INSTITUTE OF MARINE ENGINEERS

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SESSION 1913-14.

President: THOMAS L. DEVITT, Esq.

PRIZE ESSAY.

(Competition for Associate Members, 1913.)

The Economic Use of Coal on board the Modern Steamship.

BY THETA (MR. WALTER SMITH, Associate Member).

To state that any particular power installation has a higher overall efficiency than another does not necessarily imply that it is also superior as a dividend-earning concern. This may at first glance appear parodoxical, but a moment's investigation not only substantiates the truth of this statement, but also serves to indicate the involved nature of the problem under discussion. Let us take for example a typical power station generator unit using saturated steam and exhausting into 25″ vacuum, it would probably use not more than 15lbs. of steam per B.H.P. per hour or in other words ·75 H.P. per lb. of coal. Now consider a similar plant using super-heated steam and exhausting into 28″-29″ vacuum. This installation would give approximately ·9 H.P. per lb. of coal. From these figures it will be seen that the economy in the latter case is much the higher, but it is questionable whether the saving shown would justify the extra capital involved, together with the enhanced running charges due to the extra power required for the air and circulating pump and the more expensive packing and lubricants.

From the foregoing illustration it will be seen that our opening statement is fully justified, and that the efficiency of a power installation is not a direct measure of its value as an investment and therefore it is necessary when installing new plant to make a careful compromise of the several factors which are essential to the final success of the undertaking. We should for instance adjust our capital expenditure, so that the extra nett gain that would be obtained by installing a more expensive plant shows a poorer return than we could obtain otherwise. We should also find it necessary to consider the locality, the cost of labour, and of coal, the facilities for handling the latter and the many other more or less important factors, which favourably influence our endeavours to obtain the most power for the least money.

It is not the object here, however, to consider the commercial aspect of the marine engine, but rather to discuss the most important practical points which make for higher efficiency.

Anyone who has followed the development of the marine steam engine through the last ten years or so, cannot fail to have noticed that while considerable attention has been given to the main and auxiliary machinery very little has been done to improve boiler room practice. This is unfortunate, as a very considerable economy could be effected by the adoption of scientific methods against the rule of thumb conditions that at present exist. Let us take for instance the problem of mechanical versus hand firing; now it is the generally accepted view amongst land engineers that mechanical stoking is much the more efficient, also it has been shown that hand-firing is of very variable quality, for under similar conditions as to plant and steam generated, different firemen have varied as much as 20 per cent. in the amount of fuel used. Such a thing as this could never occur with mechanical stoking, as the constant thickness of the fuel bed, the complete removal of ash and clinker, and no opening of furnace doors all tend towards perfect conditions. In spite of its many advantages, this method has found but little favour with marine engineers, and in view of the scarcity of data relating to this subject, a brief account of the result of a test on the s.s. *Pennsylvania* may be of interest. The main machinery was of 2,000 H.P. quadruple engines, steam being supplied at 250 lbs. square inch from two water tube marine type boilers. Three mechanical stokers of the underfed type were fitted to each boiler. The coal used had the low calorific value of 11,790 B.T.Us. per lb., and contained much refuse. The evaporation from and at 212° F. was given at 8·86 lbs. of steam per lb. of coal as an average of five tests, which gives a boiler efficiency of 72·6 per cent. with a comparatively poor grade coal. The total amount of steam used in operating the stokers was 138·6 lbs. or 4·29 per cent. of the total steam generated.

There is, however, one point which is of more importance than the foregoing, and it is, the admission of the correct amount of air into the furnace. This is usually judged by the appearance of the fuel bed, and the smoke emitted from the stack. Some idea of the importance of this point may be gathered when it is stated that incomplete combustion results in CO while perfect combustion results in CO_2. Now 1 lb. of carbon (which being the chief constituent of coal need only be considered) burned completely to CO_2 gives 14,000 B.T.Us., whereas if it was only burnt to CO it would yield 4,450 B.T.Us., roughly 31 per cent. of its full heat value. It therefore follows that if we can analyse our flue gases for one of the above constituents, we can tell exactly what degree of completeness we are realising in the combustion of our fuel, and so regulate our air admission to the best advantage. This analysis can be effected by means of the CO_2 recorder which automatically measures the per cent. of carbon dioxide passing away in the flue gases. There are several reliable types on the market and the instrument is looked upon with much favour in land installations, but has not as yet intruded to any great extent into the realms of practical marine engineering, but that it will eventually find a place in the boiler room of every well-appointed ship is undoubted.

Having obtained the maximum amount of steam per lb. of fuel it now remains for us to use it to the best advantage. About 10 years ago marine engineers began to realise that they had reached the practical limit of economy as far as the recriprocating engine was concerned, which type was at that time standard. This fact probably had a considerable influence upon the rapid way in which the steam turbine came into favour, but its adoption was restricted to vessels of speeds above 21 knots.

More recently, however, low pressure turbines working in conjunction with reciprocating engines have been adopted for vessels of intermediate speeds and the results obtained show a very favourable economy. For boats of 12 knots speed or lower, the most satisfactory solution of the problem appears to lie in the use of mechanical gearing between the turbine and propeller, thus enabling both to be run at their most efficient speeds. Whatever system is adopted, however, the final economy will depend to a very large extent upon the design and operation of the auxiliary machinery. This is especially true in regard to the condensing plant, for besides maintaining the required vacuum with the maximum sea temperature, it is necessary that the difference between the temperature due to that vacuum and the temperature of the hot well should be as small as possible. This condition cannot be realised when we have a single pump dealing with the air, water and vapour; also with such a pump any increase in air leakage above the normal amount would necessitate the speeding up of the circulating pump. This would enable the air pump to maintain its vacuum at the expense of a lower hot well temperature. The Weir dual air pump is a most practical and efficient solution to this problem, and when used in conjunction with their Uniflux condenser it forms the most effective method of dealing with condensation. It consists essentially of a wet and a dry air pump arranged side by side and operated from the same steam cylinder, the dry air pump being driven by a beam and link, as this pump works under a very light load. There is a separate suction to each pump, both are, however, taken from a common connection on the condenser, but so arranged that the water will all flow into the wet pump, which works on the usual principle of the three-valve air pump. The dry air pump, however, departs somewhat from this principle as it takes in with the air and vapour a quantity of water from a cooler which forms part of the installation. This water seals the valves and condenses the vapours, thus increasing the air withdrawing capacity of the pump and allowing it to operate at a higher temperature than would otherwise be the case. The discharge of the dry air pump is delivered into the wet air pump at a point below the head valves, the discharge pressure being only 4 lbs. per square inch, which adds greatly to the efficiency of the pump.

Of the many advantages which accrue from the practice of heating the feed by means of the exhaust steam only two have any bearing on the economy: 1 The utilisation of the heat in the exhaust steam which would otherwise be wasted; 2 Better steaming of boilers owing to increased rate of heat transmission due to hot feed. The steam for heating is taken from the auxiliary engine exhausts, and is sometimes supplemented by a supply from the L.P. receiver. The type of heater most generally in use is that known as the direct contact, in which the feed water and heating steam mix freely in a common chamber. This assists de-aeration and has the additional advantage of simplicity. The temperature of the heater discharge is usually about 218°F., which necessitates the heater being placed in an elevated position in the engine room so as to create a pressure on the suction side of feed pump, thus preventing vaporisation. The economy to be obtained from this method of feed heating depends upon the source of the steam supply, as it is obviously less economical as the ratio

$$\frac{\text{steam from L.P. receiver}}{\text{,, \quad ,, \quad aux. exhaust}} \text{ gets greater.}$$

Much valuable information may be obtained by the judicious use of an indicator, and the careful analysis of the cards thus obtained. For instance we can at once detect a leaky valve or piston, also the effect of a missing packing piece between eccentric strap and rod. These, however, are abnormal conditions and need not be further considered.

To obtain the utmost information from a set of cards they should be reduced to a common scale and combined. The theoretical diagram can then be added when the various losses due to wiredrawing, clearance, condensation and inability to use high vacuum will be shown.

The cards can then be further analysed by transferring them to a temperature-entropy diagram when the expansion can be compared with the ideal adiabatic. The dryness fraction at any point can also be conveniently obtained, and the number of heat units used per lb. of steam will be represented by the area of the diagram thus transferred.

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PRIZE ESSAY.

Competition for Graduates (1913).

The Safety Devices required in a Modern Marine Boiler and Machinery Installation.

By "L.N.W.R." (Mr. Jas. Marsden, Graduate.)

The safety devices required on a modern marine installation of machinery are of two kinds, those which directly conduce to the safe working of the machinery, such as safety valves, relief valves, etc., and those which indirectly conduce towards the same end, such as non-return valves, filters, strainers, etc.

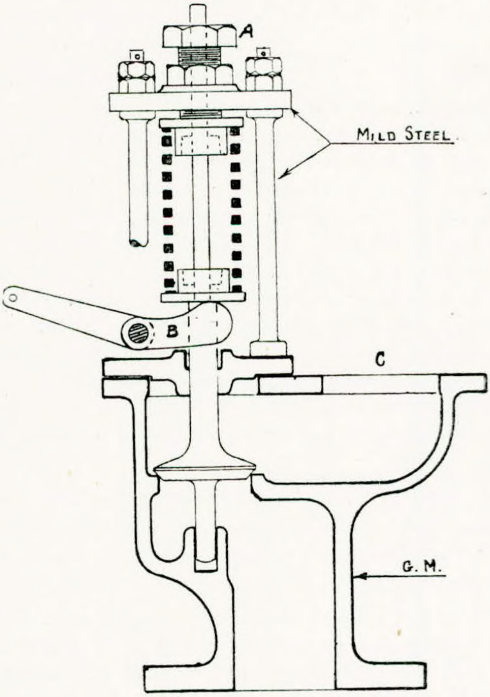

Fig. 1.

