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# "Boiler and other Repairs by Electric Welding"

(ILLUSTRATED BY LANTERN SLIDES),


BY MR. R. S. KENNEDY (Member of Council),


READ

*Tuesday, March* 12, *at* 6 *p.m.*

CHAIRMAN: MR. JAS. SHANKS (Member of Council).

The CHAIRMAN: We are met to-night to hear a paper of great interest and importance to all Marine Engineers. The author is well known to the majority of us as an expert on the subject of "Boiler and other Repairs by Electric Welding." I have much pleasure in calling upon Mr. Kennedy to read his paper.

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IT is hardly necessary to remind an audience of engineers that welding is one of the oldest branches of the working of metals. In some respects it is a lost art, as there are good grounds to believe that the ancients were able to weld some of the bronze alloys.

In the following remarks the author proposes to confine himself to the welding of iron and steel, unless otherwise stated. A weld is the intimate union of two pieces of metal, produced when the pieces have been raised to welding heat, by pressure or hammering, and the welding state of a metal only exists within a limited range of temperature, being something like 100° for iron and steel but varies with the metal. As a rule, good iron will stand a higher temperature than steel, although certain steels, such as blistered or good shear, will stand a high temperature. In the smith's fire steel can, and should be, forged with a lighter tool than iron, the blows being in rapid succession. In the ideal weld the two surfaces to be united are brought to the plastic heat together, neither at too high or too low a temperature, when the point of juncture should be as strong relative to its section as any other portion. From the foregoing remarks, however, it will be appreciated that much depends upon the skill and experience of the operator, and it is recognised in ordinary engineering practice that an allowance has to be made for inevitable human frailties.

The first process of electric arc welding to be employed in a commercial sense was that of De Bernardos, which was used in Messrs. Lloyd and Lloyd's Works, over twenty years ago, in the welding of flanges and branches to iron and steel pipes. In the De Bernardos process a carbon is employed, an arc being drawn between the carbon and the job, a portion of which is brought to welding heat, and the added metal is heated in the flame of the arc. In the early Bernardos process the work was made the negative pole and the carbon the positive, but latterly the poles were reversed, thus doing away with the dangers of carbonisation of the metal caused by the natural flow of carbon particles from the positive to the negative. The Bernardos process is still largely employed in this country.

Slavianoff substituted a metal electrode for the carbon electrode of the Bernardos process, although Bernardos as far back as 1885 had the idea of using a hollow carbon filled with the adding metal. In fact, there is very little that Bernardos does not seem to have anticipated, his difficulty being that, like many other great inventors, he was in advance of the means and appliances of his time.

The names of many investigators and workers in our own and other countries during the eighties and nineties of last century could be honourably mentioned, each doing their little bit to advance what is practically a new trade. Among them Charles Lewis Coffin, of Detroit, U.S.A.; Mark Wesley Dewey, of New York, U.S.A.; Pommee, of Altona, nr. Hamburg; W. P. Thompson, of Liverpool; Thos. Odlum, of Virginia, U.S.A.; Francis Todd, of Newcastle-on-Tyne; Joseph Fouilloud, of Paris, etc.

You will remember that we have already referred in the Bernardos process to the arrangement of the poles of the electric arc. Now it is generally agreed that the province of the engineer is to utilise the forces and methods of nature for the benefit of mankind, and nature in this case has provided that the positive pole of the electric arc shall be much hotter than the negative pole. We consequently arrange in electric arc welding that the positive pole shall be on the bigger mass, which in 999 cases out of 1,000 is the job, and the negative pole on the smaller mass of metal, which in modern electric arc welding is the metallic pencil of the adding material. By working with nature we thus provide favourable conditions for the first essential of a good weld, namely, that the pieces to be united shall be brought to a welding heat at the same time. You will note that we have only provided favourable conditions; the actual carrying out of this requirement rests with the skill of the operator.

This consideration of the difference in temperature of the two poles of the electric arc makes it at once apparent why direct current is more suitable than alternating for arc welding. On the other hand, alternating current is quite suitable, and probably better than direct current for what is known as resistance welding or for spot welding.

The writer's Company were the first to employ the metallic electrode in this country on a commercial scale—namely, early in 1910, although about a year previously Mr. Copeman, of the Furness Lines, had carried out a few experimental jobs to his own vessels. Since 1910 the annual output of the British Arc Welding Company has increased at least 100 times, and during the present war its services have been utilised in directions which would not have been permitted under peace conditions. In making this statement, however, the writer wishes to acknowledge assistance received from kindly and constructive criticism from the Board of Trade and Lloyd's Register in pre-war days, but everything has now been speeded up. In particular, the tests of electric welded specimens carried out to the instructions of the Board of Trade in 1909 and 1910 were of great value.

These tests were made not only with the object of getting at the tensile strength of the weld, but of finding out if the process of welding affected the neighbouring material. Numbers of specimens were tested, and some of these were annealed, but it was found that annealing made no difference to the results, and the material immediately adjacent to the weld behaved in a normal manner. These tests gave a tensile strength of about 17 to 18 tons per sq. inch, but since then improvements in the materials and methods have increased the tensile strength of welds in boiler steel to about 27 tons per sq. inch. In practice, however, the writer would not recommend that a tensile strength of more than 20 tons per sq. inch be worked to, this giving a sufficient margin for possible small defects in workmanship. It might here be remarked that in no single case has the writer known an electric weld to give way suddenly; failure has always been preceded by a small crack, which has gradually developed.

Electric arc welding is primarily a form of autogenous welding—that is to say, that the metals to be united are heated to such a temperature that they will fuse together on contact without the application of external pressure. It is, however, found in practice that the application of even the moderate amount of pressure produced by a hand hammer increases the tensile strength and tenacity of the weld from 5 to 10 per cent.

It is, however, essential that this work should be put into the material when it is at welding heat or, at any rate, above the black heat. It may here be remarked that it is often said that the value of metal added in this fashion is analogous to the ball of iron obtained in the puddling furnace. This, however, is not the case, and the better results are probably due to the fact that the iron wire used is of the very best material, with preferably a small percentage of manganese. This iron wire has been very heavily worked in the process of manufacture, and subsequently annealed, and as used by the writer's firm shows a tensile strength of 28 tons with an elongation of 50 per cent. Somewhat similar results are obtained in another field with cast iron, which has several times been remelted. The whole question of the amount of work put into the material of a weld is very fascinating, and there is no doubt that the capacity of a weld for taking up rapidly alternating strains for a long period, and for absorbing sudden shocks, very much depends upon this factor.

## BOILER AND OTHER REPAIRS BY ELECTRIC WELDING.

Returning to our blacksmith, whether under the spreading chestnut tree or in the more prosaic conditions of the modern smithy, we find that they all employ some kind of flux, usually sand or borax. This flux surrounds the heated iron or steel and protects it against the impurities of the fuel, removing at the same time the coating of scales. Some impure wrought irons flux themselves, but with steel other mixtures are used. The flux, as its name indicates, also increases the fluidity of the heated metal.

In electric arc welding with a metallic electrode one great advantage is that, with the exception of the atmosphere, we have no impurities to guard against, except such as are introduced in the materials. The source of heat is pure, and we have to see that the job is properly cleaned and the metallic electrode of suitable material.

Still, to provide against oxidisation and also to increase the fluidity of the metal a flux is necessary to good work in arc welding, and the heated metal is protected from oxidisation by an inert gas given off by the flux. The most convenient method of applying the flux is to coat evenly the metallic electrode, thus providing a constant and uniform supply.

Electric arc welding is a process of building up, and consists of adding metal to an existing structure. For this type of welding the electric arc has one great advantage in its high temperature. This is the highest known, and thus by the application of a small number of calories a part of the job, say about $\frac{1}{2}$ in. diameter, is almost instantaneously raised to welding heat, and the drop of adding metal from the pencil, also at welding heat is united to it, and the process of building up is continued till the required section is reached. The small quantity of heat required does not cause any undue expansion of the job in hand, and contraction troubles are reduced to a minimum. It is quite a common practice to weld over a riveted seam, although in this case it is necessary that rivets in the area dealt with should be completely welded over, and not left half covered. After welding a seam it is necessary to caulk the landing edge for some 6 ins. at each end of welded portion. Cracks in furnaces, end plates, combustion chambers, etc., are dealt with by cutting out the defective portion, leaving a V-shaped opening, which is filled in with the welding material. Work can be carried out directly overhead, or in any position that is accessible to the welding pencil, and where the operator can see what he is doing. As the work is one requiring constant attention on the part of the operator, it is advisable, in order to get the best job, to make it as accessible as possible, and that the operator should be reasonably comfortable.

