WELDING

APPLICATION IN THE ROYAL NAVY

BY

N. G. H. THUELL, A.M.I.MECH.E., A.I.MAR.E., A.M.I.W.

The subject of welding as applied to engineering covers a vast field and the scope of its application involves not only a means of production by fabrication, but also a method whereby repairs can be made effective with the least possible delay. The literature on the subject is profuse, and it is no exaggeration to say that anyone wishing to obtain a clear and comprehensive outline for his particular problem, is faced with such a formidable mass of literature, much of it highly technical, some of it contradictory, and more than a little of it dull, that it may prove overwhelming and not a little confusing.

It is generally known that welding is a term used to indicate a method of joining two similar pieces of metal together by the application of heat, and the earliest example of the method is the well-known smith's weld. With its introduction at the end of the 19th century, improvements and developments have produced many types of welding, but the methods may be divided into two main groups : 'plastic' and 'fusion' (or fluid) and these may be classified as shown in Tables I and II.

TABLE I

PLASTIC WELDING								
Type of Weld	Forge furnace	Pressure butt	Electric resistance					
Medium of Pressure	Hand or machine	Machine	Hand or machine					
Current or Heat Medium		Gas	A.C.					D.C.
Regulation		Automatic	Electro-mechanical or electronic valve					Static or magnetic
Seam		Square butt	Edge	Surface				Surface
Type		Tube weld	Flash butt upset	Spot	Stitch	Seam	Projec-tion	Percussion Stud

TABLE II

FUSION OR FLUID															
Type	Gas		Atomic	Argon Arc		Argonaut or Aircomatic		Carbon Arc			Metal Arc				Chemical
Heat from	Oxy. gas		Arc	Arc		Arc		Arc			Arc				Chemical reaction
Current			A.C.	A.C.	D.C.	A.C.	D.C.	D.C.			A.C.		D.C.		
Machine	Torch		Trans-former	Trans-former	Motor	Trans-former	Motor	Motor			Trans-former		Motor		
Operation	Hand or machine		Hand or machine	Hand or machine		Hand or machine		Hand or machine			Hand or machine				Chemical
Electrode			Tungsten	Tungsten		Bare wire		Graphite			Bare wire		Coated or washed		
Protection	Gas	Gas or flux	Gas	Gas		Gas		None	Gas or slag	Gas	None	Gas	Slag	Gas or slag	
Protective Source	Flame	Flux	Flame	Flame		Flame				Jet or flux		Jet or flux	Coat-ing	Jet or coat-ing	
Added Metal	Filler		Filler	Filler		Electrode		Filler			Electrode				

Of the processes, the methods used in engineering at the present time are :—

(i) Gas welding (oxy-acetylene) etc.
(ii) Metallic arc (hand or automatic)
(iii) Carbon arc
(iv) Atomic hydrogen
(v) Argon arc
(vi) Argonaut
(vii) Electric resistance—spot, seam, stitch, projection, pressure, flash butt
(viii) Thermit welding
(ix) Pressure butt (gas) for pipe work.

Each method has its own specific application to the requirements in engineering, and one of the main considerations in the fabrication and repair of a unit for service is the design of the item and the selection of the appropriate welding process to achieve the desired weld, provided the material is of a weldable quality. Thus it may be stated that the first essential is to ascertain the class of metal to be used in the fabrication or the unit repair, and these may be assumed to fall into two groups, ferrous and non-ferrous. The following are the main types within these groups as far as engineering is concerned :—

Ferrous

(*a*) Cast iron
(*b*) Cast steel for steel castings
(*c*) Wrought iron
(*d*) Steel : mild and low carbon
(*e*) Alloy steels : (i) high carbon
(ii) chrome steels and nickel steels
(iii) stainless steels, etc.

Non-Ferrous

Metals	*Alloys*
Copper	Brasses
Lead	Bronzes
Zinc	Aluminium alloys
Aluminium	Copper-nickel alloys
Tin	Monel metal, etc.
	Whitemetal, etc.

Each material has its own particular welding characteristics.

Before deciding to adopt welding for fabrication and/or repair work the following must be decided :—

(i) The material to be welded
(ii) The service for which the item is required
(iii) The type of welding to be used
(iv) Method of repair
(v) Sequence of welds
(vi) Practical application of the welding
(vii) Stress requirements

(viii) Class of weld required and type of inspection
(ix) Acceptance standard required.