It is now common practice to have all valves, except very large ones, cast in gun metal or in brass instead of in cast iron or cast steel as was formerly the standard practice.

Commencing with the steam generators the safety valve (Fig. 1) is the outstanding safety device. The function of the safety valve is to allow steam to blow off to the atmosphere after a predetermined pressure has been reached in the boiler, thereby ensuring that no excessive pressure will be attained. For marine purposes all safety valves and relief valves are spring loaded, as shown in sketch, with an adjusting screw A by which means it is possible to produce the required load upon the valve. A lever B is fitted below the spring which is operated through the safety valve easing gear so that the valves may be opened when required.

Two valves are always placed in the valve body having a common outlet C. The area of the valves must be as near as possible equal to the area of the steam pipe leading from the boiler. The reason for fitting two valves in the valve body is to minimise the risk of the valves sticking.

Water gauges are fitted to each boiler at the normal water level with internal pipes, one leading well up into the steam space and one well into the water space. The water gauges show the water level in the boiler for 3″ or 4″ above or below its normal level. Two water gauges are fitted independent of each other to each boiler. These are made of transparent glass tube, sometimes enclosed in a glass casing. A cock is fitted to each gauge at its upper and lower end, so that should the inner glass tube burst it is possible to prevent steam and hot water escaping and also to admit of the gauges being cleaned from deposits. On small installations where 2 or 3 boilers are used the water gauges are run to the forward engine room bulkhead, and are thus under the constant supervision of the engineer.

The boiler stop valve (Fig. 2) fitted to each boiler at its highest point has to be so constructed that steam at a higher pressure than that in the boiler will not find its way into the boiler, as often happens when a battery of boilers have a common steam pipe.

The boiler stop valve is indirectly a safety device as it must prevent, without continuous attention, any steam entering the boiler. It will be seen from sketch that it resembles a check valve. Should the pressure over the valve exceed the boiler pressure it will shut immediately until the pressure in the boiler is sufficient to lift the valve. By means of the hand wheel it is possible to regulate the amount of lift of the valve; the valve spindle runs easily through the adjusting screw to enable inspection to be made when the boiler is out of use. These valves are now invariably made of bronze or copper alloys, but for large water-tube boilers of 7 to 12,000 H.P.

they are made of cast steel, with the valve, spindle, and seat in bronze, and are double beat valves. The bridge and columns are always made of mild steel.

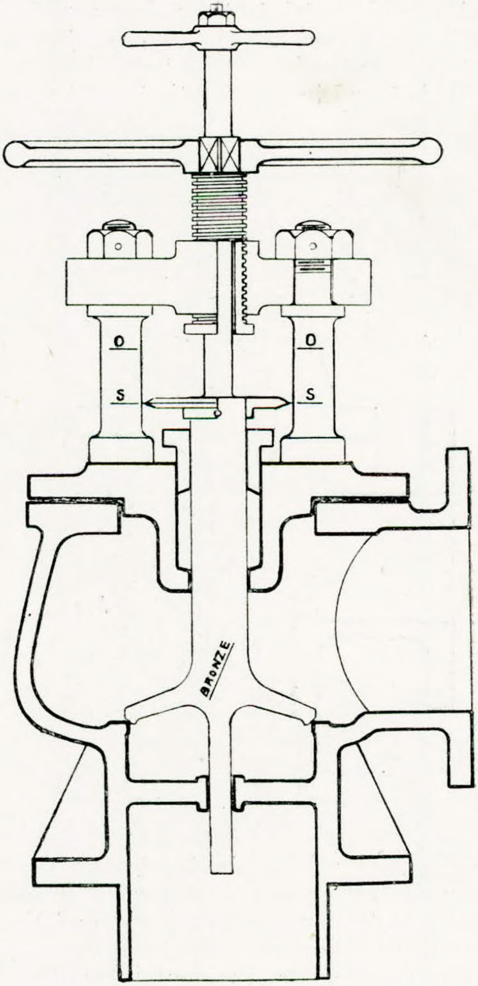

Fig. 2.

Scum valves are fitted to boilers at their normal water level, a spigot is cast on the boiler side of the scum valve which is an ordinary stop valve; to this spigot is attached a perforated internal pipe suspended at the normal water level and running the full length of the boiler. On raising steam this valve is open, and the scum discharged overboard or into the bilges. By ridding the boiler of this scum deposits are disposed of, which otherwise would get into the valves and piping.

The water level in the boilers is regulated through the check valves (Fig. 3); the lift of the valve is regulated by the hand wheel. It is found in practice that great wear takes place on the threads of the valve spindle, due to the hammering motion of the valve, it is now common to introduce a gunmetal cock between the boiler check valve and the feed water pipe, thereby enabling the feed supply to be regulated independently of the check valve, incidentally adding to the safe working of the former.

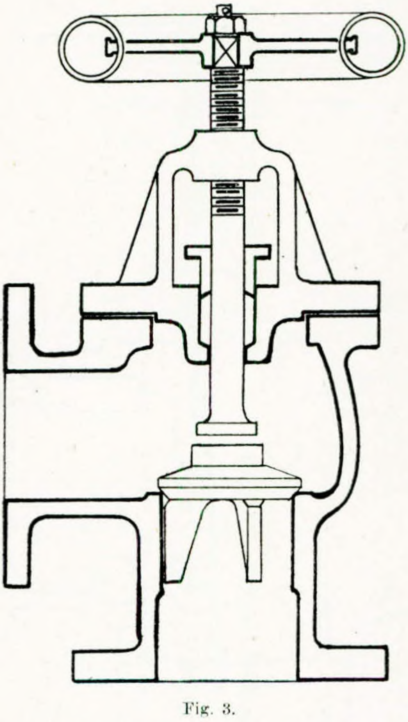

Fig. 3.

In modern machinery installations the engineers in charge of the engine room are responsible not only for the main engines but for the numerous auxiliaries which have come into use during the last decade, especially so in cases where the main engines are steam turbines, in which case the auxiliaries are all independent. On old installations the circulating pump, air pump, and feed pump were run off the main engines through levers connected to the cross heads; this practice has almost died out, and only the air pumps are run off the main engines, but even this practice is falling out and independent air pumps, feed pumps, and circulating pumps are frequent with reciprocating main engines, as is the case with steam turbine main engines. The safety devices found on reciprocating engines either for large or small powers are the spring-loaded relief valves, fitted to the top and bottom ends of each cylinder. These relief valves are set to blow-off at the pressure to which the cylinder has been tested. It is usual for the relief valves to blow off to the atmosphere at the cylinders, but sometimes a pipe is run from the relief valve to the bilges. The former is most popular as the engineer in charge can locate at once the source of trouble. Should the pressure in the cylinder exceed a predetermined quantity through water collecting either above or below the piston or through some other cause, the relief valve will blow off and give warning.

Drain cocks are also fitted to the upper and lower end of each cylinder, and to the lower end of the steam chests, to enable the water of condensation to be drained away.

The reciprocating main engines are controlled by at least two methods: (1) the reversing gear and (2) the main steam stop valve which is attached to the H.P. valve casing; should either of these methods fail the boiler stop valves may be closed, thereby preventing steam from reaching the main engines. With turbine main engines the controlling is dependent upon the manœvouring valves or main steam stop valves, one supplying steam to the ahead end and the other to the astern end of the turbine. In some turbine installations, valves are fitted into the nozzle chest controlling the steam entering the nozzles, in which case there are three distinct ways of controlling the supply of steam to the turbine, namely, the nozzle chest, the manœvouring valves and the boiler stop valves.

Where high pressure steam is used as in turbine installations some of the auxiliaries such as the circulating pump, fan engines, fire and bilge pumps, service pump, oil pumps for forced lubrication, and the dynamo engine are run at a lower pressure; about 100 lbs. per square inch may be taken as an average case. To obtain a constant and regular supply of steam at that pressure when perhaps the main engines are supplied with steam at 200 lbs. per square inch, a reducing valve (Fig. 4) is connected between the auxiliary and main steam pipes the former obtaining steam through the reducing valve

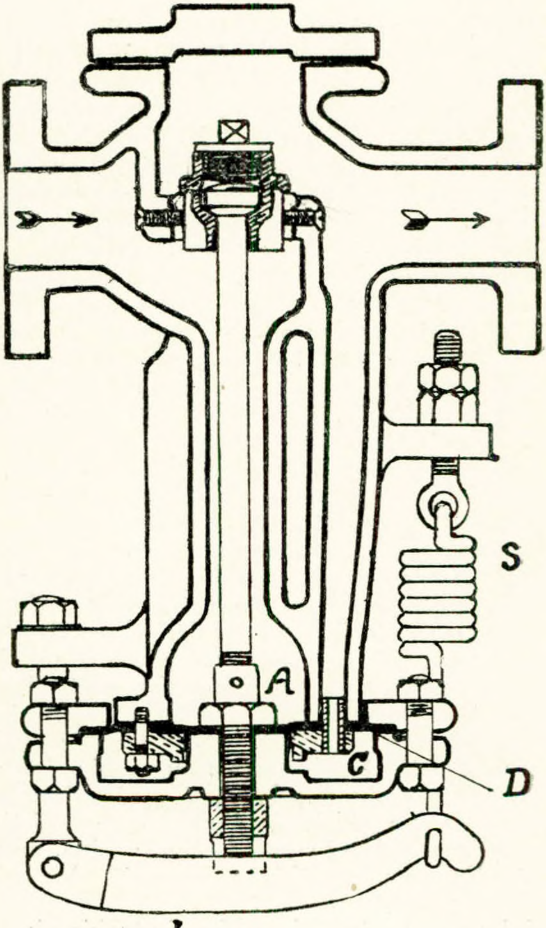

Fig. 4.

from the main steam pipe. The reducing valve in view is known as "Aulds Quitetite" reducing valve, and is to be found in most installations. Its action is as follows:—High pressure steam enters the valve body as shown and acts on the valve and on piston A which are of the same area and therefore in equilibrium on the H.P. side.