Most of those present here to-night have no doubt had experience of arc welding, and will understand that, in common with all hand welding, a good job depends on the conscientious work of the man. The writer's firm have always trained their own welders, and keep them in constant employment. A full report is made of each job, and the name of the welder recorded, and the whole object of the training is to inculcate a sense of responsibility.

The materials at present dealt with on a commercial scale are wrought iron and steel and cast steel, and occasionally cast iron. The range of temperature of the welding heat is the determining factor in the adaptability of a substance for welding. Much successful work has been done with cast iron, notably with castings of considerable age, which have not been subjected to corrosive action, and with the good mixtures of more modern times. It is probable that there is a welding temperature of cast iron, but the range of this temperature is very small, something of the nature of 10°.

The voltage across the metallic arc is about 22 to 25, and the writer adds an equal steadying resistance, which makes the voltage at the terminals of the dynamo about 45. A substitutional resistance is employed which is put in circuit by an automatic switch, when the welder breaks his arc, thus keeping the load on the machine constant. The amperes actually employed are about 175, but in practice a 200 ampere machine is necessary, while the writer's firm use machines designed for 250 amperes. In the big passenger liners it is the practice to weld from the ship's dynamo, suitable welding and substitutional resistances being provided.

By a special winding of the dynamo, known as separate excitation, the machine can be steadied under varying loads, but even in this case the writer still prefers to retain the substitutional resistances in addition.

The design of the portable machinery for generating electricity presents many interesting problems. Plant is designed to meet the varying conditions, and consists of wagons generating their own electricity, portable petrol driven generating sets, self-propelled or dumb barges with steam-driven or paraffin sets, steam turbine plants, and last, but not least, the motor generator sets.

This last plant is of great service in a port like London, where the docks are well served with electric power mains at a constant voltage. The design of the dynamo is a matter for the electrical engineer, but the conditions of working are trying, and it is advisable to have ample commutator surface and good ventilation, as in urgent marine repairs it is possible that a machine may be asked to run almost continuously for two or three weeks.

The preparation of a job for electric welding is a matter of considerable importance, as the presence of impurities is likely to be detrimental to the weld. In dealing with the external or fire surfaces of a boiler it is usually sufficient to use an ordinary chipping hammer, and then thoroughly wire-brush the metal to be dealt with; but some superintending engineers prefer to have a light chipping taken over the surface, which is, of course, the ideal preparation. In marine work, however, the time available is often so short that as a general rule the former method is adopted. When, however, it comes to dealing with the water surfaces of a boiler greater care is necessary, especially if zinc plates have been freely used. The welder, if a properly trained man, would at once recognise this difficulty and apply the only remedy, which is to chip down till pure metal is reached.

Arc welding being a building up process, cracks are dealt with by veeing out at the line of fracture, the vee being made wide enough to ensure that the welder can reach with his pencil to the bottom on either side with a certainty of striking his arc at any required position. As the welder is a highly skilled man, it is usual for the boilermakers to prepare the work to instructions, and the welder himself puts in the finishing touches. The welding in of new backs to combustion chambers or tube plates, or work of that kind is dealt with in precisely similar manner, although here certain allowances have to be made for the work drawing together as the welder proceeds. It should be mentioned that in dealing with cracks it is absolutely essential that the whole of the fractured portion be cut away, and a very good guide is to cut away till a solid chipping is obtained, and then go a bit deeper to be on the safe side. If welding is carried out over a partially cut away fracture it is certain that sooner or later it will work to the surface.

One of the most unsatisfactory matters we have to deal with is the welding of a crack in the original weld of a furnace, as it is most difficult to say where the defective weld ends, and a further defective portion some short distance along may work back into the part dealt with.

As in all engineering matters, it is better to know the worst and deal with it. The writer recalls an incident in our early days—about 1910—when we were called in to weld a crack, apparently about one inch long, in the back of a combustion chamber of a Swedish vessel. Our man started to cut out the crack when with a loud report the chamber back split right across, shewing a fracture a full sixteenth open. This caused great alarm at first, and we were charged with using undue vigour ,but on veeing out the fracture for welding it was found that the back was grooved right across on the water side, so we were exonerated. It is a merciful dispensation of Providence that such defects develop mainly when the boiler is cold or under banked fires, and it is generally recognised that a boiler is never safer than when warmed up and steaming steadily. Owing to its higher temperature the electric arc is more suitable for dealing with the heavier sections than the oxy-acetylene or oxy-coal gas, while, on the other hand, for thicknesses of $\frac{3}{16}$ in. and under one or other of the gas systems is preferable.

The writer has been asked to summarise as briefly as possible the conclusions reached in the very able papers recently read by Commander E. P. Jessop and Naval Constructor H. G. Knox, both of the U. S. Navy. The full report of these papers has been largely circulated on this side by our leading technical journals, and has no doubt been seen by most of you. The principal welding consisted of the repairing of the cylinders of some eighteen German vessels, where large pieces had been broken from the upper portions. The method of repair consisted of the welding in by the electric arc or oxy-acetylene gas of a new piece in cast steel or cast iron to replace the portion broken away. In arc welding the old and useful device of tapping short steel studs into the cast iron was used to enable the added steel (in this case) to make a surer weld. The electric arc welding repairs were carried out with the cylinders in place, while with the oxy-acetylene process it was necessary to remove the cylinders so that the joints for welding could be laid in a horizontal position, and also that the cylinders could be heated. Commander Jessop quite truly points out that the great difficulty found in the arc welding of the cast iron surface was to get the first layer of the adding steel material to adhere, and that this layer was always added before the patch was put in position for welding. In the oxy-acetylene jobs, as before remarked, the cylinders were secured in place, and, the joints being horizontal, both sides of the joint were made fluid, and cast iron sticks melted into the bath thus formed. . Both methods appear to have given excellent results, and the repairs are certainly the largest of their nature that have yet been carried out, and reflect the greatest credit on all concerned. It would not be wise, however, to generalise on the treatment of cast iron from these results. You will remember that we have before remarked that with good mixtures of cast iron one can with fair certainty make a good weld. It must be remembered that these were high class vessels, and that in all probability the very best metal would be used in their cylinders and liners, and certainly in superheater jobs the H.P. cylinders and liners would be of a very special mixture, which so far as the writer's knowledge is concerned has only been made in this country during the last five or six years. The writer trusts that we may hear further on this point, but his present information is that these vessels were superheater jobs.

The writer claims that arc welding, where carried out by skilled operators with suitable materials, is absolutely reliable, and can point to some 20,000 jobs, some of a very big nature, while the percentage of even partial failures would, at any rate, be on the right side of the decimal point. These partial failures would be mainly accounted for where the work was carried out under unfavourable conditions, and often in the nature of a forlorn hope. Great difficulties are met with in hurried repairs to the lower portions of the hulls of vessels in dry dock, where water is constantly dripping from the leaky portion, and owing to the cement inside it is often impossible to stop it in the time available. It must, however, be remembered that metal added by the heat of the electric arc or other methods has not been subjected to the same amount of work as a rolled steel plate or forging. It is, therefore, not so well adapted to take up work suddenly applied, and one would not recommend it for a position of responsibility where such conditions arise. This, however, is a condition generally recognised by engineers with all welds.

The question of the resistance of welds to rapidly alternating stresses and shocks is somewhat obscure. Some year or two ago the writer's firm were asked to weld the broken piston rod of a 10 cwt. steam hammer, which had already been twice welded in the fire. This was carried out, and is now running satisfactorily.

It is not permitted at the present time to refer specially to work carried out, but outside of the boiler repairs, repairs to hulls include the welding of broken stern frames, "A" frames for twin screws and the welding in of a new piece of stem is quite an everyday occurrence.

