessary to obtain a greater load on the volume of the furnace of, say, 300 to 400 kg./m.³ p.h.

(5) For the purpose of securing high loads on the volume of furnaces, water-tube boilers with natural circulation may be recognised with other types as practical and necessary for marine purposes.

(6) The maximum efficiency is represented by the modified Schultz-Wagner boiler (Fig. 10).

(7) The angle of inclination of the tubes should be determined in each separate case, according to circumstances.—*"Soudostroienie", No. 9, 1937.*

EXTRACTS.

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

Appointment of Engineer and Ship Surveyors to the Board of Trade.

The Board of Trade announces that the qualifications regarding service in steamships required in connection with the appointment of Engineer and Ship Surveyors have been modified. The revised regulations are as follows:—

Any person desiring appointment must apply on a special application form, which may be obtained from the Chief Staff Officer, Establishment Department (Mercantile Marine Branch), Board of Trade, Great George Street, London, S.W.1.

Limits of Age.—Candidates must be within the ages of 25 and 40 on the first day of the examination.

Note.—A candidate born on the day of which the first day of any Civil Service Examination for the appointment is the anniversary would be admitted on the 25th, but not on the 40th anniversary of his birth.

Nationality.—Every candidate must be a natural-born British subject, the child of a person who is or was at the time of death a British subject; provided that exception may be made:—

(*a*) In the case of candidates serving in a civil situation to which they were admitted with the certificate of the Civil Service Commissioners.

(*b*) In the case of natural-born British subjects who served in His Majesty's Armed Forces in the Great War between 4th August, 1914, and 11th November, 1918.

(*c*) In the case of natural-born British subjects who have satisfactorily completed a period of not less than five years' service on full pay in His Majesty's Regular Forces.

Provided also that if the Civil Service Commissioners are satisfied, in the case of any candidate who is a British subject but does not fulfil all the requirements of the rule as to nationality and descent, that the candidate is so closely connected by ancestry and upbringing with His Majesty's dominions that an exception may probably be made to that rule, they may accept such candidate as eligible provided that this discretion shall not be exercisable unless (*a*) the father or the paternal grandfather of the candidate was a natural-born British subject, and (*b*) neither the father nor the paternal grandfather had acquired any other nationality by naturalization or by any other voluntary and formal act.

Health and Character.—Successful candidates will be required to satisfy the Civil Service Commissioners that they are duly qualified in respect of health and character.

Salary.—The present salary scale for Surveyors commences at £400 per annum on appointment and rises (subject to the approval of the Board) by annual increments of £18 to £526 per annum and thence by £25 to a maximum of £650 per annum.

Surveyors are eligible for promotion to a higher grade on a scale of £650 per annum rising by annual increments of £25 to a maximum of £800 per annum, and there are certain posts above this grade which are also open to Surveyors.

The scales of salary are liable to review.

Conditions of Appointment.—Surveyors will be required to give their whole time to the duties which may be required of them. They must be prepared to perform duty, including the examination of Engineers for Certificates of Competency, in any port in the United Kingdom to which they may, for the time, be assigned, and in special circumstances, they may be required to perform temporary duty at a foreign port.

All appointments will continue only during the pleasure of the Board of Trade. The first year of appointment will be strictly probationary, and at the expiration of that time each Officer will be required to pass an examination by the Board's Principal Professional Officers to prove his proficiency.

A candidate for the appointment of Engineer and Ship Surveyor must have passed to the satisfaction of the Board of Trade a Sight Test which will include colour vision. Particulars of the places at which Sight Test examinations are held can be obtained from any Mercantile Marine Office. Normally the tests must be undertaken without the aid of glasses, but as a moderate error of refraction does not disqualify a candidate, application may be made to the Assistant Secretary, Mercantile Marine Department, Great George Street, London, S.W.1, for permission to take the test with glasses, stating the place at which the candidate desires to be examined.

Method of Selection.—When a written application on the special printed application form has been submitted by the applicant, he will be informed if he is regarded as possessing the qualifications deemed essential for this appointment, and if his name has been placed on the list of candidates. When a competition is announced, a number of candidates will be selected by the Board of Trade to compete in London for the appointments at an examination which will be partly written and partly oral.

The examination will be designed to test

Technical Knowledge,
Personal Qualities.