To do this, it is essential that the welding supervisor must have a knowledge of :—

(i) General engineering, especially regarding systems, units, etc.
(ii) Engineering design, especially regarding stresses
(iii) Metallurgy
(iv) General knowledge of all machinery used in engineering, viz. boilers, turbines, gas turbines, evaporators, gearing, shafting, etc.
(v) Welding processes
(vi) Welding principles and applications
(vii) Practical experience regarding work to be undertaken
(viii) Accessibility of the work as regards application of the weld
(ix) Inspection procedure, and methods to adopt to ensure a good weld
(x) Acceptance standards required for the particular work
(xi) Radiography, including X-ray and Gamma-ray equipment
(xii) Precautions necessary in the use of the methods quoted in (xi)
(xiii) Interpretation of radiographs, including density and contrast required of radiographic plates, etc.
(xiv) Other methods of non-destructive testing, viz., ultrasonic, magnetic, fluorescent penetrant, etc.

WELDABILITY

The following general summary of the weldability of the commoner materials used in engineering may be of interest.

Cast Iron

This material generally has a very high carbon content, and is prone to cracking during welding. It can be welded by the gas or electric arc process but, owing to its lack of ductility the success of the weld cannot be guaranteed. If the material has to be welded, the unit should be preheated to a degree applicable to the material and the thickness to be welded. The preheat should be applied to cover as great an area as possible, and after welding is complete, the cooling should be as slow as possible.

If preheat is possible, gas welding, using a silicon filler rod, is preferred, but if preheat is not acceptable owing to the particular nature of the casting, it would be advisable to weld by the electric arc process using a nickel alloy electrode. However, the welding of cast iron is always a very tricky job and should be undertaken with great care. Brazing of cast iron can also be done, but this is not fusion welding.

Steel Castings

The welding of steel castings is mainly connected with the repair of defects, but the present trend is towards the fabrication of pre-cast parts. This latest method of fabrication enables very large and intricate castings to be subdivided into sections, in such a way that the intricate parts can be cast separately in small units of more handable size thus reducing shrinkage cracks, etc., and stresses in the casting. The several units are then welded together to form the complete item, and this ensures a sounder unit.

Before welding steel castings, the material must be analysed to ascertain the composition of the metal, especially with regard to the carbon content. This is especially important with alloy steels where, although the carbon content may