Boiler repairs are of infinite variety, and include the welding up of cracks to any extent, the welding in of new plates, thickening up of corroded surfaces, and building up of landing edges and defective rivets. Leaky stays and tubes have been welded in position with excellent results, and in cases of trouble with stays with loose washers it is excellent practice to build up from the solid plate to form the washer, which can then be faced off with a special tool.

Before proceeding to show the few slides which it has been found possible to prepare in these strenuous times, the writer wishes to refer to a few gentlemen who have been of great assistance in the development of arc welding in this country early in 1910.

The superintendent engineer of Messrs. Geo. Thompson & Co., had carried out the first electric welding repair of any size, being the welding up of a number of cracks in the Purves furnaces of the SS. *Moravian*. This was closely followed up with large repairs to the circumferential seams of the boilers of the Port of London Authority's Hoppers Nos. 3 and 4. One of our Vice-Presidents was early in the field, and it was due to his insistence that resistance plant was designed to weld from the ordinary electric lighting sets of the larger vessels. Generally, however, it was found that the process supplied a long-felt want, and the writer's task consisted mainly in seeing that none but fully trained welders were allowed to undertake any welding repairs. The writer's father, Mr. John Kennedy, and his Hamburg colleague, Mr. Bartlett, were the prime movers in introducing the process of the metallic electrode to this country, and the former was our tower of strength when in the early days it was necessary to overdraw at the bank, while Mr. Halket and Mr. Thom were indefatigable in assisting and advising in early experiments.

We will now proceed to consider the few slides that it has been possible to have made:—

(1.) This shows the first motor wagon plant used for electric arc welding, and is of considerable interest. The chassis was originally built by J. and E. Hall, of Dartford, to W. A. Steven's patents as a petrol electric motor-'bus, and was the forerunner of the present Tilling-Steven's petrol electric motor-'buses. This machine ran experimentally between Roehampton and Brighton, but was bought by the writer's Company, and the electrical equipment converted to arc welding purposes, still retaining the electric road drive. The same principle was adopted by the War Office for portable searchlights. It will be noted that this chassis is driven by two motors, which engage the driving wheels through a worm drive; in the later machines the drive is from one electric motor, which drives a cardan shaft, and ordinary differential gear to the driving wheels. When the machine arrives at the job the current is switched from the road drive to the welding circuit, so that the same engine and dynamo answer both purposes.

* (2.) In January, 1912, this repair was carried out to one of the Canadian Pacific liners in Liverpool. The first slide shews the defective portion of the flanging of the front end plate cut out ready for welding. The second slide shews the completed repairs.

* (3) In May, 1912, this repair was carried out to one of the Atlantic Transport liners at Tilbury. Two tube plates were thus dealt with, and in a number of other furnaces smaller portions were cut out and new pieces welded in. This repair was the most difficult that had been up to this time attempted, as it was necessary to weld the new lower half to the existing half tube plate perforated with holes for the tubes. It was, however, satisfactorily carried out, and has never given any trouble. It may be of interest to mention that nine tube plates have just been similarly dealt with at Cardiff for the same owners.

(4.) This slide shews what is now quite an ordinary job carried out to a small cargo vessel in January, 1912. It consisted of welding in a new lower half to the front end of the furnace, the size of the new plate being 2 ft. 6 in. by 1 ft.

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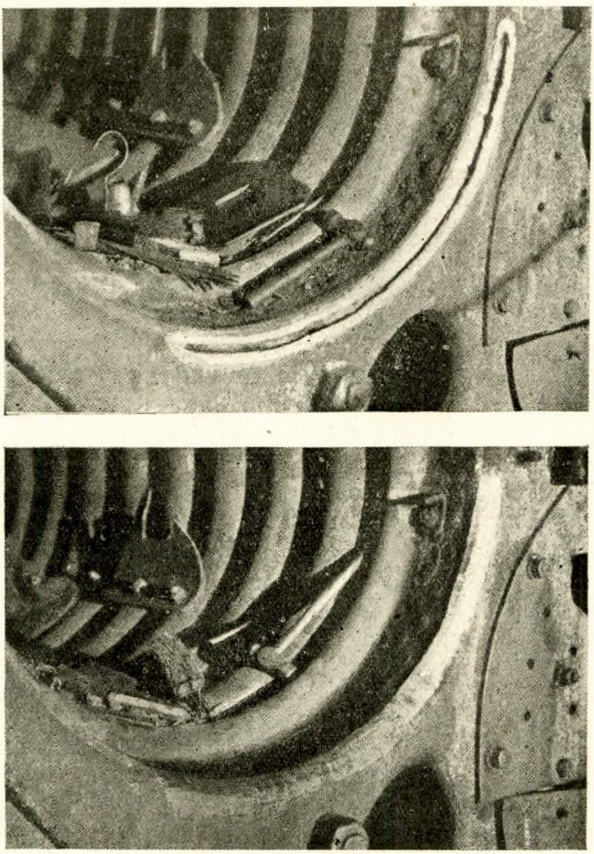
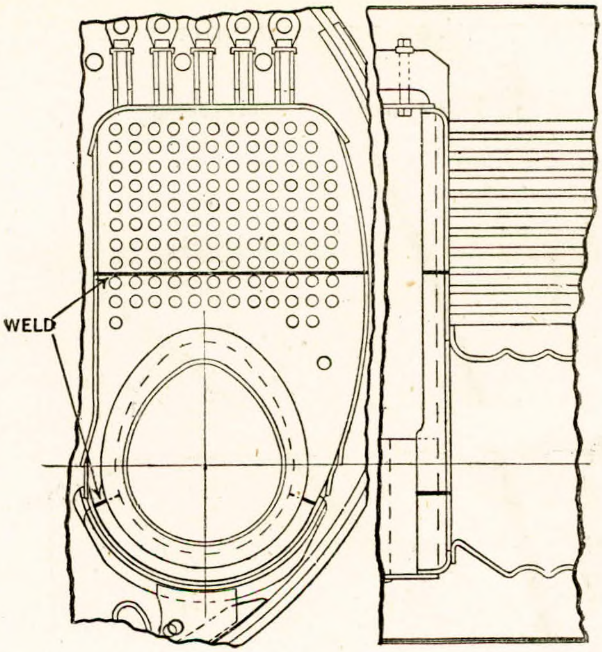
* Blocks for the reproduction of these, also of the other illustrations have been kindly lent by *The Marine Engineer and Naval Architect.*



2.
Upper Illustration—Before Welding.
Lower Illustration—After Welding.




3.

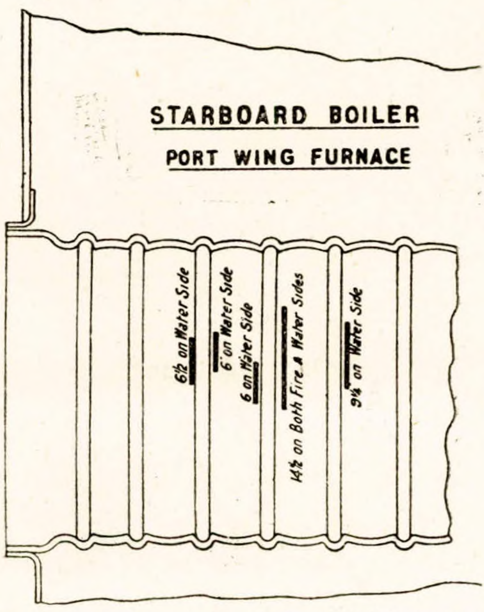
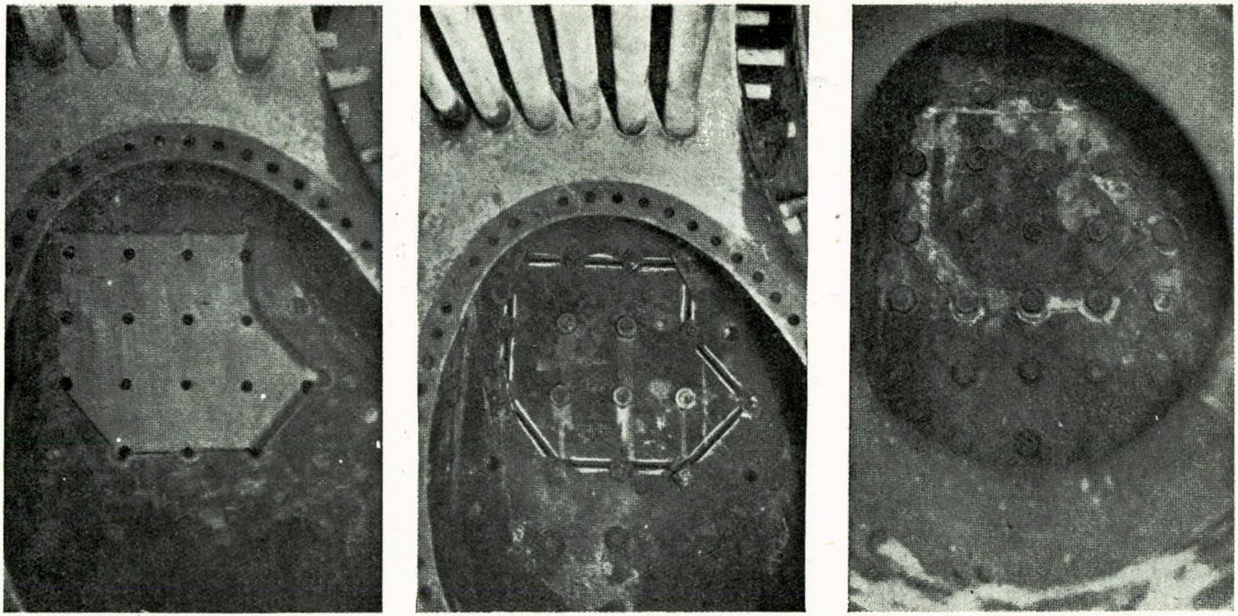