Qualifications.—The applicant must have served an apprenticeship to a firm of engineers, or iron and steel shipbuilders, and copies of testimonials of service, together with a statement as to the description of the works in which he was an apprentice, the different workshops or departments in which he was engaged during his apprenticeship, and the length of time served in each workshop or department, must be submitted. He should have served at sea as an engineer officer, as indicated below, in foreign-going ships propelled by steam or heavy oil engines for at least five years, of which at least two years must have been served in ships propelled by steam engines; experience of heavy oil engines is desirable. Service in home trade or coasting ships propelled by steam or heavy oil engines of not less than 66 n.h.p. will be accepted to a limited extent in lieu of service in foreign-going ships, 18 months' service in home trade or coasting ships being regarded as equivalent to 12 months' service in foreign-going ships, but a candidate must have served for a period of at least two years in foreign-going ships propelled by steam or heavy oil engines and the total service in steam ships must, at least, be equivalent to two years service in foreign-going steam ships. The qualifying service should normally have been performed on regular Articles as a chief or a watch-keeping engineer officer on the main engines or boilers, but consideration will be given to service of equivalent value.

Copies of testimonials must also be submitted by the applicant furnishing particulars of his sea service, and any appointment he has held on shore since the termination of his apprenticeship.

The applicant must possess an Extra First Class (Board of Trade) Certificate of Competency as an Engineer, or a First Class (Board of Trade) Certificate of Competency together with a B.Sc. (Engineering) or other equivalent voucher of scholarship.

Syllabus of Examination in Technical Knowledge.

A general knowledge of mathematics, sufficient for the working of problems relating to engineering. A knowledge of the calculus is not essential.

The fundamental principles and practice of mechanics, including the strength of materials and theory of structures and the equilibrium of floating bodies. The theory and practice of heat and heat engines, and the combustion of fuel. The general principles of electricity with special reference to the use of electric power on board ship. A knowledge of the construction and propulsion of steel ships. Ability to make calculations for and working drawings of the details of marine engines, boilers and other ship machinery.

The maximum marks assigned will be :—

Written papers in Technical knowledge (including 100 marks for an essay or report on a technical subject) ...	400	Pass Standard 350
Oral examination (*see* note below) Practical knowledge and experience	300	
Personal qualities	300	
	1,000	

NOTE.—Personal qualities and experience are of importance for the situation of Engineer and Ship Surveyor. The degree to which the candidate possesses these will be judged, and marks awarded after the candidate has been interviewed by a Board appointed for the purpose.

Fee.—A fee of £6 15s. 0d. will be payable by all candidates admitted to the examination.

Modern Marine Power Plants.[*]

By J. J. NELIS[†]

"Marine Engineering and Shipping Review", March, 1938.

Consideration of ship propulsion by the use of mercury vapour is of value to everyone connected with power plant design for ships. It is another indication of the coming changes in marine power plant practice. During the next few years many new and novel types of marine power plants may be proposed.

Mercury vapour requires a binary cycle, i.e., the mercury is first heated to obtain power from its vapour, the exhaust from the mercury vapour turbine being at such a temperature that it is necessary to use this heat to produce further power. In this case the exhaust of the mercury vapour turbine is used to heat water forming steam. This means there are two turbines in operation and it would be an interesting experiment to balance them in the usual changes of power required by a ship while manœuvring when entering or leaving port. It also means we have all the latent heat losses to a condenser common to any efficient steam plant.

Another binary cycle which has found some use in Germany is the zinc ammonicate. This is a binary cycle using an ammonia turbine, the exhaust of which is used to heat water to operate a steam turbine. This has not found any extended use but is also a cycle like mercury vapour with a low pressure and low latent heat of vapour.

Another special liquid now coming into rather extended power plant practice ashore is Dowtherm, a mixture of 73·5 per cent. diphenyl oxide and 26·5 per cent. diphenyl. This, however, can be operated as a single or a binary cycle. It has the same characteristics of low pressure and low latent heat for high temperature. It keeps its liquid form to 500° F. and in the vapour form above 500° F. Where the boiler can be set below the turbine, no pump is required in the cycle. Dowtherm is also used as a liquid for temperature work such as recovering heat from the waste gases of the high-pressure boilers in shore plants instead of air heaters, thus eliminating long expensive air ducts. It is also being used as a boiler with the vapour to drive turbines and for other special process or heating work. There are more Dowtherm boilers in

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[*] From discussion of paper on "Ship Propulsion by the Mercury Vapor Process", presented by William L. R. Emmet before The Society of Naval Architects and Marine Engineers, New York, November 19, 1937.

[†] Vice-president, Foster Wheeler Corporation, New York.

successful use to-day than any other special type except steam.

There are other special liquids available, nearly all of which have the characteristic of attacking the metal of the boiler. Dowtherm is immune to this characteristic of attacking the metal of boilers and that is one reason it is becoming more widely used.

Water vapour in the form of steam is almost universally used for power plant practice ashore and afloat. It is well known that water vapour is not the best medium of transferring the heat in the fuel to the prime mover, yet on account of its reliability, simplicity, first cost and ease of operation it is almost universally used.