Reduced pressure is obtained by increasing the tension on the spring S. Acting through the lever L the tension of the spring opens the valve. When the pressure in the low pressure side tends to rise above that required, it closes the valve by acting on the back of the valve and in the chamber C. When the pressure falls, the tension of the spring overcomes the force holding the valve closed and opens it, allowing more steam into the low pressure side. A rubber diaphram D makes a steam tight packing between the stationary and movable lower part of the valve. This diaphram is protected from the harmful action of the steam by the water of condensation which collects at the bottom of the valve. A pointer fixed upon the spring bolt indicates the pressure on the L.P. side. A spring loaded safety valve is sometimes fitted to the top of the casing, otherwise a blank flange is fitted. The reducing valve is made totally of gun metal except for the spring, but on cheap jobs a cast iron body is used with gun metal valve, seating and spindle.

The exhaust from the main engines is delivered direct into the condenser; the auxiliaries, however, do not always exhaust directly into the condenser, in some instances the exhaust is bypassed to the evaporator, thence through a spring loaded valve into the condenser. Sometimes the exhaust of some of the auxiliaries, including the Weir pumps, is discharged into the L.P. cylinder valve casing through a spring-loaded valve, or if the main engines are turbines, into the turbine casing at a suitable point, also through spring-loaded valves, which are so constructed that they may be set to lift at any desired pressure by turning a hand wheel which increases the load upon the valve.

On the condenser a safety valve is fitted which blows off to the atmosphere in the engine room; it is invariably set to blow off at 30 lbs. per square inch so that should the pressure in the condenser exceed this quantity, through some unforeseen mishap to the air or circulating pump, it will give warning. The valve and body are usually in gun metal. A water gauge is sometimes fitted to the condenser, but this is not an actual necessity.

The Board of Trade require two sets of boiler feed pumps to be carried on board, each of which must be capable of supplying the boilers with enough water, so that should the one break down the other may be kept working; similarly with the oil pumps for forced lubrication. Where oil fuel is employed one steam pump is sufficient, provided there is on board a small hand pump for starting up from cold.

The air pump discharges the water into a feed water tank, from there the feed water passes through the feed filter, this is used to cleanse the water from oil and other impurities which get mixed with the steam in the reciprocating engines. The filter is a tank containing several slides of perforated steel or gun metal plates which are covered over with flannel. The slides are so placed that the water must pass through them on its way to the boiler feed pump, thus allowing the oil it contains to saturate the flannel, which may be cleaned or renewed. Another type of feed filter is a tank filled with sponges, the oil impinging upon these sponges, which are rinsed periodically. The feed water then goes to the feed pump and is discharged to the feed heater on its way to the boilers. A spring loaded relief valve is fitted to water side of the heater to prevent any excessive pressure accumulating in the heater through the generation of steam in it. The feed pumps are fitted with relief valves either embodied in the plunger or, as is most commonly done placed on the discharge side of the pump, or on the feed pipe itself, it is usual to keep this valve exposed, but in many cases it is allowed to blow off into the feed tank.

The feed water relief valve is generally set to blow off at about 25 lbs. per square inch above the normal boiler pressure. The necessity of fitting this valve on the delivery side of the feed pump is to prevent excessive pressures rising in the piping which may easily be caused by accidentally starting the pumps when all the check valves on the boilers are closed. The forced lubrication pumps have a similar relief valve arrangement for the same purpose.

Lately oil firing has been installed on several marine boilers; this innovation has entailed devices to ensure the safe and constant working of this new system. The commonest type at the present time both here and in the States is the solid pressure system as with the mixed pressure where a steam jet is employed to spray the oil out of the burners.

The latter system is more expensive as the steam employed to spray the fuel is lost and cannot be regained. In the former type the oil is kept at a constant pressure of about 200 lbs. per square inch, and sprayed through a sprayer on the burner. The oil is drawn into the pump through a strainer fitted on the suction side of the pump at the oil tank or piece tank. The strainer is a perforated steel plate having holes of $\frac{1}{2}''$ diam. so placed in a gun metal box that the oil must pass entirely through the strainer. On the discharge side of the pump a relief valve is fitted as in the boiler feed pumps, but discharging into the piece or oil tank. The oil is then passed through another strainer (Fig. 5), this strainer is placed between the pump and the fuel heater, and is employed as a further means of eliminating solid matter from the oil, which may choke the burners, thereby extinguishing them and causing excessive pressure to bear on the piping and pumps.

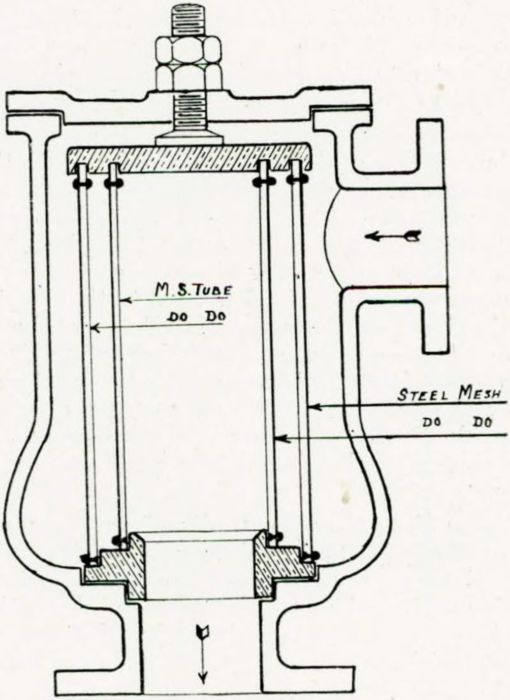

Fig. 5.

The strainer as shown in sketch is made up of two solid drawn steel tubes, an inner and an outer one. The inner one is perforated with small holes of about 3/16″ diam. and entirely covered with steel gauze of 1/32″ square mesh; the outer tube is perforated with $\frac{3}{8}$″ diam. holes and covered with gauze 1/16″ square mesh; a valve is placed on each flange so that the strainer may be put out of action for cleaning out purposes, two strainers are therefore placed side by side, each of which must be capable of filtering the full supply of oil. The oil on leaving the strainer is passed through the oil fuel heater which is heated with live steam. On the oil side of the heater a sentinel or relief valve is fitted which is merely a spring loaded valve discharging into the oil or piece tank; it is usually set to blow off at about 20 lbs. square inch above the highest pressure permissible on the oil fuel installation. The oil from the heater is led to the distribution box on the boiler. When starting up from cold a small hand pump is employed pumping the oil from the steam pump suction pipe to the discharge pipe, which goes in the usual way through the strainer and heater to the distribution box. On some marine boiler installations steam is raised from cold by coal fires.

The Bourdon pressure gauge is now universally employed in marine installations; its construction is too well known to require explanation. A pressure gauge is fitted on each boiler. In the engine room, pressure gauges are fixed on all the steam chests of the reciprocating main engines. A vacuum gauge which is identical to the pressure gauge is fixed to the condenser, a pressure gauge is also fitted to the auxiliary steam pipe. In turbine main engine installations the above are used; on the turbine a pressure gauge is fixed to the ahead and astern end nozzle chests and one gauge at a point in the ahead casing where the pressure ends and vacuum commences; this gauge is capable of reading either a pressure or a vacuum. The vacuum readings are always in red on all vacuum gauges in this country.

It is not possible within the limits of an essay such as this to deal with this important and very interesting subject very thoroughly. The writer has merely endeavoured to state to the best of his ability the underlying principle of the safe and regular working of modern machinery installations such as are commonly met with.

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PRIZE ESSAY.

(Open Competition 1912)

The Welding of Iron and Steel. Past and Present Methods.

BY "FLUX" (MR. ROBT. J. WALKER, Graduate).

IT is a far cry from the primitive smith's forge to the modern systems of welding with their mass of apparatus and complicated reactions. The engineer is not now content to be bound by the limitations of the coke fire and hammer, but has pressed into his service the most modern developments of chemical and physical science.

The oldest and still, with various modifications, by far the most widely practised method of welding iron and steel is briefly as follows:—The parts to be dealt with are placed in a coke fire, and by means of an air blast, produced by any means from the blacksmith's bellows to the latest high-speed motor-driven blower, are brought to a "welding heat."

The point at which this temperature is reached varies greatly and can only be determined after extensive experience. Malleable iron may be welded at a white heat, but for steel the temperature is considerably lower, as this metal, particularly the "high-carbon varieties, becomes "burned" and "rotten" if brought to anything like the welding heat of wrought iron. The purer and softer the iron the more heating it will stand and the better it will weld. When the proper heat has been attained the two pieces of metal are withdrawn from the fire, superimposed, and forged under the hammer into a solid piece.