Illustration of furnace showing a repair carried out by building up wasted portions as indicated by the black lines.



A. B. C.

A.—Defective portion of Combustion Chamber, back cut away. B.—New portion of Plate shown in position for welding. C.—The work of welding completed.

(5.) This slide illustrates a common method of repair in case of collision damage. A new piece of stem about 16 ft. long was welded in place to the lower portion, thus saving the removal of entire stem to fore foot and lower plates in way of same, also considerable dry dock rent.

(6.) This slide shews the defective portions of the combustion chamber and tube plate, which were cut out from two chambers in a marine boiler on the Tyne, the new portions being welded in position where plates had been cut.

Other slides were shown, including one of a recent visit of His Majesty to a welding job in the East India Docks.

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The CHAIRMAN: I am sure you have all enjoyed the paper, which is bubbling over with interest and debatable matter. The meeting is now open for discussion and members or any gentlemen present are invited to express their views without loss of time.

Mr. R. J. McLEOD: I must congratulate Mr. Kennedy on the lucid and able paper he has been good enough to read us this evening. As he has confined himself to arc-welding, I would like to add a few words on another form of electric welding which is referred to in the paper as "resistance" or "spot" welding; these remarks being intended to be supplementary to the paper. Resistance welding or otherwise the "Thomson process" is a form of electric welding particularly adapted for manufacturing repetition parts in large quantities, the principle being that by passing an electric current of such voltage and amperage through the parts to be welded, that the resistance to the flow of the current produces sufficient heat so that when the parts are pressed together fusion takes place, or in other words they are welded. The process is carried out by means of welding machines, these machines being designed to have suitable mechanical contrivances and motions to suit the particular job for which they are intended. Alternating current of single phase is preferably used and transformed down to a low potential of about 1 to 2 volts; for this reason the transformer must be placed on the machine close to the work and an easy path given for the current to pass to the ends of the electrodes without loss of potential. I have here a number of samples illustrative of machine welding; the first is a steel diaphragm for a patent steam trap; it is joined from two corrugated discs, with studs welded in the centre of each and afterwards the two discs are welded together in what is known as a "seam welder," that is a welding machine with two rotary electrodes which revolve and carry the work along, welding the seam at the same time. The second sample is the same as the first, except the diaphragm in this case has been charged with spirit, sealed and thrown into the fire so as to test the weld; you will notice the diaphragm has expanded into almost a sphere with all the corrugations stretched out entirely, yet the welds remain perfect. My next sample is a piece of 28-w.g. sheet mild steel, seam welded; I may here say that the machines upon which these samples were welded are supplied with single phase alternating current of 200 volts and 50 periods, and this particular seam took 25 amperes, which, taking the potential as 2 volts at the electrodes equals a current strength at the weld of $\frac{200 \times 25}{2} =$ 2,500 amperes. Another sample here illustrates "spot welding" and two further samples are comparatively high carbon spring steel which you will notice does not weld, but has fused and burnt in places; the last sample is a piece of $12\frac{1}{2}$ per cent. nickel silver, which although stuck together has not welded, proving that alloys are generally unsuitable for welding. This remark applies to high carbon (above 1·4 per cent.), chromium. nickel and other alloyed steels. While machine welding as described may not be of immediate importance to marine engineers, it is of increasing importance in the manufacturing world. For instance, it is now the practice to make light iron and steel chains, up to 1″ dia. I believe and over, on automatic welding machines, bars being fed in at one end are bent, threaded, cut and welded into complete successive links; again the bulk of the hollow ware now made, such as kettles, etc., are all electrically welded, as also are paint drums, steel barrels, etc., and I see no reason why the light steel work on shipboard could not be machine welded. Ship ventilators for example could be produced considerably cheaper in this way and be a stronger job. Machine welding is quite distinct to arc-welding, and of course unsuitable for repair work such as described in the paper. It has, however, a very wide scope of application and can be depended upon to produce good work. I will not attempt any criticism of Mr. Kennedy's paper as it can easily be recognised he has both the knowledge and experience of the expert, and any comment I could make on arc-welding would fall short of his standard.

Mr. B. P. Fielden: There is one paragraph in the paper which I would like to have explained by Mr. Kennedy. He states that "When, however, it comes to dealing with the water surfaces of a boiler greater care is necessary especially if zinc plates have been freely used." I should like to know what is the effect of zinc plates on the surfaces as far as welding is concerned. Mr. Kennedy has mentioned a case dealt with where nine tube plates were partly renewed. The ship referred to was built by foreigners and the design of the boilers was very bad, and as there was heavy leakage big renewals had to be carried out. The diameter of the furnaces was larger than the holes in the front end plates, and therefore, to get the furnaces out, it would have been necessary to remove the lower portion of the front end plate and also the back end flange of the furnace was carried up on the combustion chamber side of the tube plate so that the lower portion of the combustion chambers would have had to be released to allow the furnace to drop to clear the tube plate. The furnaces in a fore and aft direction were very rigid, and it was thought that the rigidity was the cause of the cracks in the furnaces where they were flanged up into the back ends, so instead of simply renewing the furnaces and repeating bad design it was arranged that the furnaces should be burnt out in small enough pieces to pass through the end plate holes, that new furnaces of smaller diameter should be fitted so that they would pass through the end plate holes and have the Gourlay back end connection, and that part new tube plates should be fitted so that the furnace flange would be inside the boiler. The tube plates were therefore cut between the tube holes and new lower parts were fitted and electrically welded to the remaining portions. I mention this case to show what can now be done in the matter of repairs which some years ago would have cost very much more. We have an advantage over our predecessors in being able to use the welding process, and we ought to feel grateful to the patentees because we can often save extensive renewals by a small repair by welding.

Mr. S. G. Martlew: Of autogenous welding applied to many jobs, I have had practical experience, and have found that, given suitable material, when conscientiously performed, such welds will stand up to requirements very satisfactorily. Much of my work has been with the oxy-acetylene process, particularly for parts of relatively small section, but I have pleasure in testifying to the efficacy of the electric. One case in particular gave trouble, inasmuch as after repeated attempts at oxy-acetylene welding a crack in a steel valve-body for superheated steam, oozing manifested itself during the necessarily severe hydraulic test, so resort was finally had to the electric welding, with complete success. While thanking the author for his paper, I would like to ask him whether his firm is open to weld a broken piece of 2 in. dia. wrought iron line-shafting, as I know of a workshop drive which is being delayed by Government formalities consequent upon the attempt to obtain a new shaft.