There are two places in the usual marine power plant where major losses occur, first the waste boiler gases to the stack, second the condensing water. In the boiler room we are now approaching 90 per cent. efficiency and could obtain higher efficiency but the cost involved would not justify the additional heat recovery. Whatever type of heat transfer medium is used between the fuel and the prime mover in the engine room, whether water or any of the special liquids such as those mentioned, no great increase of boiler room efficiency is probable or desirable.

Therefore, the main opportunity for future marine power plant savings is in the engine room. We can at moderate expense make further economy gains in the engine room both in the prime mover and its auxiliaries. A further possible large gain for marine use is in the propeller. The propeller has been greatly improved in aeronautical use in a limited period. If some of this new propeller knowledge could be used for ships' propellers, it might make a greater fuel saving than any other change in the power plant.

In operation aboard ship to-day we have variations in power plants from the old low-pressure boiler with reciprocating engine, no superheat, no heat recovery device above the boilers and a fuel consumption well above one pound of oil per shaft horsepower. We have medium steam pressure, medium superheat power plants with heat recovery devices above the boilers operating at approximately 0·6lb. per shaft h.p. Mr. Emmet proposes a mercury vapour power plant which would use more than 0·4lb. of oil per shaft h.p. We have many Diesel engine marine power plants reported well below 0·4lb. oil per shaft h.p. Therefore, from the standpoint of weight of oil burned only, the Diesel engine is the most efficient and if this were the only consideration it would be almost universally used.

The cost of fuel oils varies. Generally speaking, the cost of special light oils used for Diesel engines exceeds that of the heavier Bunker C oils used by steam plants. At the present time along the Atlantic Coast Diesel oil costs 60 per cent. more than Bunker C oil for steam plants. This means that for the average ship now building of about 4,000h.p., while the weight of the fuel oil required for the steam plant is greater than the Diesel plant, the fuel cost per h.p. produced is lower with the steam plant. There is a definite place for the Diesel engine in spite of this difference in fuel cost. In small sizes and where the plant operates only intermittently, such as in tugs and harbour work, the Diesel is probably a better power plant than steam for the work required. With larger size power plants and more or less continuous operations, such as a tanker with probably 300 days per year at sea, the steam plant can just as definitely give lower fuel costs and less repair costs than the Diesel.

If some of the new special liquids such as mercury, Dowtherm or zinc ammonicate or forced circulation boilers at high pressures and extremely high temperatures are used, it is probable that on very long trips this type of power plant would show the lowest fuel and direct operating costs. It is doubtful if any of the plants mentioned in moderate powers will exceed the present-day steam plant in final cost over the usual 20-year-period of a ship's useful life.

In the face of these facts on fuel weights and costs required for different marine power plants the major portion of all marine power plants both in service and building at present are steam. Probably the main effect of competition from the Diesel engine and other competing special liquid or vapour phase cycles will be to force the steam plant to better economies. It is readily possible to design a steam plant for higher pressures and temperatures and at a reasonable first cost which would have a fuel oil consumption of 0·5lb. of oil per shaft h.p. hr. and would be equally reliable as the present type of steam plants.

It is possible that in the near future the marine steam power plant will be carried to an extreme for special cases similar to some of the recent land plants. We have at present in use on ships several types of forced circulation boilers to use extremely high steam pressures and temperatures. They are frankly experimental and some are now reported to have dropped back to a more moderate pressure. It is questionable whether very high steam pressure results in a more efficient power plant than a moderate steam pressure with the maximum steam temperature now possible when using the best alloys available.

Any power plant is simply a heat exchange problem, therefore a greater gain is to be made by raising superheat temperature than pressure, especially for use with turbines, and where this temperature, except for a minor loss in radiation, can all be put to work, and there is no loss of latent heat to the condensing water from the heat put into the steam for superheating.

In the final analysis all marine power plants will be governed by commercial considerations, not by a single item such as weight of fuel burned. These include reliability, first cost, fuel cost and total operating cost. The operating cost will be governed by design and by the class of operatives available for marine work. We are necessarily conservative in marine design. Our power plants are sent to sea, may get in difficulty many thousand miles away from home and must somehow get into port. This is entirely different from the average land plant where in cases of emergency or other trouble the manufacturer of the equipment can promptly supply the necessary replace material and technical help. Therefore, reliability means more in marine work than some minor saving in one item only such as fuel cost or first cost. Marine fuel cost probably averages about 25 per cent. of the total power plant operating cost in marine work. It is an important factor but the other 75 per cent. of total operating cost must determine the type of power plant to be used.