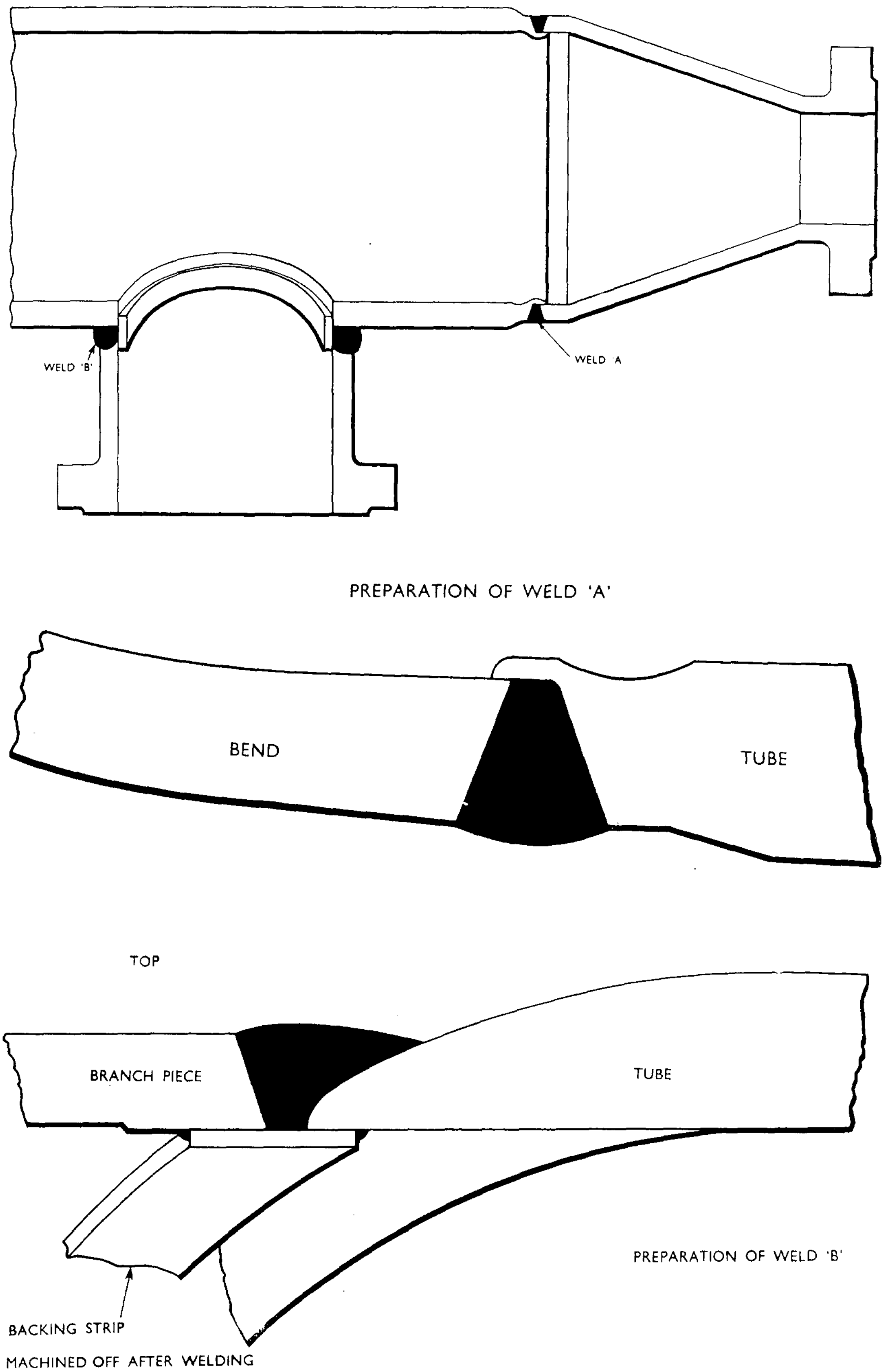

WELD 'B'
WELD 'A'
PREPARATION OF WELD 'A'
BEND
TUBE
TOP
BRANCH PIECE
TUBE
PREPARATION OF WELD 'B'
BACKING STRIP
MACHINED OFF AFTER WELDING

FIG. 1

be low, other constituents such as manganese, nickel, chromium, molybdenum, vanadium, copper and even phosphorus add to the difficulty of welding the material and must be taken into account. In this respect, a carbon equivalent figure is obtained which will give a guide to the weldability of the metal. High carbon steels must be treated with caution.

Electric arc welding is better for steel castings, and the electrodes used should be of a quality to give a deposit as similar as possible to that of the parent material.

When undertaking the repair of a steel casting, the full extent of the defect must first be ascertained by various methods of inspection. The full area should then be excavated before welding so that all defects are removed, preparation being done by chipping and grinding. Contractional stresses can be greatly reduced by judicious positioning of the preheat, and by the welding technique. Distortion can be regulated by the use of jigs, manipulators and temporary stays.

Wrought Iron

This is a low carbon material and can be easily welded in the same manner as ordinary steel, taking normal precautions.

Steel

There are many types of steel and these are generally classified by their carbon content. A rough guide can be stated as follows :—

Material	*Percentage of Carbon*
Mild steel and low carbon steel	up to 0·15
Medium carbon steels	0·15 to 0·30
Higher carbon steels	0·30 to 0·50
High carbon steels	0·50 to 2·00
Cast steel	0·70 to 1·50
Cast iron	2·00 (approx.) upwards

The welding of ordinary quality mild steel and medium carbon steels up to say 0·25 per cent carbon presents few difficulties, but the higher the carbon content and the higher the U.T.S. of the steel, the greater the difficulty in welding becomes. The technique employed will also depend upon the thickness of the material to be welded.

Gas welding, electric arc and carbon arc processes can be used for thin materials, but as the thickness increases electric arc is the better process. This will be borne out in the matter of tube welding where it will be found advantageous to use gas welding for tubes up to say $2\frac{1}{2}$ in. diam. and approximately $\frac{3}{16}$th thickness, but above these dimensions electric arc is better. With steels, depending on the type and thickness, manual or automatic A.C. or D.C. welding can be used.