Mr. F. O. Beckett: The human element always comes first in style and class of work; prejudice comes next. I advocated the welding of a grooved wasting in the root of a furnace flange, and got nothing but ridicule some nine or ten years ago. A strange thing occurred lately to a vertical donkey boiler; a patch was welded on in the fire-box under the fire-hole doorway flange. The boiler stood the hydraulic test—so I am told—to twice the working pressure, but after working under steam for a week the shell plate, about 4 ins. to 6 ins. away, developed a crack 2 ins. to 3 ins. long. Of course, the welder got the blame. There is thus, I find, this danger of excessive local heating, and no way of annealing or restoring the strained metal, or metal as in the case of a double riveted joint. I find welding very useful for repairs, but not for new manufacturing purposes. But welding is less to be depended upon than lap welding for pipes and boilers.

Mr. F. A. Corns: I have had some experience of electric welding, which was not entirely satisfactory. The throat-piece of a Cochrane boiler developed a crack along the flanging. This was electric welded, but very shortly after it gave out at the end and extended; it was again welded, and again the same thing happened; ultimately I believe it was made tight. I also had experience of electric welding in connection with the water supply of Cobalt (Canada), when all the pipes were electric welded together, and again on long coil work for heaters; in this case the results were first-class.

Mr. J. B. Hall: At the start one is tempted, without in any way detracting from the high value of Mr. Kennedy's paper, to ask, how,—if his dictum as stated at the commencement of the 2nd par., p. 46 of his paper is correct,—and where, "welding" comes in, when viewed from the standpoint that in the work carried out by his firm, *No Pressure*, and only a small amount of hammering, such as may be taken as negligible, when making "the intimate union of two pieces of metal." That a perfect amalgamation of the metals takes place is undeniable, and being so, it must then follow that: "A weld is . . . *et seq.* . . by pressure, hammering and/or by the electric arc." This is, I submit, qualified by the statement made later on in par. 2, p. 48. By this, by the way, what I would recall to Mr. Kennedy's mind is a repair carried out by his firm to a large double main beam of a pumping engine. The beam about 24 feet—26 feet long, as originally built-up of plates and angles, after working for some time gave signs of movement in various parts, due no doubt to the fact that when constructed, punched and not drilled work was *de rigeur.* Ultimately a crack developed in one of the flange members of the beam as well as some rivets broken off. When repairs were carried out it was decided, in addition to welding up the crack in the broken flange member, to increase the length of another of the flange members by electrically welding on an additional length of about 2 ft. to help in equalizing the strains set up. Here one has in the finished repairs, when the beam is working, every stress which materials have to resist brought into action,—compressive, tensile, bending, and torsional,—each and all recurring at an average of 20 periods per min. and at times the engine works continuously for 12 to 18 hours. The result as found in the future from and of these repairs must undoubtedly be of inestimable value in determining the reliability of electric arc welding. Whilst holding no brief for any particular process of electric or autogenous welding, one is bound to find, *Experentia docet,* that in the process described by Mr. Kennedy it is the most adaptable to the many repairs called for in boilers, etc.; repairs that certainly no engineer would admit of being carried out by any process where a large area of the surrounding material is considerably heated when getting the actual point of repair up to a welding heat.

Mr. R. J. N. Willcox: The immense possibilities of a correct application of electric welding have been of supreme interest to me for many years. In the Bernardo's system the carbon arc is used to melt the steel casting at the defective part and small pieces of steel, usually punchings, are dropped into the fused metal and the arc maintained until the whole is fused. Sufficient metal is added in this way to fill up the void and then the arc is withdrawn, and as the metal solidifies it is hammered down to make the surface smooth and level. The added metal is so hard, however, that it can only be machined with great difficulty. It is impossible to produce a true machined surface on a steel casting so repaired owing to the tool jumping and digging as it passes the hard spot. Moreover the intense local heating sets up internal stresses which only the most thorough annealing of the whole casting appears to be capable of removing in part. My experience with a very large number of welds made by this process in steel castings is that they invariably fail unless prolonged annealing is effected and very often fail when even it is done. Its chief use is to fill up unimportant defects. On the other hand many repairs have been made to mild steel castings by means of the metal arc process in vital parts subject to intense stress and vibration, and I have not yet had a failure. Some years ago I used oxy-acetylene for building up wasted parts of boilers, but was deeply impressed with the intensity and extent of the local heating. It seemed to me that it could not be regarded as sound engineering and to be contrary to all accepted ideas as to the proper heat treatment of steel in so important structures as boilers. Having acquired some knowledge of what was being done on the continent I welcomed the advent of the electric arc process to this country, and made use of it on the first opportunity, and on a large scale, and have continued to do so with uniformly satisfactory results. The author's statement that the strength of welds has now been brought up to 27 tons induces me to ask for confirmation of the many statements which have reached me that the thin shell plates of land boilers of the Lancashire type are frequently built up when corroded away on the water side. I do not myself advocate a repair of this nature because failure may lead to catastrophic accident, but the statements referred to are apparently based on fact. But if extensive experience has shown that such repairs on so thin plates are reliable, and if we can also rely upon 27 tons stuff then very wide possibilities in boiler construction are open to us where heavy plates are in question. Obviously, the percentage loss due to this method of joining thick plates is much less than in the case of thin ones. A definite statement from the writer of the paper would, I am sure, be of very great service. I am not in agreement with Mr. Kennedy as to the beneficial effect of hammering or "pæaning" the weld as work proceeds. My own observation is that the metal is at dull red or colder before the hammer gets to work. If a large nodule of metal is struck the tendency is to splay it over the other surface, and a false weld is made, which I think accentuates the tendency to porous work and in fact defeats the very object in view. The only possible benefit I have been able to conjecture is that the hammer blows might detach any hard scale or slag which may be adhering to the metal. But on the other hand the temperature at the actual point of the weld is so high as to volatilise any scale or slag, so that it seems little is to be feared on this account. The best work always appears to me to be done where the worker goes straight on adding his metal in a succession of ripples for an inch or two at a time. Mr. Kennedy makes a curious and most interesting remark about the necessity of special precautions where zinc plates have been lavishly used. On reflection I am inclined to think that Stromeyer's investigations into the influence of caustic solutions under high pressure and temperature in steel have a bearing upon this. Those who indulge lavishly in zinc plates are generally the same folk who use a great deal of soda in their boilers. Stromeyer has proved that concentrated solutions of alkali destroy the nature of even thick plates, and it may be that what Mr. Kennedy has observed is the same thing only in a minor degree. It would be of great interest to know if the same thing has been noticed in the plates of boilers in which so-called scale preventives have been freely used since these are generally composed chiefly of concentrated alkali solutions. Then as to welding special steels. I use large quantities of heavy and expensive castings subject to great wear by abrasion which have to be thrown away long before their strength has been affected. If they could be repaired by building up the worn part, or better still, if very hard parts could be welded in where the wear takes place it would mean a very great saving directly, but indirectly the saving would be multiplied many times over. After several experiments which appeared to indicate the possibility of welding high manganese steel parts to a mild steel casting, tenders were called for a large casting for a dredger to be fitted with wearing plates of manganese steel welded to it. Only one offer, that of a foreign company of very high repute, was received and was accepted. The job looked an excellent one, but when the casting was warmed up to shrink it on its shaft each one of the manganese steel plates lifted perceptibly, and on examination it was found that the weld to the mild steel was perfect, but there was none whatever to the manganese steel; the metal merely overlaid its edges. Mr. Caldwell in his recent paper read before the Institution of Engineers and Shipbuilders of Scotland states positively that high carbon steel has been satisfactorily welded by the metal arc process, but in several trials made by different firms skilled in the art I have learned only of failure. A very recent experiment is now being watched, and up to now is reported to be satisfactory. Metal arc welding is capable of immense development, and, to my mind, in no direction so important and extensive as in ship construction. A good many years ago I ventured to suggest in the technical press that as electricity became cheapened and the cost of labour increased it would be commercially possible to do away with rivetted seams in plates and all rivetted joints in beams, angles, etc. There have been great developments recently in the reduction of cost of electricity, and as we all know an immense increase in the cost of labour. When the very large economy which such a system would effect indirectly as well as directly in labour and also in capital outlay in a shipyard laid out for working entirely on this system is contemplated, the conception has many fascinations. I am convinced that the time for its adoption is very rapidly approaching if, indeed, it has not already arrived. But to ensure its satisfactory development it will have to receive much more sympathetic assistance than it has hitherto appeared to do from the powerful Shipping Registers. The time has now come, surely, when they should lead instead of following its development or we shall see other countries such as Norway, where both electric power and labour are cheap, doing what we have been only talking of doing and cutting the ground from beneath our feet. As an illustration of what appears to be possible a rough estimate of the cost of welding the butt of a heavy keel plate, paid at the rate of present cost of awkward boiler repairs which includes establishment charges and liberal profit, is less than the wages of the riveters alone.