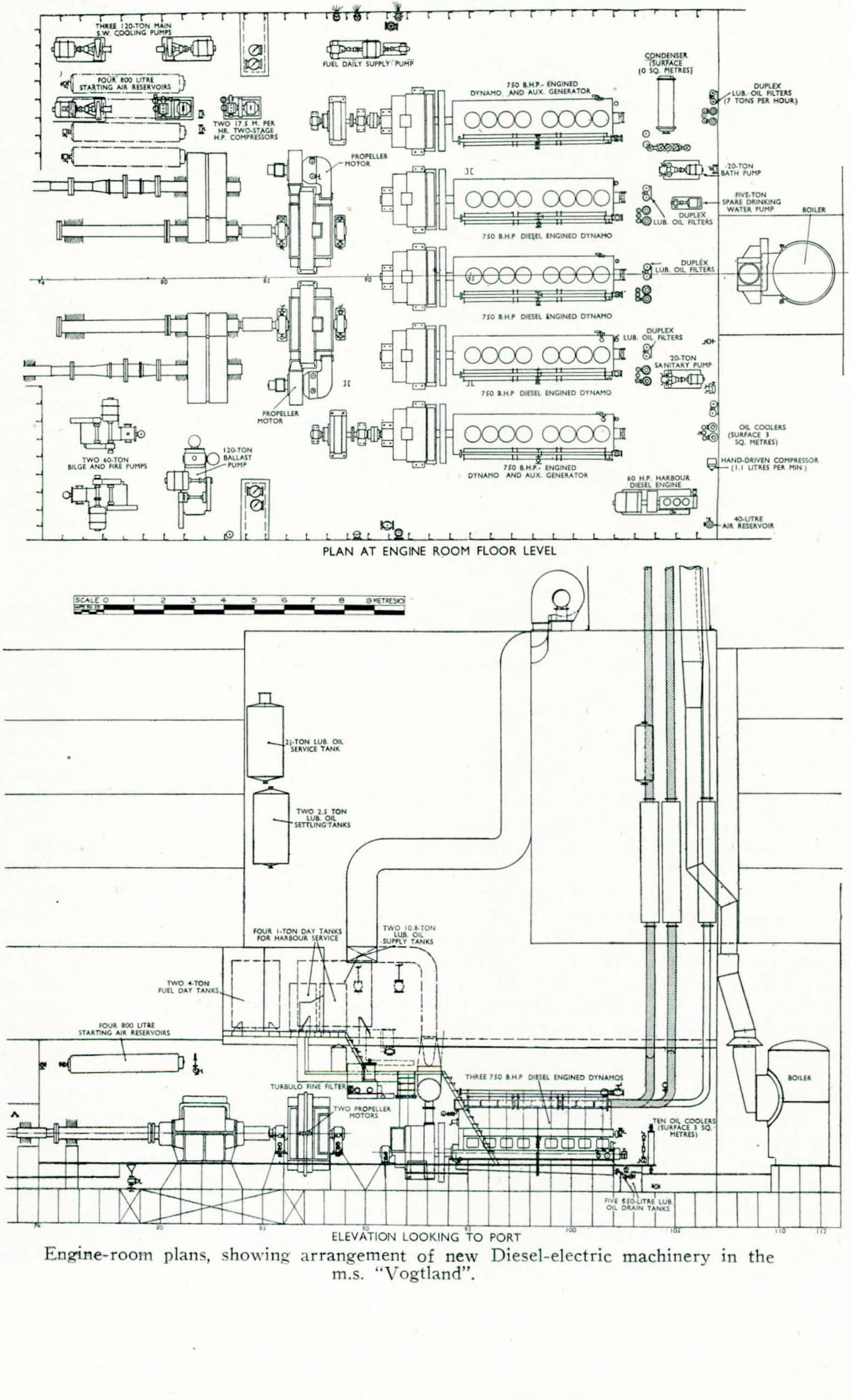
Those of us in the marine design field will witness many experiments in the near future. None can afford to prophesy what these will be, none can afford to ignore every development being tried out, but must check them carefully from an operating and a technical standpoint. Some of the developments will become future standards. The steam plant has a long way to go both in reducing first cost, fuel required and operating cost. It will at least be a serious competitor of any other type of marine power plant for future use. Through it all, we will make definite progress.

A Five-engined Motor Ship.

Unusual Conversion of a Hapag Oil-engined Vessel by the Installation of High-speed Diesel-engined Generators.

"The Motor Ship", March, 1938.