Alloy Steels

These are steels of high carbon content or low carbon with alloying elements such as manganese, nickel, chromium, molybdenum, etc. These alloys are inserted to obtain high tensile and other qualities with a less carbon content.

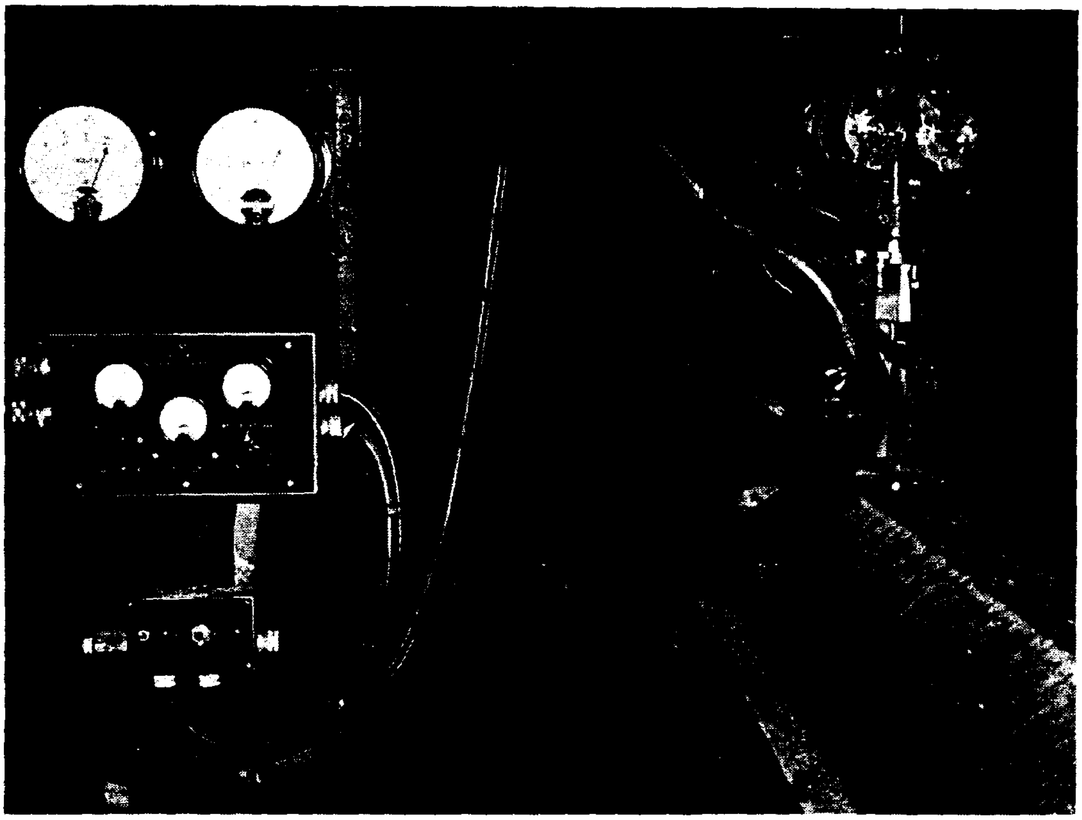


FIG. 2—EXTERNAL WELDING OF A CATAPULT CYLINDER : UNIMELT PROCESS
(*A. G. Ingram Ltd., Edinburgh*)

With the addition of these alloying elements, welding becomes more difficult, and, as stated under steel castings, the exact composition of the steel must be known before welding is started. Depending upon the thickness to be welded, it can be taken as a general rule that a carbon equivalent content above 0·3 per cent requires special precautions, and preheat must be employed.

At present, the engineer is mainly concerned with low carbon steels and the welding of such metals presents no great difficulties for, with the usual precautions, a sound weld can be obtained. However, with increased pressures and temperatures, higher tensile steels have to be used and difficulties then increase.

In welding any material, there are three zones in the weld area :—

(*a*) The fused zone
(*b*) The heat-affected zone
(*c*) The parent metal at the junction.