Mr. J. Thom: The Institute of Marine Engineers members must think themselves favoured by having such a practical and educational paper from Mr. Kennedy. I am sure we all appreciate it very much, and he has our very best thanks. Speaking of the work I have seen done by the electric arc, I must say it is wonderful, and would astonish anyone out of the zone—say, in the Colonies—for the last decade. The great benefit to the shipowner is the saving in cost and time of repairs. Take the case of a fractured stern frame, which in the ordinary way would have to be taken out and welded or renewed, and then replaced. With the arc welding the broken one could be welded in place at the cost of some two or three hundred pounds, against as many thousands by the former method. Minor matters such as incipient flaws can be dealt with without renewal, the oaxter plates being a common example. Some years ago in liners the upkeep and renewals of boilers was a very expensive matter, and the worry of the superintendent engineers, in fact necessitating hundreds of workmen in the stokehold during the whole time the vessel was in port, many times regulating the time you could proceed to sea, viz., when the boilers were made good. Owing to the satisfactory jobs done by this class of welding, boiler trouble is disappearing, or has at least assumed reasonable proportions, and the engineer can sleep soundly. The lantern slides show very clearly what can be done in combustion chambers or tube plates, the saving in such jobs running into thousands of pounds, without taking into consideration the time saved. While talking of large figures, it does not do to forget that "a stitch in time saves nine," which as applied to the boiler is of the greatest importance; small cracks and wastage can be dealt with at its earliest stages and in time to keep the boiler up to its original duty and pressure. There is one thing we often forget about, viz., that fractures in steel castings are often due to initial strains, and that when once these fractures have been cut out and welded up the casting is stronger than it was originally. Fractures in boilers generally denote overstrain or local weakness, and once this has been released by fracture and the part welded up again the internal stresses are done away with. It is well to bear in mind that such repairs must be carefully considered, and entrusted only to skilled and experienced workmen.

Mr. Wm. McLaren: I should like to ask the author if the welding is done locally, for instance, a small area at one heating, such as is shown in the boiler furnace front-end crack or split? Also can any hammering be applied in such a welding repair? Welding electrically must have pressure to bring and keep the surfaces together while under the arc. What is the power required? I am led to understand that it takes 20 h.p. to weld an inch bar. I congratulate the author in bringing these particulars of the electric welding process before the Institute, but I would certainly appreciate a higher voltage than 25 to 45 volts, so that the range of machines would be greater for welding on the spot rather than having to carry a special plant when a skilled welder might be easier secured than the special plant.

The Chairman: Before asking Mr. Kennedy to reply I may add that I have had little experience with electric welding, but years ago had considerable experience with acetylene welding, before electric welding came into its own, principally with building up the landing edges of tube plates in the combustion chamber, and although apparently a good job was made I found that the trouble from cracking of the plate at these landing edges was worse than before, and I should like to know if electric welding has overcome this evil. If it has, a great advance has been made in repairs of this character. Mr. Fielden's remarks about renewing non-withdrawable furnaces recalls to my memory that I did similar repairs before the days of electric welding. New saddles suitable for withdrawable furnaces were fitted in halves and afterwards welded together by the acetylene process, the weld, of course, was below the fire-bar line and not subject to the full impact of heat and flame, which may account for no trouble arising from welding. I have now pleasure in calling upon Mr. Kennedy to reply.

CONTRIBUTED BY CORRESPONDENCE.

Mr. W. H. SMITH: By the kind invitation of Mr. J. Wilson, I was present at the lecture last evening on electric welding and I would be very pleased to hear from Mr. Kennedy, his remarks on the following:—Foden Steam Wagon Tyres.—A tyre having burst, it is electrically welded by the building-up process and then heated in a furnace to red heat; it is then lowered on to the wooden wheel and hydraulically pressed up at a pressure of 20-25 cwt. per square inch, cooled out, and is then put into use. Fairly frequently they burst again, sometimes quite soon, but it is noticed that they very rarely go where they have already been welded, but some two to three inches away, apparently at the spot where the local heat of the weld terminates. Now, is this caused by structural changes in the iron at the weld or to internal stresses set up through contraction and expansion, or has the subsequent heating and pressing up any influence upon the weld? Of course, due allowance must be made for the very bad condition of the roads at present. I shall be extremely grateful for any information you can give me upon the matter. I should like to state that tanks used for carrying fuel oil leaked very badly when only riveted, apparently due to the surging effect of the oil while in transit, but remained tight when electrically welded.

Mr. R. J. MCLEOD: It has occurred to me in further reference to Mr. Kennedy's paper on arc-welding to add that the elucidation of one or two points in the paper and raised in the subsequent discussion might be instructive and helpful. It can be accepted fundamentally that direct or continuous currents are best suited for arc-welding and alternating currents for resistance welding, the reasons being as follows: Alternating currents are used for machine or resistance welding because current at ordinary pressures can be used and transformed down on the machine to the required low potential. The potential being so low it becomes necessary for the transformers to be fixed on the machine close to the work and an easy path given for the current to pass without sensible loss to the ends of the electrode. If it was proposed to use continuous currents a special dynamo would have to be fitted to each machine in the position occupied by the transformer, and on account of the high amperage and low potential extraordinarily large commutators would have to be provided to collect the necessary current. With alternating currents the direction of flow is continually reversing according to the periodicity, so that there is no polarity. Continuous currents, however, have a definite direction, and are therefore polarised. This polarisation is of great assistance in arc-welding on account of the metal from the electrode being attracted to the job in accordance with the fundamental law that like poles repel and unlike attract mutually each other. This makes overhead and vertical welding possible, but it can readily be seen that this same law which assists the arc-welding would defeat resistance welding owing to the tendency of the electrodes to deposit either on the job or on each other, it being understood that copper electrodes are used in resistance welding for steel and non-ferrous metals.

Mr. J. H. Anderson: The paper on electric welding was exceedingly interesting and proves that considerable scope is possible with this class of work. It may be further interesting in view of the dates given in the paper to know that so long ago as 1908 we have had cast steel hydraulic pump barrels electrically welded to replace the material destroyed by electrolysis between the brass fitting and the steel; in this instance it is the steel that suffers. We have also had experience of the welding of cast iron cylinders up to 12 in. dia. by 18 ft. stroke, a crack about 6 ft. long was repaired quite successfully by the Anglo-Swedish Electric Welding Co., Greenwich. This repair was a novelty at the time and was a risk in a certain way of experimental cost, which was justified owing to the long time it would take to secure a new cylinder (6 months). The repair was executed in a few days, and the cylinder has been in constant use ever since with a working pressure of 750 lbs. per sq. in., and in addition the inertia shocks added to that. This same firm has now done several cylinders since, one of which I quote as being 14 in. dia. by 6 ft. stroke, part of the cylinder was cut away, due to blow holes and then built up afresh; this cylinder has been at work for 16 months at a working pressure of 1,000 lbs. per sq. in., and is giving every satisfaction. The photographs I gave you show repairs to cranks, those marked A (on the back) are $8\frac{3}{4}$ in. crank shafts for gas engine, and those marked B show a 6 in. crank shaft. You will see in B a new piece was built in altogether. I also enclose a pamphlet showing several everyday repairs as one may term them. The photographs show that a considerable amount of scope is still open for this class of work and are well worth reproducing if conditions admit.