The great obstacles to good welding are the skin of iron oxide, which forms on the surface of the metal when heated, and the mill scale. These prevent proper contact between the surfaces of the pieces to be joined, and if allowed to remain in the joint would result in a faulty weld. Wrought iron can be heated without injury to the temperature at which the oxide fuses, and as the oxide in this form can be forced out by the hammer in the course of the work it is possible to weld malleable iron without any flux. With steel some other method is necessary of reducing the oxide to a liquid form, and for this purpose a flux, generally sand or borax, is thrown on to the joint. Borax answers very well for steels which cannot be heated to a high temperature as it melts readily and dissolves the oxide, but sand is more generally used, the silica combining with the oxide to form a ferrous silicate, fusible at temperatures which are quite safe for most steels.

The striking expansion of the field for welding is nowhere more evident than in its application to iron and steel pipes. Welded steel pipes have many advantages over cast iron ones, the greater tensile strength and uniformity of thickness enabling them to be of very light construction, and iron pipes with steel flanges have, to a large extent, taken the place of copper for steam pipes. This is due not only to the greater tensile strength of the iron and lesser cost as compared with copper, but also to the fact that iron lap-welded is far more reliable than brazed copper. Welded seams in pipe work are greatly superior to lap-riveted ones as there is no edge of plate or projecting rivet heads to cause frictional losses and retard the velocity of flow, and there is also complete freedom from leakage; this cannot always be said of riveted joints. Welding also saves a considerable weight of metal and thus keeps down cost.

Where such work as boiler fire-boxes is concerned the superiority of welded over riveted seams is at once apparent, the welded joint giving a flue immune from leakage, of unbroken surface, and of uniform thickness, a point of great importance where plate joints are exposed to fire.

In the manufacture of furnace tubes two styles of welding are employed: These are

(1) *The lap weld.*

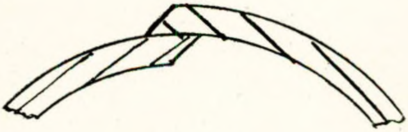

Fig. 1.

The edges to be welded are planed to an angle of 45° before the plate is rolled. After rolling, the planed edges come together as shown, the tube being rolled somewhat smaller than the finished diameter in order to ensure that the edges lap to the desired extent (about $\frac{3}{4}''$). These edges are kept apart while they are being heated in order to ensure through heating.

The tube in the vicinity of the seam is then brought to a welding heat by a gas or coke fire and air blast, and the weld made either by rolling longitudinally under hydraulic pressure or by closing the seam with steam or pneumatic hammer.

(2) *The glut weld.*

In this case the plate edges are so planed that when the tube is rolled into shape the seam assumes the form shown, the edges being about $1\frac{1}{2}''$ apart (Fig. 2).

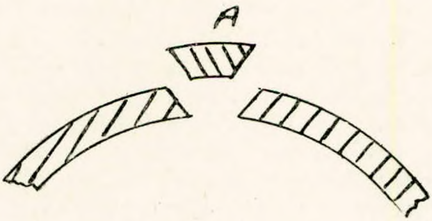

Fig. 2.

The seam is brought to welding heat as in the lap weld and a piece of Lowmoor iron as shown at A, is welded in under the hammer. This method is the more widely used of the two.

In both cases the heating may be done by coke-fire or by gas,—water gas, owing to its cheapness and cleanliness being very generally used, and giving excellent results.

After welding, the furnace is annealed and rolled to remove any strains and distortion produced by the local heating and pressure, and when cold all traces of the weld are removed by dressing with an electric or pneumatic grinder, thus making the tube absolutely uniform in thickness.

Fig. 3.

Small tubes, such as boiler tubes or steam pipes, are brought to a welding heat and the joint made by rolling at high speed on a cast iron mandril. This mandril is of the form shown in the sketch (Fig. 3) and is pushed through the tube from end to end as it revolves.

Oxy-Acetylene Welding.

This process is by far the most adaptable of all systems of welding. As its name implies, the heat required for welding is produced by the combustion of a mixture of oxygen and acetylene, the great heat value of the latter giving a most intense flame. The flame is blue in colour with a small white cone at its centre. The temperature at the apex of this cone is about 3,500°C and it is with this apex that welding is done. The proportions of the gases used are usually one volume of acetylene to one and a half volumes of oxygen.

The applications of oxy-acetylene welding are almost innumerable. In light wrought iron and steel work, such as that of the motor and cycle trades, fusion welding is greatly preferable to brazing. Its introduction has revolutionised the manufacture of steel drums, calorifiers, and tanks of every description; neat welded seams taking the place of riveted joints with a consequent great improvement in appearance and saving in weight, to say nothing of the fact that the edges of the seam are literally fused together and immunity from the leakage, which must be looked for occasionally in riveted seams is secured. A notable instance of this is furnished by the vapourisers of suction gas producers. Riveted seams in these are almost always unsatisfactory, leakage taking place after a few months of use, but if the bottom of the vapouriser is lapped over the shell plates as shown and the whole welded together no failure of the joints need be feared (Fig. 4).

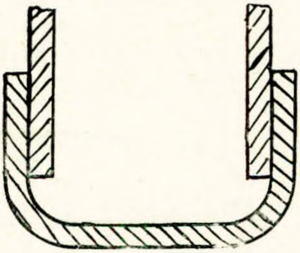

Fig. 4.

The jointing of iron and steel pipes which are exposed to great heat, such as those used in superheaters, is an important use which has been found for this method, but the application which has perhaps the greatest interest for the engineer is its use in connection with the repair of boilers and similar work. Wasted plate landings, cracked tube plates and furnaces, etc., may be efficiently repaired, the finished job being perfectly sound and the metal in no way damaged by burning or oxidation. In combustion chambers oxy-acetylene welding often saves the use of a riveted patch which might possibly be an eternal source of trouble, especially if at the level of the fire-bar line, and which has, perhaps, to be made in two or three pieces in order to pass through the furnace. If the boiler ever comes into the market such riveted patching seriously affects its value, but if the patch is welded in there is no trouble from leaks, burning of rivets, etc., and the repair is hardly noticeable.

Although this process is often spoken of in connection with repairs to steel forgings and castings it is not good practice to have welds in such steel parts subject to tension.

Oxy-acetylene welding can be carried out by two processes. These differ only in the method of supplying acetylene.

In the high pressure method the acteylene is supplied compressed into cylinders previously filled with porous substance soaked in acetone. In this form it is quite free from any risk of explosion, and consequently lends itself to ease of handling. Acetylene, compressed in the ordinary way to more than two atmospheres pressure, is readily exploded by any shock. Another feature of this process is that only absolutely pure gas can be compressed (or dissolved) in this way; a very important point where welding is concerned, as good results cannot be got if the acetylene is at all impure.

The chief advantage, however, which the high pressure system possesses over the low pressure is the great range of work for which it is suitable. A cylinder of dissolved acetylene (as the gas in this form is called) of 200 cubic feet capacity will yield 80 cubic feet per hour if necessary, and the cylinders are very much smaller and more portable than any acetylene generating plant made, far less one of this capacity. At the same time the yield can be controlled within narrow limits, and there is no waste of gas. This cannot be said for a generating plant unless it has large reservoir capacity and consequent loss of portability.

Although the high pressure plant is applicable to a much greater range of work than the low pressure, and is on the whole, less costly, when we take into consideration such factors as the gas which blows to waste from the generator, the time and trouble involved in cleaning and running the latter, and its efficiency in extracting the gas from the carbide (rarely more than 80 per cent.), the latter is much more widely used. It is, of course, the older process, but apart from this, it has the great advantage, as far as the acetylene is concerned, of being self contained, the gas being generated direct from the carbide of calcium.

A diagrammatic view of a low pressure welding plant, with the exception of the generator and its accessories, is shown in Fig. 5.

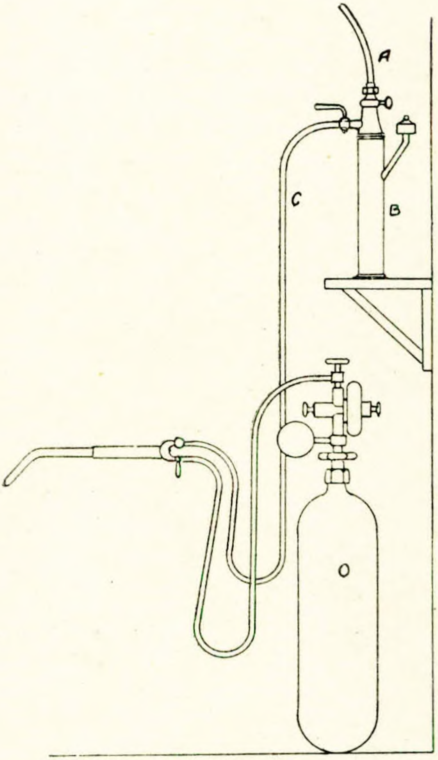

Fig. 5.

The acetylene from the generator, after having been washed and purified and thoroughly cooled in the process, passes through the tube "A" into the hydraulic back-pressure valve "B." The function of this valve is to prevent, by means of a water seal, any oxygen from entering the acetylene generator in the event of a wrong connection being made, the blowpipe choking, etc., and to render impossible the ignition of the gas in the generator when the flame back fires at the blowpipe.

When the gas is taken direct from the generator, as in the ordinary injector type of blowpipe, one of these valves must be fitted between each blowpipe and the source of supply, and as close to the blowpipe as possible.

From the back pressure valve the gas passes through pipe "C" to the blowpipe.