The basic difficulty in the successful welding of such material as alloy steel lies mainly in the heat-affected zone since, due to the improved hardenability of H.T. steels, there is a risk of hardening and the production of micro-cracks in this zone, and these minute cracks are very dangerous.

In general, the electric arc process is employed for the welding of all types of steel, but special techniques must be used for the particular type of steel in use.

Copper

This material is produced in two general forms for industry : the ultra pure metal for electrical purposes and the less pure grades for general engineering. Of the two grades the second is the more weldable, and even in this grade

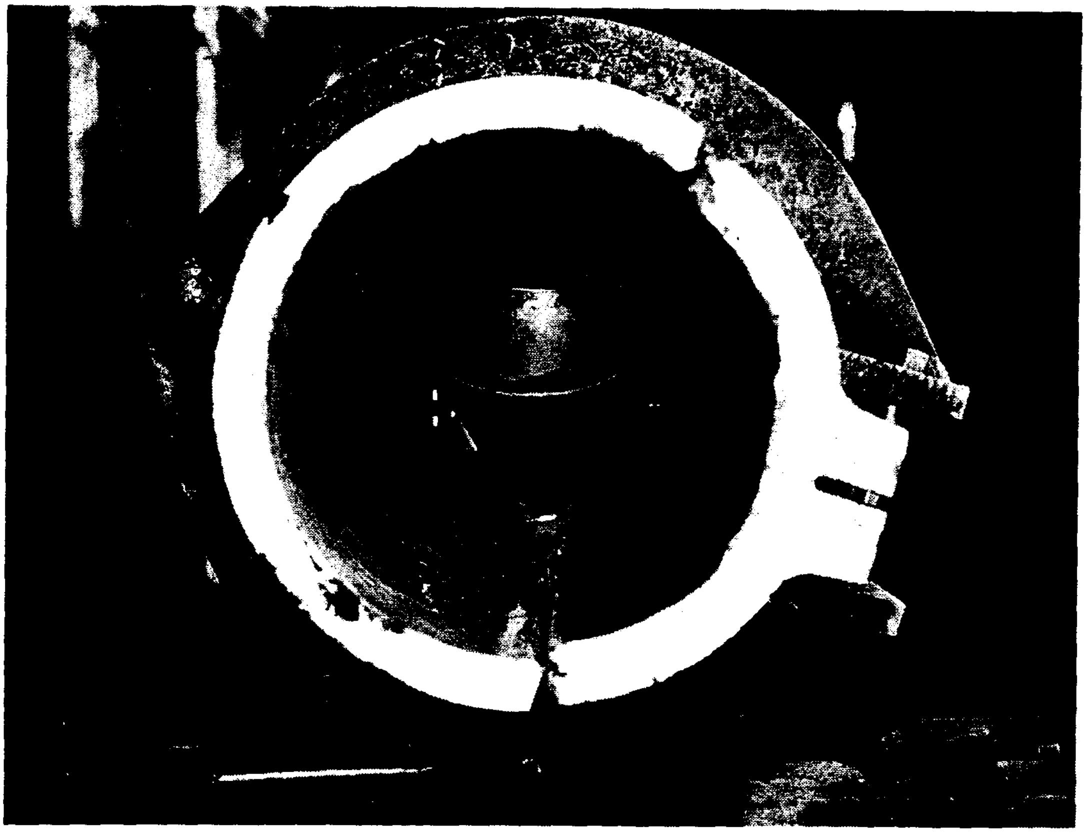


FIG. 3—INTERNAL WELDING OF A CATAPULT CYLINDER : LINCOLN SUBMERGED ARC
(A. G. Ingram Ltd., Edinburgh)

de-oxidized copper should be used. Thus copper alloys are the more readily weldable.

Copper can be welded by both the gas and electric arc processes, but gas is he more successful and is generally employed. If electric arc is used, D.C. current should be used.

Brasses and Bronzes

These materials, which are actually alloys of copper, can be welded by the gas and electric arc processes but require special techniques. There are so many brasses and bronzes of various compositions that it is impossible to enumerate them in this paper ; however, it can be said that gas welding is preferred for all types, although electric arc can be used with advantage for some alloys.