Mr. A. Cameron, R.E.: I was extremely interested in your paper, illustrated by lantern slides, on "Repairs by the Electric Welding Process," and although I did not take part in the discussion at the meeting, I think the members of the Institute of Marine Engineers and others are indebted to you for giving them the benefit of your experience and for the information which you have collected and made the subject of a paper, to be included in the "Transactions" of the Institute. Electric welding is a process which is of vast importance to naval architects, engineers, and shipowners, and in this connection it is gratifying to hear you acknowledge the assistance rendered by the B.O.T., Lloyds, and other societies. Perhaps they have been compelled to as a "War emergency." Engineers generally are the original "Show-me folk," but I think it has been shown conclusively that electric welding is much superior to the oxy-acetylene process. It has a wide field of usefulness, and in some cases it is a technical necessity. Of course, it is not claimed to be a perfect process. It has its defects, and I regret that you did not include some "Notes on defective electric welds," but perhaps we can look forward to a separate paper on that point at some future date. You lay special emphasis on the "human agency," and that is a factor which cannot be eliminated. No matter how well a plant is designed and equipped, success or failure depends very largely on the care and skill of the operator. The term welding is now somewhat loosely applied. Meaning originally the union of two pieces of metal within their plastic range, but below their melting point, it has been applied in the form of "autogenous welding" to denote a process of union by fusion. Such a process is really one of autogenous soldering—not welding. In true welding there is mutual interpenetration, and if oxidation is completely prevented, there is no reason why the weld should be weaker than the remainder of the metal. In practice the weakness which is frequently observed is due to incomplete union. The conditions are rather different when the method of autogenous soldering is applied. In electric resistance welds the presence of oxide is to be clearly traced along the plane of union and a zone of coarse crystallisation is obtained. In welding by means of a carbon arc local carburisation is very apt to take place.

One often hears "the weld is stronger than the original metal." It is beyond all reason to claim that soldering process can produce the exact character of rolled steel. It is not sufficient to show that fracture does not take place in the plane of union. It is not the weld, but the adjacent zone, which is impaired. The data available as to the strength and reliability of autogenous welds is incomplete. A series of fatigue tests on repaired parts would be interesting.

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Mr. R. S. Kennedy, in reply: I wish to thank you for your very kind attention this evening, and to express my appreciation of the many valuable points that have been brought out in the discussion.

Mr. McLeod states that his remarks are somewhat foreign to the general purport of the paper, but they are certainly of great interest, and the specimens of resistance and spot welding he has brought with him show the valuable nature of the work done. So far as a brief inspection enables one to judge, they seem to be very good jobs, and I am also extremely interested in his failures in the experiments with the high carbon and some special steels. This bears out the general experience, and the author is of opinion, as indicated in the paper, that the most promising line of investigation is in the investigation of the effects of different temperatures of the source of heat.

Mr. Willcox also refers later to the difficulty, and Mr. McLeod gives us some very interesting particulars as to suitable machines for resistance welding. The reasons given are additional to those mentioned in the paper as to alternating current being preferable to continuous for resistance welding, and relate to electrical difficulties, while the author considered the matter more from the welding standpoint. Resistance welding could almost be considered as a form of arc welding with a very short arc, with the further difference that the objects to be welded together are usually comparable as regards mass, so it is an advantage in this case to have both pieces subjected to the same temperature.

Mr. Fielden's remarks on the reasons for carrying out the welding repairs to the nine tube plates illustrate the very great saving in labour and time that can be effected in repairs. The cutting of the tube plates between the rows of tube holes and welding on a lower portion is one of the most difficult jobs we have to undertake, and this case is particularly interesting, as the first one attempted in 1912 was also carried out to Mr. Fielden's direction and to the survey of the Board of Trade. In this first case an actual tube plate was first experimentally welded and tested before the real job itself was undertaken. Bearing in mind the great responsibility of the work undertaken, the Board of Trade restrictions have all along been in the best interests of progress. It is only right to mention that Mr. Fielden is the gentleman who was the moving spirit in inducing us in this country to develop welding from the current supplied from the dynamos of the larger vessels.

Mr. Fielden also refers to the author's remark about difficulties experienced in the building up of water surfaces where zinc plates have been freely used. This is fortunately a somewhat rare occurrence, but it does occur, and the effect is that it is impossible to make a good weld with the affected surface. The author has always attributed this trouble to the penetration of the surface of the plates by a zinc deposit, which, of course must be removed before an efficient weld can be made. Mr. Willcox, later in the discussion, mentioned that Mr. Stromeyer, in his book on "Marine Boilers," had referred to the destructive effects of caustic solutions under high pressure. It is possible that this may also be a cause, although the author has usually found this trouble in old boilers of, say, 70 lbs. working pressure. There may be other causes, as Mr. Macfarlane Gray found signs of copper at the bottom of pit holes, which he considered came from internal copper pipes. The practical point for the welder, however, is that there is a possibility of trouble on the water surfaces from some cause, and that his only remedy is to chip away till he comes to pure metal.

Mr. Beckett and Mr. Willcox both referred to the difficulties experienced with oxy-acetylene owing to expansion troubles. This is, of course, due to the lower temperature of the oxy-acetylene flame as compared with the electric arc, whereby it is necessary to impart a much larger quantity of heat to raise the required point to welding heat. This is a very serious matter in the constrained surfaces found in a boiler, and the author calls to mind the many devices that were attempted to overcome expansion troubles. It was really wonderful what could be done in this direction, but, of course, it necessitated very careful and experienced study of individual cases.

Mr. Willcox remarks that if the strength of an electric arc weld can be taken as 27 tons per sq. in. tension then there is no reason why boiler shells should not be welded, and ships welded instead of riveted. This is certainly going ahead with a vengeance, and there is no doubt that circumstances might warrant risks being taken; but at the same time the author wishes to emphasize the fact that in arc welding one is dependent on the skill and attention of the operator, and it is necessary for every care to be taken. The author considers that it would be quite possible to make a sound job with a boiler shell by adopting the method of hole welding, introduced and protected by him some five or six years ago. This would consist of retaining the external butt strap, which would be welded to the shell plate all round, and instead of being rivetted would have holes drilled through it, by means of which it could be welded to the shell at intervals. A similar method could be adopted with a lap joint. There would be no saving in cost as compared with a rivetted joint; in fact, it would be more expensive, but there would be no troubles from leaky joints. Similar means have been adopted in repairs to stem frames where broken. Certain trials have been made with small vessels with welded plating, but the cost figures are not yet available.

Mr. Smith refers to leakage of tyres where electrically welded some three inches away from the weld. It would depend on how the welding was done, as if properly carried out there should be no deterioration of the neighbouring materials. Is it possible that some deformation of the true circle or bearing surface is a contributory cause?

Mr. Anderson instances some repairs to cast steel cylinders by electric welding, which, if carried out in this country at the time mentioned would presumably have been done by the Bernardos process. His remarks about repairs to cast iron cylinders are interesting, and they seem to have been a good job, but sound repairs in this metal are common; the only point is that there is not the same amount of certainty as in dealing with wrought steel and iron or cast steel.

While on the question of dates, the author might mention that the first electric welding repair to a marine boiler with the metallic electrode, of which he has personal knowledge, was the welding of a crack in a saddle corner of the British S.S. *Arana*, at Hamburg, in 1907. Previous to this, foreign vessels had been electric welded at this port, and possibly other British vessels of which the author has no knowledge.

Mr. Corns referred to trouble experienced with the flue of a Cochrane boiler, which was several times welded with unsatisfactory results; it is probable that this was a case of the original weld giving out, which, as mentioned in the paper, is often a difficult matter, although Mr. Corns does not mention the process of welding adopted.*

Mr. Thom brings out fully in his remarks the great saving in time and cost of repairs as compared with ordinary methods. The saving in actual money is very considerable, but more important still to the shipowner is the saving in time. At the present time the nation is the big shipowner, and these conditions are accentuated.

Mr. MacLaren refers to various oxy-acetylene repairs, and the author wishes to thank him for the very efficient manner in which he has worked the lantern this evening. There has not been a hitch, and the slides have shown up better than the original photographs. We had a rehearsal here a week ago, and Mr. MacLaren's advice was much appreciated as to which slides to show and the order in which they were to be taken.