The oxygen supply is furnished by the cylinder "O." The gas as supplied by the manufacturers is at a much higher pressure than that required for welding, and a reducing valve in some form between cylinder and blowpipe is necessary. This valve is embodied, together with a pressure gauge and safety valve, in a neat and compact little apparatus known as a regulator, which is screwed on to the nozzle of the cylinder. The blowpipe is shown in the sketch and requires no description.

The cost of welding by this process is fairly high, but much depends on the skill of the operator, and in heavy work a considerable saving of gas and time (30 per cent. to 50 per cent.) can be effected if the joint can be preheated by coke fire or otherwise. The best Swedish iron is used in the welding of wrought iron and steel by this method, no flux being necessary.

For cast iron a special ferro-silicon compound is required. In all cases the joint should be thoroughly cleaned before work is commenced.

The chief disadvantage of oxy-acetylene welding is that quite a considerable area round the joint is heated in the course of operation, and that in repair work especially, effective annealling is practically impossible.

This defect is overcome in

Electric Welding. This process utilizes the heat of the electric arc, the most intense flame known for welding and cutting iron and steel. It is capable of applications similar to those possible with oxy-acetylene welding, but the heat is so concentrated that no part of the metal, except the actual weld, is affected.

This process is particularly useful for filling up blow-holes in steel castings. These blow-holes occur in spite of every precaution, and the loss consequent on scrapping large castings from this cause would assume serious proportions, hence the saving effected by having recourse to electric welding is very considerable.

When the holes are in such a position as not to affect the strength of the casting the practice of welding them up is quite legitimate, but the abuse of this method by welding parts subject to tensile stress is very dangerous.

These welds are similar to those effected by the oxy-acetylene process in that they are quite soft and are easily machined, and if the work is properly done no trace of the weld can be detected after machining.

Electric welding has been widely adopted for welding flanges, rings, etc., on to wrought iron and steel pipes, and is, for many purposes, much to be preferred to the usual methods of riveting or screwing and expanding. It is also used for making branch pieces in iron and steel pipes, many complicated arrangements of piping being easily dealt with.

A good example of the repairs which can be effected by this process is the welding of new teeth into broken gear wheels; the teeth have been found to be in all respects as strong as the original teeth.

The electric welder is economically used for joining tubes, bars, etc., end to end. In such cases the necessary heat is generated by passing a very heavy current of low voltage through the parts in the vicinity of the joint. The current used may be as much as 50,000 amps. at 1 to 5 volts, and is taken from a simple form of step-down transformer which forms part of the machine. The rods or tubes are forced together mechanically when the proper heat is reached; in joining wires and other small work springs are used to force the two parts together. The welding of chain links also comes within its scope, and machines are on the market which mechanically cut off and form chain links and make the joint electrically.

"*Thermit.*"—A very neat and simple method of welding, and for some purposes an extremely handy one is that known to engineers as the Goldschmidt process, and to chemists as "aluminothermy." This takes advantage of the fact that the combustion of powdered aluminium is accompanied by the liberation of enormous quantities of heat. It is used in the laboratory for obtaining metals by reduction of their oxides.

In practice the materials used are "Thermit," a mixture of iron oxide and finely pulverised aluminium in definite proportions, and a powder consisting of a mixture of barium peroxide and aluminium, the function of the powder being to start combustion.

The joint is first cleaned and surrounded by a clay mould. This is dried. The "Thermit" is placed in a crucible over the mould, the bottom of this crucible being provided with a removable plug. The powder is put in the middle of the "Thermit" and ignited by means of a red-hot iron, and as combustion takes place molten iron collects at the bottom of the crucible, the aluminium floating. When the "Thermit" is consumed the crucible is tapped and the molten metal allowed to run into the mould, thus making an almost perfect joint.

The process is purely chemical in its action, and requires no costly apparatus. Although it has not the same wide application as the other methods, and the mechanical strength of the weld is, as yet, a somewhat doubtful factor, it is admirably adapted for some purposes, particularly the bonding of the rails of electric tramway systems.

As the rails serve, to a large extent, as the negative main of the circuit, it is important that the contact between the lengths of rail shall be as electrically perfect as possible, the tensile strength of the joint being a secondary consideration, and the method described has certain advantages as regards cost and efficiency over bonding the rails together with copper bars, etc.

In conclusion these modern systems of welding can never hope to displace ordinary forge welding where this is applicable, the costs of working being much higher, but for the special purposes mentioned they stand unrivalled, and their introduction bears witness to the facility with which the engineer can adapt to his special requirements the discoveries of the laboratory, and undoubtedly marks a very appreciable advance in engineering science.

PRIZE ESSAY.

(Open Competition 1913).

The Welding of Iron and Steel. Past and Present Methods.

BY "MACHINATOR" (MR. THOMAS E. DODDS, Graduate).

WHETHER the Cyclops were acquainted with the process of welding as a part of their art in the fabrication of the thunderbolts of Jupiter, the shield of Pluto, and the trident of Neptune seems not to be recorded in the Greek mythology; nor are there any indications of such knowledge among the bas-reliefs of Egypt or Assyria; but the process is certainly several centuries old. The scoriæ discovered at West Bromwich and at other places in Staffordshire, and the bloom found at Corstopitum (Corbridge) show that the Romans were acquainted with iron smelting and the art of forging, and, perhaps, that of welding also.

Welding is the property possessed by metals which on cooling from the molten state pass through a plastic stage before becoming perfectly solid, of being joined together by the cohesion of the molecules that is induced by the application of an extraneous force, such as hammering. This property is exhibited in a marked degree by iron and platinum at a white heat. Welding may also be effected, though to a less degree, when two clean surfaces of a metal such as lead are brought into intimate contact in the cold. Gold, silver and copper in a state of minute division, as when precipitated, will cohere under the action of great pressure and form a solid mass. Copper medals have been struck by Ozam on this principle. Fournet obtained silver bars by this method, and worked them like bars resulting from fusion; he regarded these as examples of true welding, *i.e.*, union at a temperature below the fusing point.

Jordon, President of the Société des Ingénieurs, said that welding was a phenomenon exactly similar to the regelation of ice. But it is known that when snow is very dry and the temperature of the air below the freezing point, the snow flakes will not cohere, but that with snow during a thaw a compact snowball can easily be made. Jordan applied Sir W. Thomson's explanation of regelation to the cases of iron and platinum welding, maintaining that both phenomena are identical. But they are diametrically opposite: the welding of both iron and platinum being effected at a temperature considerably below their melting point, while the primary condition for the cohesion of two pieces of ice by regelation is that they shall be exposed to a temperature not below their melting point. A simpler explanation of welding is found in the junction of substances in the viscous or semi-fluid condition, such as pitch and wax: they cohere by an action similar to the transfusion or intermingling of two liquids. Other metals are not weldable, because the intermediate condition of plasticity is practically non-existent. At the welding temperature of iron the oxide is not viscous like metallic iron, and must therefore be rendered so by the addition of a flux, which forms a fusible silicate of iron and is extruded from the joint by pressure.

Welding may be described as the crystallising into union of two solid metallic surfaces when they are brought together under suitable conditions. That such is the case is proved by microscopic examination, for on polishing and etching sections of the welded metals the crystals along the junction are found to be common to each of the original pieces of metal. In perfect welding there is no visible joint, for the plane of junction is occupied by crystals, portions of which belong to one piece of metal, and portions of the same crystal to the other piece. When the boundary of the crystals are coincident with the juxtaposed plane surfaces it is evidence of non-welding; unless the crystals become common to the two pieces there is no welding.

The celebrated "coffin joint," effected by placing together the fractured ends of a broken bar and heating the junction to a red heat, out of contact of air, was undoubtedly the result of crystallisation, and in the general sense is an example of true welding. But in the above case the iron or steel crystallised or was welded at a temperature far below the so-called welding point.

The operation of hand welding proceeds in the following manner: the parts to be welded are carefully scarfed and fitted together; they are then brought to a welding heat, which for soft steel should be dark white; for hard steel bright yellow; and for iron scintillating white, and before removing the parts from the fire the welding powder is added; the work is then quickly removed from the fire and a superficial union is effected by light hammer blows. Welding powder is again scattered on the weld, and the work returned to the fire and heated nearly to the welding heat, after which complete union is effected by more vigorous hammer blows.

In the welding of bars the work is usually "upset," or in some way enlarged in size, so that after the junction the part of the bar in the vicinity of the weld is larger in section than the original bar; this part is then hammered continuously until the metal becomes dark red, thus breaking up the coarse crystals produced at the high temperature. With careful welding and mechanical working the finer structure of the material is restored so far as the metal immediately adjacent to the weld is concerned, but there is always a spot within 6″ or so of the weld which must necessarily have been overheated without subsequently receiving mechanical treatment, *i.e.*, hammer refining till the proper temperature was reached. This explains why most welded pieces break at a point not far from the junction and under a load much less than that required to break the natural bar; thus if a bar do not break at the weld it cannot be inferred that the weld is as strong as the natural bar. Tests performed by the Royal Prussian Testing Institute show that welded bars are far inferior to the natural pieces, both in strength and ductility; it was observed that coarse crystallisation adjacent to the weld was the cause of failure.

On the introduction of steel into structural engineering, great difficulty was experienced in welding steel to steel, and more so to wrought iron. This is due to the presence of the carbon in the steel; the more nearly equal the proportion of carbon in steels the more easily they are mutually weldable, for their melting points more nearly coincide, and at the welding heat the range of plasticity is about the same for such steels. If the previous conditions are not satisfied the hammer blow has different effects on the two pieces to be welded. Moreover, a difference in the rate of expansion between any two pieces of metal to be welded together is another unfavourable condition.