At a time of considerable demand for tonnage and of difficulties in obtaining engines quickly, the



PLAN AT ENGINE ROOM FLOOR LEVEL

ELEVATION LOOKING TO PORT

Engine-room plans, showing arrangement of new Diesel-electric machinery in the m.s. "Vogtland".

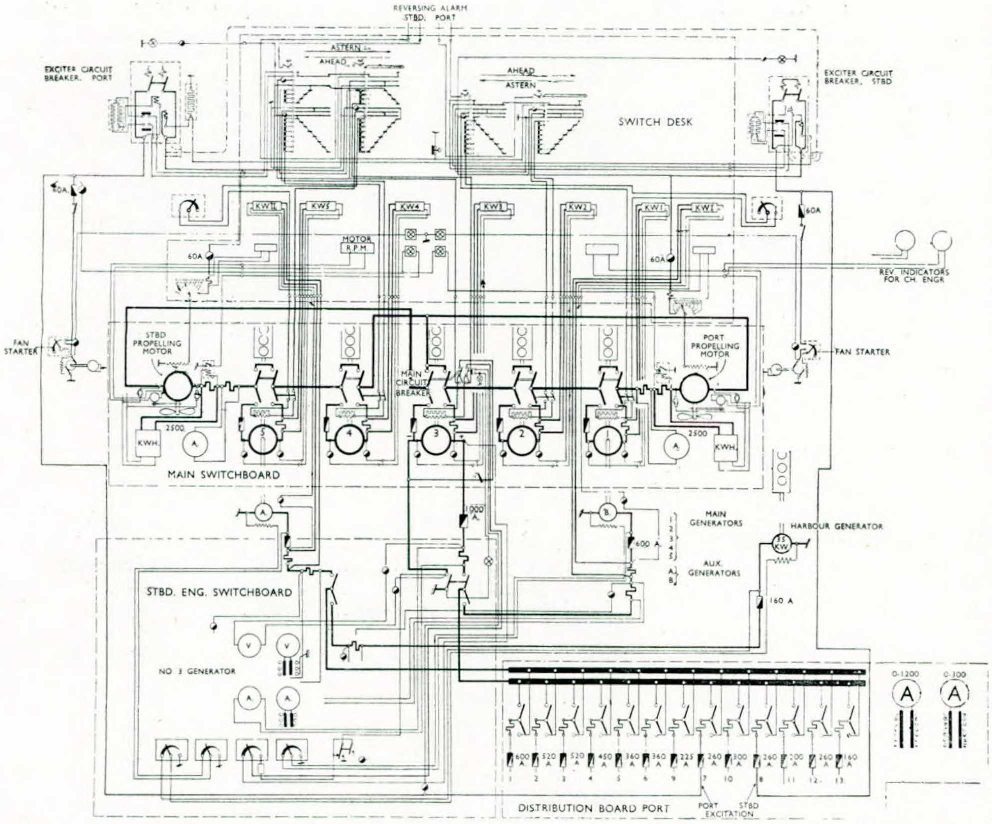


Diagram of electrical connections for the generating sets and switchboard in the "Vogtland".

Hamburg American Line built the motor ship "Havelland" in 1921 and the "Vogtland" in 1924, and equipped them with 10-cylinder four-stroke M.A.N. submarine engines. They are not specially suitable for mercantile ship propulsion, and had to be installed in conjunction with reducing gear. These engines, which have a cylinder diameter of 530 mm., were arranged to drive two propellers at 85 r.p.m., the engine speed being 230 r.p.m. This is much below the designed speed for submarine propulsion, and the engines, which were originally rated at 3,000 b.h.p. developed 1,650 b.h.p. at the lower speed mentioned, thus giving a total of 3,300 b.h.p.

Some time ago the owners decided that the engines of the "Vogtland" had reached the end of their useful life and arranged to re-engine the ship. It was found that by adopting an installation of five high-speed Diesel-engined generators supplying power to electric motors, the machinery could be obtained more quickly than a smaller number of larger units; and, in fact, it was possible to place the vessel in service six months earlier than would otherwise have been the case. Were it a question of new installations, larger sets would have been adopted, as this would have allowed a lower cost of fitting, a reduction in weight and space occupied, also a simplification of the piping arrangements, easier supervision and lower upkeep costs. It may be borne in mind, however, that the engine-room with the installation made in 1924 was very roomy, so that any saving in space and even of weight was not of much importance. This explanation is necessary lest it be thought that the owners consider this adoption of a large number of units of relatively small power preferable on general grounds to the utilization of larger engines of higher output.