Mr. J. B. Hall and Lieut. Cameron both quite justly query the correctness of the term "electric welding" as applied to what is known as arc welding. Mr. Hall drives the attack home by quoting two definitions of the author which are undoubtedly antagonistic. The author can only plead that he has adopted the term in common use, although probably "fusion" would be more correct than "welding." The Spaniards call it "electric solder," which is just as much wrong on the other side, as in soldering the metals to be united

* Mr. Corns explains that it was done by the electric welding process. The welding was porous and gave out at the end, the fracture extending into the flange.

are not themselves brought to a heat of welding or fusion. The author is obliged to Mr. Hall for recalling the repair to the beam of a large pumping engine, which certainly was a practical test, which surpasses laboratory experiments on alternating stresses and fatigue of metals. Lieut. Cameron goes on to say that a paper on defective welds would be instructive. The author has mentioned as far as he can recall the circumstances affecting the making of an efficient weld. These are usually apparent at the time, but given favourable conditions a bad weld is due to defective workmanship or materials, and the operator should be able to detect defective materials when in use. Lieut. Cameron emphasises two very important points, namely, the necessity of the trained operator, and that a statement that the weld is stronger than any other part usually means that the neighbouring material has been deteriorated. It is possible to increase the strength at the point of welding by increasing the section, but it is only in this connection that the strength can be legitimately increased beyond other parts. Mr. Hall and Mr. Willcox both question the value of hammering the weld while work is in progress. The author's conclusions were based on tests made some five years ago, but he is quite prepared to admit that the point as regards increasing the tensile strength is a debatable one, and the welders themselves are divided in opinion. There is little doubt, however, that it tends to decrease any tendency to porosity in the added material.

The author, while on the subject of experimental work, would like you to pay a tribute to the results achieved by Dr. Passmore, on the chemical side, who is largely responsible for the increase in strength and reliability of electric welds, owing to the care taken in the selection and analysing of materials used by the welders. Mr. Atkinson Adam and Dr. Dugal Clark have conducted many experiments on temperatures and mechanical tests, on which some of the conclusions recorde have been based.

The Chairman, in his concluding remarks to the discussion refers to his own experiences with oxy-acetylene welding and renewal of the old non-withdrawable type of furnace with the Gourlay neck type with a false saddle.

Votes of thanks were proposed, seconded and passed unanimously to the author for his paper and to Mr. Shanks for presiding so ably over the meeting.

# Notes.

THE DEVASTATION OF BELGIUM.—The attention of many of our members who have been in Belgium and have interesting memories of their visits is directed to an article in *Gas and Oil Power*, January 3rd, by Mr. R. E. Mathot, M.I.Mech.E., on "Engineering Devastation in Flanders; the Track of the Hun and a Warning." He refers to the methodical pillage of Belgian factories and property, which has also been extended to Northern France districts, while neutral nations have been informed of the anxiety on the part of the invaders to protect Belgium against "the exacting despotism of the British."

Those who had an opportunity of devoting attention to a study of the trade and commerce of Antwerp will be interested to read and endorse the comments made by Lord Inchcape, one of our Past Presidents, who presided at a dinner held by the Chamber of Shipping of the United Kingdom on April 19th, when delegates of the Belgian trade and commerce were guests. He referred to the efforts made by Germany to secure prominence in Antwerp to the detriment of others; but, with the co-operation of Belgian owners, British shippers would work hand in hand with them to preserve the trade under its legitimate head. The formation of the Anglo-Belgian Union, with a view to closer mutual relations, is a good step towards the harmony of things.

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DIESEL LUBRICATION COMPRESSOR AND ENGINE TREATMENT.—A paper on this subject, by Mr. J. Veitch Wilson, was read to the Diesel Engine Users' Association. It is reported in *Gas and Oil Power* of January 3rd.

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THE TIMBER INDUSTRY.—The importance of preservatives to prevent decay in wood was emphasised by the Professor of Technology of Woods and Fibres, Imperial College of Science and Technology, at a recent meeting of the Royal Society of Arts. The subject is of considerable interest to those who have refrigeration chambers under their supervision.

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# Correspondence.

British Prisoners of War.—The following letter, with descriptive booklet, accompanied by a list of books, was received and placed on the notice board, but it is published here to give greater publicity to the appeal:—

British Prisoners of War Book Scheme.
Victoria and Albert Museum,
South Kensington, S.W. 7.

Dear Sir,

May I invite you to read the enclosed booklet, and then bring the same to the attention of the President and of any members of your Council who might be interested in forwarding the scheme described in its pages. I feel sure it will appeal to many members of your Society.

Among the many thousands of interned men, we find there are a considerable number who are evincing a keen interest in subjects which your Society is anxious to promote, and any assistance which you can render or obtain in meeting the wants of these men will be very welcome. Such assistance may take the form of offers of suitable textbooks for their use, or donations for the purchase of such.

I am,
Yours faithfully,
Alfred T. Davies,
*Chairman.*

# *Appeal for Increased Membership.

The desirability of increasing the membership in all grades has been discussed from time to time, and recently the subject occupied the attention of the Council, with the result that it was decided to make an earnest appeal for the co-operation of the members to assist in the effort to materially increase the membership, as it is recognised that little can be done without their help.

Now that the Institute has commodious and well-fitted premises within the City of London area, it is earnestly desired to increase its usefulness and add to its membership, in order that its operations may be extended to embrace a wider circle.

That there is ample scope for this, it is pointed out that the present membership is only a small percentage of the number of marine engineers available. The aim of the Council is to make the Institute thoroughly representative of all branches of Marine Engineering, to advance the status of the Marine Engineer, and to foster and encourage a progressive spirit in the profession which is bound to benefit the engineer in the present and future, at the same time being of direct advantage to the country at large.

The papers read at our meetings invariably deal with the modern trend of thought on the subject chosen, and they are interesting and instructive; although the printed report may fail to convey all that can be gathered from listening to the reading of a paper at the meeting, the discussion adds a source of useful information, eliciting reports of experiences and comments based upon these. The opportunity also remains for members to forward contributions suggested by the papers, or discussions, and they are invited to do so in order that the benefit derived from the study of the subject may be as wide as possible.

The greater the membership, the more useful does the Institute become, and by attendance at the meetings in larger numbers, it is more helpful to all by facilitating the interchange of experiences and ideas. It may be pointed out that the work of the Institute is not only of great national importance at the present time, but will be even more so in future.

For the benefit of prospective new members, it may be noted that in the absence of a friend for the nomination and seconding, the application form may be filled up as far as possible and forwarded to the Hon. Secretary, with references for communications.

Suggestions to make the Institute of increasing usefulness to Marine Engineers and Apprentices are always cordially welcomed.

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* An Application Form is inserted in each issue of the Transactions.

# Election of Members.

Members elected at a meeting of the Council held on Tuesday, 9th April, 1918 :—

*As Members.*

John Allan, c/o John Gillon & Co., 129, Minories, London, E.
Robert Allen, Messrs. Allen & Simmonds, Ltd., Reading.
Wm. J. Abraham, 26, St. Peter's Grove, Southsea.
Stuart Henderson, 17, Ailsa Drive, Sunnyside, Glasgow.

*As Associate.*

F. J. S. Draper, The Laurels, Meopham, Kent.

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Members elected at a meeting of the Council held on Tuesday, 14th May, 1918 :--

*As Members.*

Wm. Boag Aitken (Engr. Lieut. R.N.) "Orcadia," Kilbarchan, Renfrew.
George Harry Connell, 45, Sholebrook Place, Chapeltown, Leeds.
James Paul Devlin, 53, Exeter Drive, Partick, Glasgow.
Wm. Arthur C. Evans, Ty Nant, Whitechurch, Glamorgan.
James Gordon, Sejua Colliery, Sejua P.O., Maubhem Dist., Behar and Orissa.
Colquhoun Fraser Grant, "Fairholme," Grange Park, London.
Alfred S. Hunter (Engr. Lieut. R.N.), 18, Horringford Road, Aigburth, Liverpool.
Alfred Morrison Singer, 34, Abergeldie Terrace, Aberdeen.
Archibald Thomson White, 63, Eversley Road, Charlton, London, S.E. 7.
Leonard Young, Union Street, Largs Bay, S. Australia.

*As Associate Member.*

Gilbert Ashton Plummer, 2, Kenwood Road, Stretford, Manchester.

*As Associate.*

Victor Lockney, (Engr. Sub.-Lieut. R.N.), 53, Manuel Street, Goole, Yorks.

*As Graduate.*

Arthur Fredk. Wm. Wells, 30, Norfolk Road, East Ham.

*As Companion.*

Joseph Henry Jacobs, 10, Mark Lane, London, E.C.

*Transfer from Associate to Associate Member.*

Herbert T. Smith, 109, Brudenell Road, Tooting, S.W.