The union of iron to steel was accomplished many years ago by a process which bears the name of Arthur Wild. The process consisted in preparing an ingot mould of such shape and size as the united piece of iron and steel was intended to produce. The steel was fused, the wrought iron heated to the welding point, was put into the mould, and the fluid steel poured in. The ingot thus formed was afterwards hammered or rolled into shape. The practical difficulties attending this process are: that wrought iron oxidises rapidly in the air, and the superficial layer of oxide prevents perfect union; and that of the great difference in malleability of the two parts at the temperature proper for the safe working of steel. The process was little used owing to its success being doubtful. Hard and soft steel can be united in the same ingot by a method similar to, but much more practicable and useful than, the above; the latter process was complimented by the award of a medal to Blake and Parkin at the Great Exhibition of 1851. This method has been employed with success and advantage in the manufacture of large machine knives requiring a fine cutting edge of the best cast steel, with a back of softer, and without detriment to the utility of the article, cheaper material. In the manufacture of wood-cutting tools no difficulty is experienced in the welding of shear steel to iron.

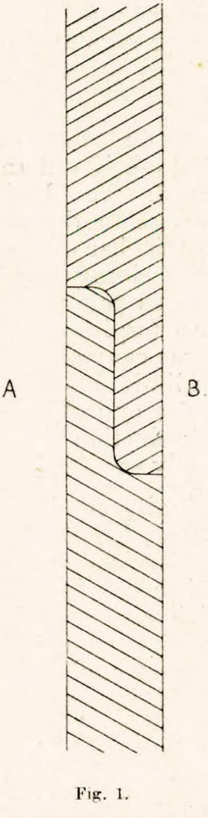

Fig. 1.

The welding of steel scrap was at one time considered impossible, but in 1878 a bar welded from steel scrap was exhibited by Kirk, of Glasgow, before the Institution of Naval

Architects; and in a paper read before the Iron and Steel Institute in 1879 is an account of successful welding, without a flux, of mild Bessemer steel for forgings, by Mr. Ratliffe at the Mersey Steel Works.

Mr. Bertram attempted to increase the efficiency of plate joints, and to economise on their cost by welding the plates together in situ instead of riveting them. The two adjacent plates were scarfed as shown, and gas flames were directed on each of the surfaces A and B until the joint attained a welding heat, after which it was united by pressure. The gas was produced by the ignition of coke or charcoal in a closed portable chamber, the supply being regulated by means of a blast. In actual practice the process proved costly and was soon discarded.

Mr. Mallet, in his work on "Construction of Artillery," was rather pessemistic when he believed that the maximum size of forgings had been attained. This limit was due to the failure of ability to heat the mass to the welding temperature: the conduction of heat along the bar caused the time required for a large mass to reach the welding heat to be so long, that the outer portions of the heated part were melted and dropped off in the furnace, and for a forging of a certain size the mass of the material thus lost was equivalent to the slab to be added. He found the maximum limit of forging with the then existing tools to be a diameter (of a cylindrical mass) of about 4ft. and 20ft. long. But the introduction of electric welding permitted the above limit to be easily exceeded.

The welding flux generally employed in the smithy is sand, on account of its cheapness; but it should be used as sparingly as possible, for disadvantageous effects, due to its use, appear in the forged article if it has to be machined: the surface presents flinty patches which very soon deprive the tool of its cutting edge. Borax, prussiate of potash, and salammoniac are also used as fluxes. A neat application of a flux was devised about 1895, and consisted in employing fine soft iron wire gauze, the meshes of which were filled with fused borax. Pieces of this welding plate were placed between the metal to be welded and thus presented the flux at the precise spot where it was needed. Under certain conditions the use of a flux is not absolutely necessary: many articles, such as tyres for railways and boiler tubes are welded without a flux; yet only a small percentage of them fails at the weld.

The presence of metalloids lowers the point at which steel is "burned." When steel is overheated it crumbles under the hammer; and if the steel is not capable of remaining united to itself, it is not probable that it will easily unite to another piece of steel or iron. A small quantity of manganese aids welding, for although it decreases the mobility at any particular temperature, it allows a higher heat to be put upon the metal without the creation of destructive crystallisation, and thus indirectly renders possible a greater mobility and maintains a more favourable internal molecular structure. Vanadium serves as a scavenger in getting rid of oxygen and decreases segregation; vanadium steel welds readily.

The process of welding forms an integral part of the manufacture of many machine tools. Three-ply plates consisting of an inner one of wrought iron and two outer ones of chrome steel are used for ploughshares; five-ply plates comprising a wrought iron plate in the middle, two chrome steel plates on its outside, and two wrought iron plates on the outside of these latter are used for burglar proof safes; it is impossible to drill through or break them. These plates are raised to a welding

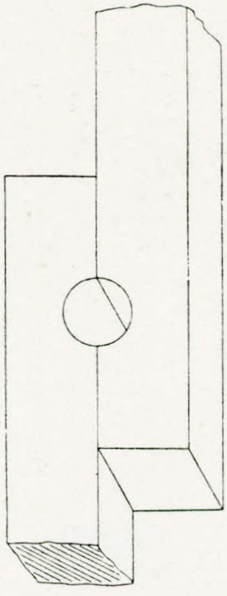

Fig. 2.

temperature and then rolled into a composite mass. Tubes are formed from strips of metal, bent into circular section by being drawn through dies; the longitudinal joint is made either by a lap or butt-weld, and is performed in a special machine. Spirally-welded tubes have been introduced to overcome the weakness due to a continuous longitudinal seam: the original Armstrong guns were made on this principle.

The following are tests employed for the welding qualities of steel:—

1. Two bars 1″ square are welded together and while hot a $\frac{3}{4}$″ hole is punched as shown, and afterwards expanded by means of taper drifts to $2\frac{1}{2}$″ diameter. The sample should show no signs of opening at the weld, and the edges of the expanded portion should be free from cracks and perfectly smooth.

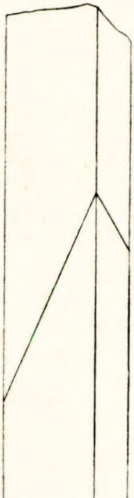

Fig. 3.

2. The bars are scarfed and welded as shown, and while hot, bent backwards and forwards five or six times without showing signs of opening.

3. This is known as the ram's-horn test. The bar is raised to a welding temperature and hammered on the anvil till it is about $\frac{1}{8}''$ thick and has come to a dull redness; a cut is made down the centre of the plated-out portion, it is reheated, and the two pieces, A and B, bent backwards as shown: the edges should be smooth and free from cracks.

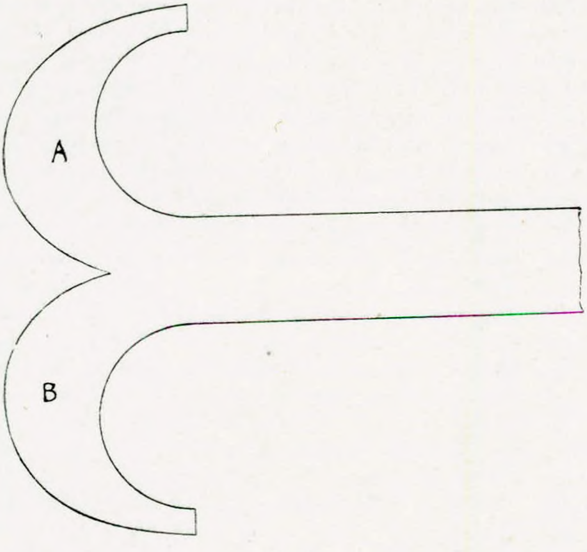

Fig. 4.

In heating the work in the old process to the necessary temperature for a good weld, much more iron is heated than that involved in the actual weld, and moreover, the heating being performed in furnaces, only a small percentage of the heat of the furnace is really applied to the iron; to reduce this loss various methods have been devised.

There are two principal electric processes by which this is accomplished. In that devised by Prof. Elihu Thomson, current of high density and low voltage is made to flow across the two surfaces to be welded. The resistance at the surface junction is high compared with other portions of the circuit; and due to the high current a rapid evolution of heat occurs, which in turn increases the resistance of the junction as an effect of the rise of temperature and thus accelerates and intensifies the heating, which remains local. As the temperature rises and the metal softens, the two pieces are pressed together by either a screw and hand-wheel or a system of levers until the weld is complete. The joint is finally finished in the usual way under the hammer. The magnitude of the current to weld two round iron rods 1″ in diameter is estimated at 5,000 amperes; rods double this diameter require 20,000 amperes. A great saving of time is also effected: the former weld requires the current for only twenty seconds; the latter for eighty seconds. The heavy current density is produced either by a low voltage high current dynamo (in this case the work is placed near the dynamo, to eliminate the loss of energy in long leads) or by the use of a step-down transformer on a high voltage circuit, a choking coil being employed as a means of regulation. The pieces to be welded are gripped in two large copper clamps so that the contact resistance shall be as small as possible; the mechanical pressure is also transmitted through the clamps.

The other process, known after its inventor, Bernardo, employs the heat of an electric arc. The metals to be welded are connected to the negative main, the positive main is connected to a movable carbon held in the hand of the operator in a suitable holder: a convenient form of holder is shown in the figure. The conductor passes through a non-conducting handle A, in front of which is a sheet-iron protecting screen B: at the other end the carbon is held in a metallic clamp, to which the conductor is connected. A powerful arc is struck by touching the carbon on the surface of the work, after which the carbon is directed over the surface of the materials to be welded; and the temperature very rapidly attains the welding or fusing point.