The five engines are Linke-Hofmann units manufactured by the Fahrzeugund Motorenwerke G.m.b.H. vorm. Maschinenbau Linke-Hofmann, Breslau. They are four-cycle sets with eight cylinders, having a diameter of 350 mm. and a piston stroke of 500 mm. Each engine drives an A.E.G. direct-current generator of 600 kW. at 350 volts. The engines Nos. 1 and 5 are, moreover, each arranged to drive an S.S.W. d.c. generator of 125 kW., the voltage in this case being 220. The smaller generator supplies current for the operation of the auxiliaries and the supply of electricity generally. If necessary, the 600-kW. generator attached to No. 3 engine can be switched on to the auxiliary network.

In normal service all or a certain number of the generators, as may be desirable according to the speed, are used, supplying power to the two propeller motors through the switchboard. Each of these motors is an A.E.G. direct-current unit rated at 1,300 kW. at a voltage of 640. They drive the propeller shafts at their original speed through gearing. As it was desired to use the original shaft there was no object in installing the electric motors right aft, and they are fitted in the engine-room, the five generating engines being arranged in a row at the forward end. For service in port there is a 60 h.p. three-cylinder Diesel engine designed to run at 500 r.p.m., coupled to a dynamo and located in the starboard forward corner of the engine-room.

The arrangement of the auxiliary machinery and the capacity of the various pumps, etc., are given in the engine-room arrangement plan. The system of distribution is illustrated in the switchboard diagram, from which it will be seen that the auxiliary circuit may be supplied from dynamo No. 3 or from either of the two auxiliary generators which, as mentioned, are coupled to two of the main engines.

From the main switchboard there are 10 feeders, as under, supplying the following circuits:

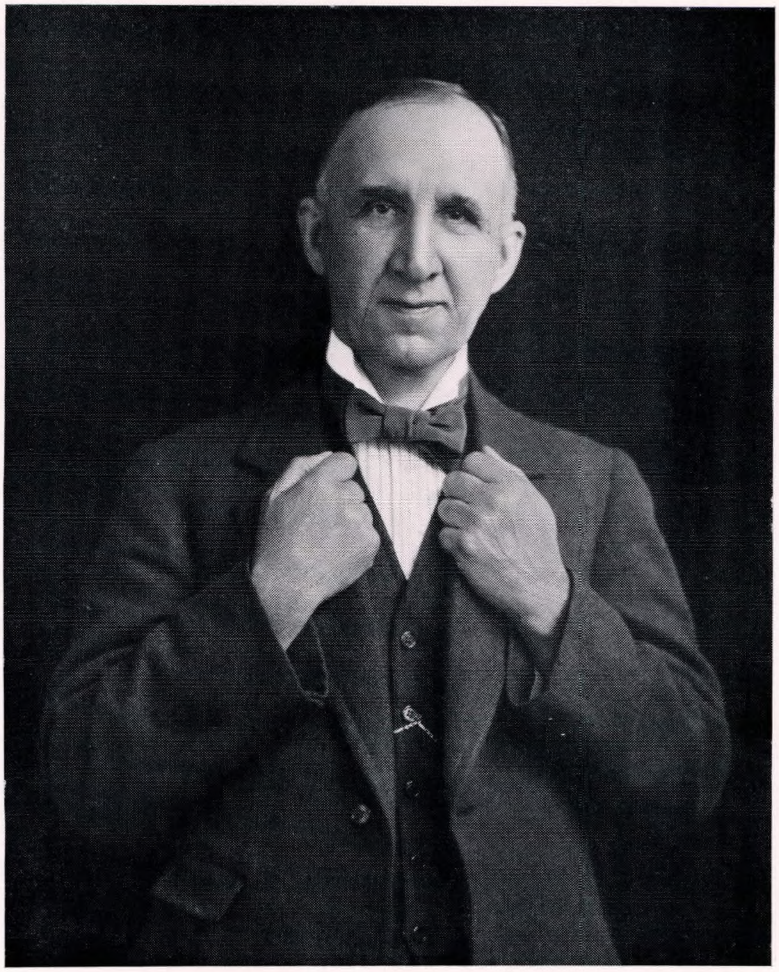
(1) Engine-room, forward (600 amperes).
(2) Engine-room, aft (520 amperes).
(3) Engine-room, aft (520 amperes).
(4) Auxiliary machinery (450 amperes).
(5) Winches, forward (360 amperes).
(6) Winches, aft (360 amperes).
(7) Excitation, port (260 amperes).
(8) Excitation, starboard (260 amperes).
(9) Distribution board for refrigerating machinery (225 amperes).
(10) Heating, promenade deck (300 amperes).
(11) Main deck (200 amperes).
(12) Anchor winch (260 amperes).
(13) Winches amidships (160 amperes).

The trials of the "Vogtland" with her new machinery were carried out satisfactorily last month.