Two carbons are employed in the Voltex process, and the arc is struck between them. The carbons are also impregnated with small quantities of oxide of iron, which are reduced to the metallic form and vaporised by the action of the arc: this prevents the carbonisation of the work. The last method is suitable only for small work. In all work with long electric arcs the hands and face must be protected from the light or burning of the skin will result. The eyes must also be protected by almost opaque glasses, for serious injury is produced by the ultra violet rays.

Electric welding is suitable for rails, chains, wire-fencing, rings, steel tubes, wheel rims, etc. Probably on account of the extremely local heating of the welded joint an electrical weld is not so tough and reliable as a good hand weld.

Goldschmidt utilised the heat evolved during the chemical reaction of a mixture of coarsely powdered aluminium and magnetic oxide of iron ($Fe_3 O_4$) to raise the temperature of the masses of metal to that required for welding. This is known as the Thermit process and has been employed to overcome the difficulty of joints on electrified railways: the sections of the rails being welded together and forming one continuous line. The line then affords a low resistance return for the current. Electric welding has been employed for the same purpose and somewhat extensively tried, particularly in America, but since no provision is made for changes of temperature along the line the metal is subjected to strains of such magnitude that they cause distortion and sometimes rupture.

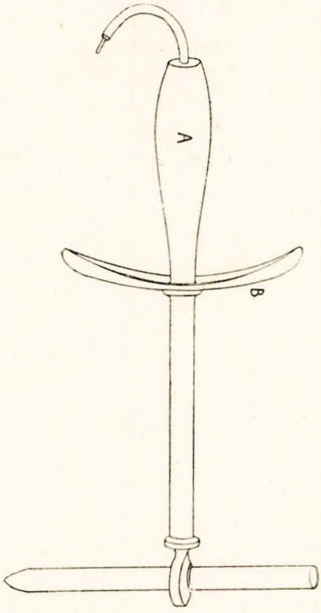

Fig. 5.

The method being extensively used at present is that of oxy-acetylene welding, a form of autogenous soldering. The very high temperature (nearly 3,000 deg. Cent.) is obtained by the dissociation of the endothermic gas acetylene ($C_2 H_2$) and the subsequent combustion of the products with oxygen; the final products are carbon dioxide and water vapour.

This process requires careful manipulation; and for satisfactory results the operators must be specially trained. The flame must always be properly regulated: excess of acetylene produces a reduced flame, which tends to carbonise the metal; excess of oxygen will burn the work. Sufficient gas must always be available to complete a weld, for the performance of the weld in parts detracts from the strength of the joint. The welding should be performed at the outer extremity of the small white cone at the blow-pipe tip. The parts to be welded must be carefully prepared, and for all classes of work of thickness greater than $\frac{1}{8}''$ the joint at the weld must be chamfered off at an angle of 45°, to enable the flame to come in direct contact with the whole of the surfaces to be united. Special iron wire is used for building up welds in iron or steel plates. The workmen are first instructed in welding thin sections of plate; and as they acquire manipulative skill the thickness of the sections is gradually increased. Smoked goggles are worn, to protect the eyesight of the operators against the intense brightness of the flame.

The welding of cast iron by this method requires special treatment. After the fracture has been grooved out to a V shape, or in the case of a new piece being inserted, all batting edges chamferred, the casting is heated in a muffle furnace or over a coke fire; when hot it is withdrawn, and the usual welding process applied: a special cast iron rod is used as the filling-in metal, and a flux is frequently necessary. When the operation is lengthy the casting is reheated. A satisfactory weld free from blow holes is obtained by rubbing the rod well into the fracture during the process. Finally the casting is replaced in the furnace heated to dull redness, and afterwards allowed to cool very slowly, either by closing up the furnace or burying the casting under dry sand: this process in a great measure restores the crystalline structure of the metal to homogenity, and consequently increases the strength of the joint.

Fig. 6 is a sectional diagram of the plant for generating the acetylene. The plant consists of a generator, condenser, washer and gasometer. The generator consists of a cylindrical chamber, the upper portion containing the carbide magazine and automatic feed mechanism; the lower portion containing the generating water. The carbide magazine is charged through the door K, the lower opening being covered by a bucket wheel A, which may be rotated through the axle provided from the exterior of the generator, where a ratchet device is provided and means for operating the same by the rise

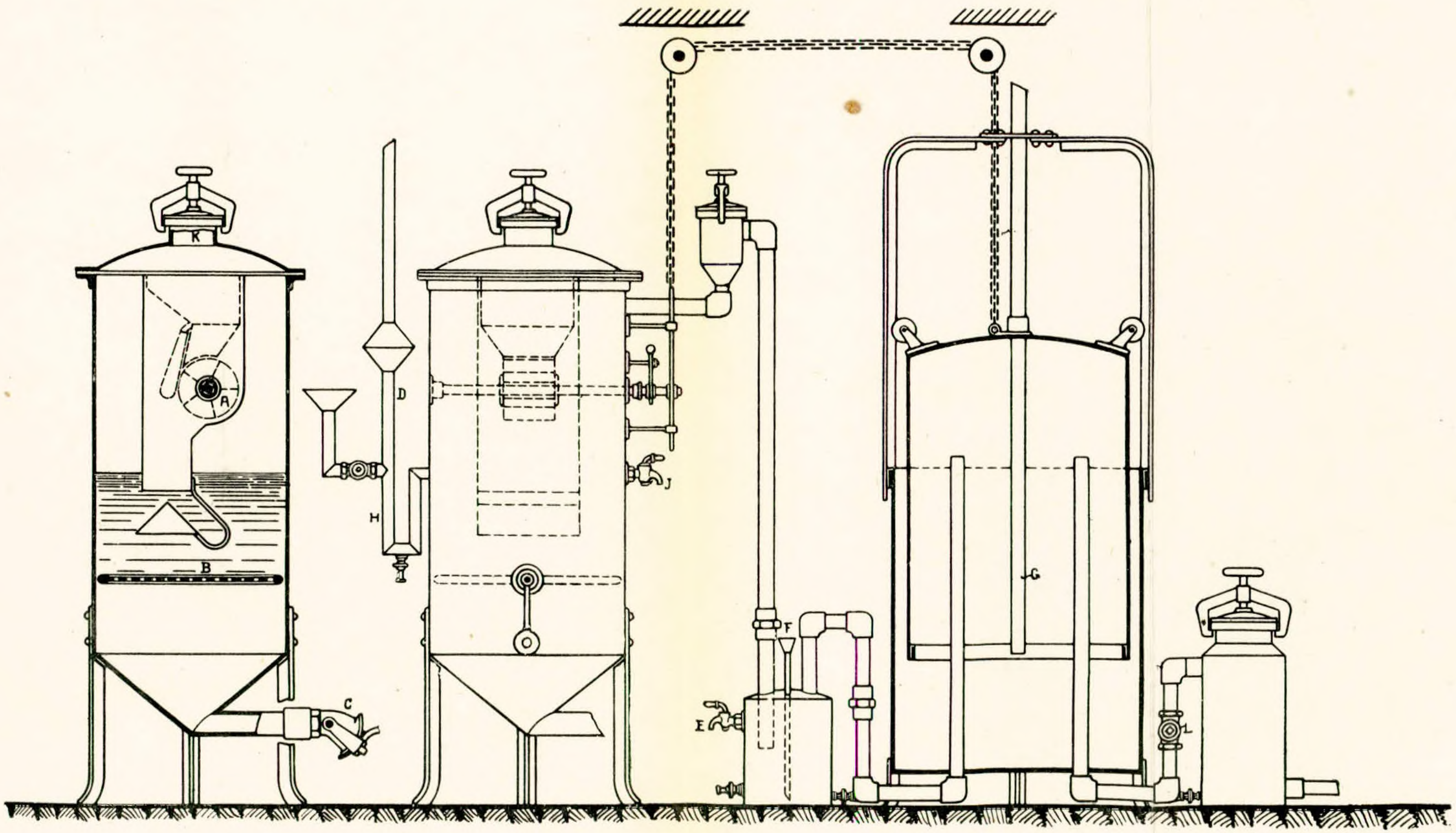

Fig. 6.

and fall of the gasometer bell. The rotatable grid B is provided to carry carbide during the process of decomposition in free water and clear of the lime-mud which deposits in the conical bottom of the generator, and may be drawn off through the sludge cock C. The safety vent pipe D and water seal H. provide a means of relief in case of overpressure of gas in the generator. In this event the water contained in the seal H is displaced into the double cone chamber, and the surplus gas escapes into the air. In normal working these circumstances do not occur. The gas is led from the generator to the condenser, provided to intercept humidity, more prevalent with some qualities of carbide than with others, thence to the washer, provided to absorb the ammonia, and also to prevent the gas returning from the gasometer to the generator. The gas then flows into the gasometer, consisting of a tank to contain the seal water, and the bell to contain and store the gas. The pipe G is a safety vent permitting gas to escape to outside air in case of over production. The chain operating the automatic mechanism is attached to the crown of the bell, and is carried over pulleys attached to the ceiling or to a crossbeam. As the bell sinks and when nearly empty, it operates the automatic mechanism which rotates the bucket wheel through one-fifth of a revolution, thereby releasing a measured quantity of carbide from the magazine to the water contained in the generator; and the gas thus generated re-fills the bell. No further production of gas is possible until the bell again falls to the point at which the automatic mechanism is operated. From the gasometer the gas passes to the purifier, which is charged with a chemical preparation having an affinity for sulphurous and phosphoric impurities; the gas is then delivered to the shop mains. The absence of impurities in the gas employed for welding purposes is of paramount importance for the production of maximum strength of the joints.