BOARD OF TRADE EXAMINATIONS.

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

Name.	Grade.	Port of Examination.
For week ended 10th March, 1938:—		
Gray, Ronald W.	1.C.	Liverpool
Nevison, Walter	1.C.	,,
Prytherch, Eric L.	1.C.	,,
Paterson, John McD.	1.C.	Leith
Allan, Malcolm	1.C.	Newcastle
Clement, Joseph T.	1.C.	,,
Cartwright, Charles K.	1.C.M.	,,
Reay, Sidney	1.C.M.	,,
Taws, Henry H.	1.C.M.	,,
Ellison, Arthur	1.C.	London
Purse, Robert B. W.	1.C.	,,
Young, Frederick	1.C.	,,
Baillie, Robert B.	1.C.	Glasgow
Corrigan, James	1.C.	,,
Ferguson, William W.	1.C.	,,
Gilchrist, Robert	1.C.	,,
Macintyre, Alistair M.	1.C.	,,
Ross, Charles W. T.	1.C.	,,
Sime, William	1.C.	,,
White, William J.	1.C.	,,
Wood, George J.	1.C.	,,
Irwing, George	1.C.M.E.	London
Verhoeven, William J.	1.C.M.E.	,,
Quinnell, Benjamin T.	1.C.M.E.	,,
Newbould, Charles R.	1.C.M.E.	,,
Compton, Aubrey F.	1.C.M.E.	,,
Brooks, Henry A.	1.C.M.E.	,,
Swanston, Rowland M.	1.C.M.E.	Newcastle
Rielly, John B.	1.C.M.E.	Leith
Howie, James O.	1.C.M.E.	,,
Whyte, Ian G.	1.C.M.E.	,,
Douglas, Malcolm	1.C.M.E.	Liverpool
Kelly, Francis A.	1.C.M.E.	,,
Young, Richard	1.C.S.E.	,,
Alexander, Alexander F.	1.C.S.E.	Newcastle
For week ended 17th March, 1938:—		
Kerr, Rodger N.	Ex.1.C.	Liverpool
Keymer, Arthur R.	Ex.1.C.	Glasgow
Apsimon, Richard D.	2.C.	Liverpool
Cadogan, Anthony	2.C.	,,
Dumbell, Geoffrey L. T.	2.C.	,,
Billing, John A.	2.C.M.	,,
Sleeman, John K.	2.C.	Newcastle
Martin, David A. N.	2.C.	Glasgow
McLean, James S.	2.C.M.	,,
Tait, John G. R.	2.C.M.	,,
Lindsey, Malcolm H.	2.C.M.	London
Elcock, Eric C.	2.C.M.	Cardiff
Tame, Sidney C.	2.C.M.E.	Liverpool
For week ended 24th March, 1938:—		
Paulsen, Harry P.	1.C.	Cardiff
Pritchard, Robert E.	1.C.	,,
Thomas, Godfrey H.	1.C.M.	Cardiff
Steven, Charles D.	1.C.	Glasgow
Proudfoot, Harry	1.C.	Hull
Yorgenson, Arthur C.	1.C.	,,
Diamond, Reginald	1.C.M.	Liverpool
Clark, George H.	1.C.	Newcastle
Richardson, James	1.C.	,,
Davison, Fred	1.C.S.E.	,,
Trewhitt, Richard	1.C.M.E.	,,
Tomlin, Walter D. K.	1.C.M.E.	London
Priestley, David P.	1.C.M.E.	,,
Anderson, David	1.C.M.E.	Glasgow
Hodgson, John P.	1.C.M.E.	Cardiff
Connor, John F.	1.C.M.E.	,,
Logie, James	1.C.M.E.	Glasgow
For week ended 31st March, 1938:—		
Ferguson, Dugald McL.	2.C.	Glasgow
Reid, Richard	2.C.	,,
White, James	2.C.	,,
Johnston, John	2.C.M.	,,
McPherson, Joseph	2.C.M.	,,
Cunningham, Thomas D.	2.C.	Leith
Kellie, Alexander A.	2.C.	,,
Catherall, John	2.C.	Liverpool
Coles, John H.	2.C.	,,
Cunningham, James	2.C.	,,
Graham, Wilfred T.	2.C.	,,
Sanders, William	2.C.	Newcastle
Spendley, Harold G.	2.C.	,,
Ward, Norman C.	2.C.	,,
Wappett, Christopher	2.C.M.	,,
Flood, Edward C.	2.C.	London
Read, Henry J.	2.C.	,,
Probett, Clifford A. M.	2.C.M.	,,
Nicoll, William P.	2.C.M.E.	,,
For week ended 7th April, 1938:—		
Ramsey, Walter S.	1.C.M.	Newcastle
Stubbs, Bertie	1.C.	Liverpool
Hill, Peter	1.C.	Glasgow
Johnstone, Norman A.	1.C.	,,
Lauchlan, Arthur W.	1.C.	,,
Martin, John H.	1.C.	,,
Rough, Arthur	1.C.	,,
Watson, Oswald	1.C.	,,
Malcolm, Thomas	1.C.M.	,,
Glennie, William J.	1.C.	London
Legg, Edward A.	1.C.	,,
Green, Henry	2.C.	Belfast
Robinson, Victor C.	2.C.	,,
Armstrong, William	1.C.M.E.	Glasgow
Murray, James C.	1.C.M.E.	,,
McLeish, James B.	1.C.S.E.	,,
Tomlinson, William	1.C.M.E.	Liverpool
Drury, Alfred G.	1.C.M.E.	London
Robbie, William G.	1.C.M.E.	,,
Carnaghan, James T.	1.C.S.E.	,,
Rawson, Albert	1.C.M.E.	,,
For week ended 14th April, 1938:—		
Barber, Richard J.	2.C.	Newcastle
Chambers, George H.	2.C.	,,
Collighan, Arthur N.	2.C.	,,
Macrae, John E.	2.C.	,,
Allen, George N.	2.C.M.	,,
Gifford, Eric A.	2.C.M.	,,
Turnbull, William W.	2.C.M.	,,
Irving, John H.	2.C.	Cardiff
Shields, Peter G.	2.C.	,,
Ferguson, William A. P.	2.C.	Glasgow
Craine, William F.	2.C.	Liverpool
Darbyshire, George	2.C.	,,
Lewis, Thomas	2.C.	,,
Manson, Peter	2.C.	,,
Moore, Noel W.	2.C.	,,
Pickthall, Harry	2.C.	,,
Jones, David L. C.	2.C.	London
Norton, Lewis D.	2.C.	,,
Sharp, James R.	2.C.	,,