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SESSION 1913-14.

President: THOMAS L. DEVITT, Esq.

"Titanic" Engineering Staff Memorial.

*This Fund now amounts to £2,566 5s. 0d., the interest of which will form the nucleus of a benevolent fund, to which donations are invited yearly for the purpose of assisting the widows and orphans of members of the Engineering Staff who may be left unprovided for, and by whom help is required in respect to placing children in an orphanage or otherwise.—J.A.

The full list of steamers from which subscriptions have been received to date, is given below.

- Abangarez
- Afghanistan
- Alert
- Amarapoora
- Anglian
- Anhui
- Arabia
- Arabistan
- Arawa
- Argu
- Armanistan
- Ascot
- Atenas
- Ava
- Ayrshire
- Bahadur
- Bankura
- Barala
- Bargora
- Baroda
- Baron Garioch
- Barrow
- Beacon Grange
- Beckenham
- Bellona
- Beltana
- Berbera
- Beryl
- Bhamo
- Blackheath
- Blackrock
- Borderer
- Buteshire
- Cadillac
- Cairngorm
- Caledonia
- Cambria
- Camio
- Canadian Government Steamers:
  - Aberdeen
  - Curlew
  - Druid
  - Earl Grey
  - Governor Cobb
  - Lansdowne
  - Lady Laurier
  - Montcalm
  - Stanley
- Caradoc
- Carpentaria
- Cartago
- Castor
- Ceiba
- Centipede
- Cervona
- Ceylon

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* £300 having been used towards the erection of a Memorial at Southampton. A Memorial will also be placed in the premises of the Institute.

Champion
Chanda
Changsha
Chihli
China
Chindwin
Chinhua
Chinkiang
Chiswick
Chupra
Chyebassa
City of Corinth
City of Edinburgh
City of Poona
City of Vienna
Cobra
Colaba
Colonia
Commonwealth
Cornelian
Crane
Culna
Cumbria
Dargai
Delaware
Demosthenes
Devon
Devona
Durham
Eden Hall
Emerald
Empire
Envoy
Epsom
Essex
Estrellano
Euphrosyne
Excelsior
Falls of Monero
Fatshan
Fengtien
Fingal
Fooshing
Frankmere
Fremona
Garesfield
Geelong
G.E.R. Steamers
Gibel Dersa
Gibel Kebra
Gibel Tavik
Gibel Zedid
Girasol
Glenlogan
Glenroy
Golconda
Gordonia
Guelph
Gwendolen
Haiyang
Hampstead
Hangchow
Henzada
Heredia
Heungshan
H.M.S. Amethyst
H.M.S. Bacchante
H.M.S. Bellerophon
H.M.S. Black Prince
H.M.S. Canopus
H.M.S. Dartmouth
H.M.S. Defence
H.M.S. Derwent
H.M.S. Electra
H.M.S. Fervent
H.M.S. Garry
H.M.S. Gloucester
H.M.S. Implacable
H.M.S. Kestrel
H.M.S. Lightning
H.M.S. Majestic
H.M.S. Ness
H.M.S. Rattlesnake
H.M.S. Recruit
H.M.S. Renard
H.M.S. Ringdove
H.M.S. Sphinx
H.M.S. Torch
H.M.S. Zebra
H.M.T.B.D. Brazen
H.M.T.B.D. Coquette
H.M.T.B.D. Cynthia
H.M.T.B.D. Porcupine
H.M.T.B.D. Vulture
H.M.T.B.D. Zephyr
H.M.T. Boats Nos. 071, 079, 3, 6, 7, 8, 9, 10, 11, 12, 17, 18, 19, 20, 23, 30, 112, 113, 114, 115
Highland Brae
Highland Pride
Highland Warrior
Himalaya
Hindu
Henley
Hoihow
Hoisang
Honam
Horlington
Hsin Pekin
Huichow
Hunan
Hupeh
Hurona
Hurunui
Hydra
Ichang
Ilford
Inanda
India
Ingeli
Inkosi
Insizwa
Intaba

Iona
Irene
Iroquois
Irrawaddy
Islanda
Jacona
Jaffa
Jelunga
Joseph Vaccaro
Kadett
Kaifong
Kaikoura
Kaipara
Karamea
Karanja
Kariba
Karma
Karonga
Karuma
Katuna
Khartoum
Kia Ora
Kian
Kinling
Kinshan
Kioto
Kistna
Kola
Kueichow
Kumara
Kurrachee
Kutsang
Kyanite
Lady McCallum
Lake Erie
Lake Michigan
Laura
Leversons
Lewisham
Lhassa
Liangchow
Linan
Lindula
Linga
Lintan
Lord Cromer
Luen Yi
Lunka
Mackinaw
Magnet
Makarini
Malda
Maloja
Malta
Mamari
Mandalay
Manitou
Mantua
Marmora
Martaban
Massapequa
Matatua
Matiana
Mazagon
Media
Mermaid
Milleped
Miltiades
Milwaukee
Mimiro
Min
Minneapolis
Minnehaha
Minnewaska
Moldavia
Mombassa
Monmouth
Montcalm
Montezuma
Montfort
Montreal
Montrose
Mooltan
Morayshire
Morion
Mount Royal
Mount Temple
Muttra
Namur
Nanning
Narragansett
Nephrite
Ngan Kin
Nile
Ningpo
Nore
Norfolk
Nubia
Nyanza
Nyasaland
Omrah
Opawa
Ophia
Orama
Orari
Orontes
Orvieto
Osterley
Otaki
Otranto
Ottawa
Otway
Pakeha
Palamcotta
Palawan
Palermo
Palma
Parisima
Patrol
Pera
Persia
Perthshire
Peshawur
Plasma
Plassy
Ploussa

Poona
Poyang
Prase
Prince Rupert
Prometheus
Pundua
Purnea
Putiala
Pyrope
Queda
Rakaia
Rangatira
Ready
Recorder
Remuera
Rhesus
Rio Squassa
Rosina
Rotorua
Royal Edward
Royal Scot
Ruby
Sagenite
Sanui
Sard
Sardinia
Satellite
Seistan
Seldanha
Sentinel
Servian
Shantung
Shasi
Shenandoah
Shropshire
Shuntien
Siangtan
Sicilian
Simla
Singan
Siren
Socotra
Somali
Soudan
Star of Scotland
St. Albans
Stella
Sumatra
Sunda
Sungkiang
Sui-An
Sui-Tai
Suwanee
Swarka
Szechuan
Tainui
Taiyuan
Talavera
Taming
Tamsui
Tean
Tenasserim
Themistocles
Thongwa
Tongariro
Triton
Trocas
Tung-ting
Twickenham
Ula
Umballa
Umta
Umtali
Usworth
Vadala
Vestal
Volute
Wai Shing
Waimana
Waimate
Waipara
Waiwera
Wallaroo
Walter Dammayer
Warden
Warwickshire
Willesden
Wiltshire
Wing How
Winlaton
Woodford
Yoro
Zaida

INSTITUTE OF MARINE ENGINEERS.

The following were elected at a meeting of Council held Thursday, 9th October, 1913:—

As Members.

Charles W. Bowen, 13, Hyde Gardens, Eastbourne.
Mark Browne, Engineers' Association, Singapore.
Alexr. Cloudsley, Asst. Fleet Engineer, I.F.C., Dalla Dockyard, Rangoon.
B. Kverndal, 72, Jerningham Road, New Cross, S.E.
E. S. Northcote, 30, Ashley Place, London, S.W.
Henry Pegler, 67, Chichester Road, North End, Portsmouth.
Harold Puffett, 4, Emmanuel Road, Balham, S.W.
Joseph S. Ryan, Chief Mechanical Engineer, Mana Dry Docks and Engineering Works, Montevideo, Uruguay, S.A.
C. Sorabji, Engineer, *c/o* Doobash Wadi, Tardeo, Bombay.
Geo. H. Taylor, Consulting Engineer, 9-11, Fenchurch Avenue, London, E.C.
William C. White, Stonebridge, Clones, Co. Monaghan.
Ernest T. Williams, "Ailsa Craig," Aberystwyth.

As Graduate.

Oswald E. Richardson, 40, Pitfield Street, London, N.

Transferred from Associate Member to Member.

H. Sutherns, "Gresford," James St., Llanelly.
Alexander Fallon, Silverton, nr. Exeter, Devon.

Transferred from Associate to Member.

Arthur E. Rowe, Sudan Govt. Steamers, Khartoum.

Institute of Marine Engineers

(Founded 1888   Incorporated 1889)

Foundation Stone Ceremony

29th October, 1913

Photographs showing
Laying of the Foundation Stone
of the New Premises, Tower Hill, London, E.C.
by the
Lord Mayor of London
(Sir David Burnett, Bart.)
who attended in State
accompanied by
the Sheriffs

(Photos—Marine Engineer & Naval Architect).

Foundation Stone Ceremony

October 29th
1913

◆

Reception Committee

Chairman of Council
Mr. Joseph Hallett

Hon. Secretary
Mr. James Adamson

Chairman of City Premises Committee
Mr. R. Leslie, R.N.R.

Vice-Presidents
Mr. A. Boyle
Mr. J. T. Milton
and
Mr. J. H. Rosenthal