The late Mr. James Howden Hume.

Portrait by] *[H. J. Whitlock & Sons, Ltd.*

OBITUARY.

Mr. James Howden Hume.

It is with deepest regret that we announce the death, which occurred in a London nursing home on Tuesday, May 24th, 1938, of Mr. James Howden Hume (past Vice-President and Member 2356).

Born in Glasgow in 1866, Mr. Hume was educated at the High School and Royal Technical College in that city. His apprenticeship as an engineer began in 1882 in the works of Messrs. James Howden & Co., founded in the year 1854 by his uncle, the late Mr. James Howden. In due course he became chief draughtsman, then general manager, and in 1900 he was made a partner in the firm. On the death of Mr. James Howden in 1913 Mr. Hume became chairman of the concern, then a private limited company, a position which he occupied until his death. During the earlier years of his connection with the firm, engines and boilers were constructed for many of the leading shipping companies, and for the past 40 years he had been occupied largely in developing the Howden system of forced draught.

During the years 1913, 1915-16, and again from 1924-28, Mr. Hume served as a Vice-President of The Institute for the Glasgow area, and his efforts on behalf of The Institute during these periods earned the keen appreciation of the Council. Mr. Hume was also a past-President of the Institution of Engineers and Shipbuilders in Scotland, a member of the Institution of Civil Engineers and the Institution of Naval Architects and a Justice of the Peace for the County of the City of Glasgow. He was a burgess of the City of Glasgow and a freeman of the City of London. For the former city he was an ex-deacon of the Incorporation of Hammermen and a member of the Merchants' House, while for the latter he was a liveryman of the ancient Shipwrights Company.

A keen politician, Mr. Hume was for many years President of the Unionist Association in the Tradeston Division of Glasgow, where the Howden works are situated. From his earliest years he was keenly interested in art, being an enthusiastic admirer of the "Glasgow School" represented by Guthrie, Lavery, Melville, Crawhall and others, and for a number of years he acted as President of the Royal Glasgow Institute of the Fine Arts. A life-long abstainer, he always took a great interest in the various societies connected with that aspect of life, being a director of the Abstainers Union in Glasgow, and, on the business side, of the Scottish Temperance and General Insurance Co., Ltd. Mr. Hume had travelled widely, and although in recent years he resided in London he visited Glasgow constantly and thus kept closely in touch with various developments in his native city. Sport was another of his interests. He was a member of the Society of the Queen's Park Football Club of Glasgow, and was connected with various yacht clubs, having owned and successfully raced on the Clyde some well-known yachts. In 1893 he married Agnes, daughter of the late John C. Munn of Glasgow, and leaves a family of two sons and one daughter.