Aluminium

This material is rather special because difficulty is experienced in the initial removal of the oxide. The material can, however, be welded by the gas or the electric arc processes, but a flux, which is detrimental to the material, is required in both operations, and must be removed immediately the weld is complete. Aluminium expands twice as much as steel, and this affects the degree of distortion, unless due allowance is made during the operation.

For general plate work in aluminium and aluminium alloys, gas, argon arc and Argonaut methods are generally to be preferred. For thin plate, argon arc would be advantageous, and would be used for short lengths of weld on thicker sections. If, however, long lengths of welding are required Argonaut would provide a much quicker process.

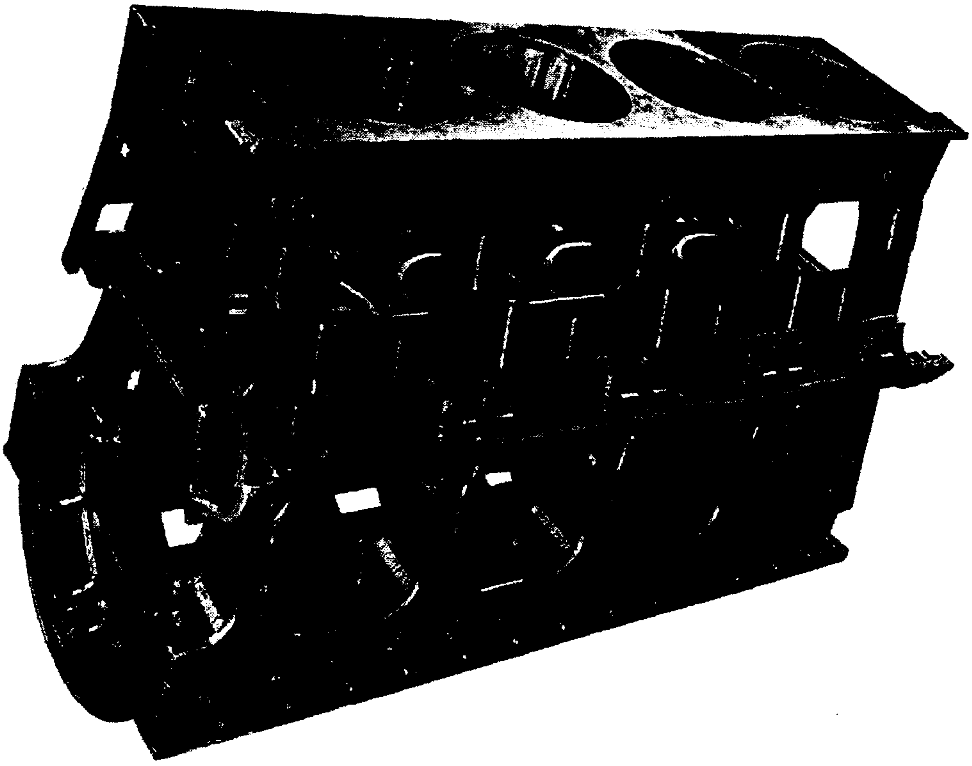


FIG. 4—A FABRICATED DIESEL ENGINE FRAME

The numerous aluminium alloys require individual welding techniques, an special welding rods and electrodes are required for the various materials.

As already stated, the inert gas method is preferred for the welding of alum inium, but this requires special equipment. For general repair work, howevei gas and electric arc methods can be used, provided special precautions ar taken.

The heat treated wrought alloys are rather difficult to weld as they are pron to cracking, but can be spot welded with ease.

Copper-Nickel Alloys

These materials should, if practicable, be welded by the gas process but th argon arc and electric arc can be used with care.

Monel Metal

This is a copper-nickel alloy and can be welded by using the argon ar process with care. Gas can also be used.

Inconel

This material can be welded with the gas process using a suitable filler ro of similar material.

Copper-Nickel-Iron Cunife

This material is a copper-nickel alloy and can be welded with care using th gas process in preference.

Titanium

This rather ' new ' metal is now being considered for use in the engineering because of its corrosion resisting properties. Welding presents several difficulties, but with very special preparation and welding technique, successful results can be obtained using the inert gas processes.

Zinc

Although not greatly used as a particular metal in engineering, it may be met in zinc based castings. Great care must always be taken when welding these and a gas process should be used with a carburizing flame.

Precaution

The above is a rough general survey of the materials used, with their welding properties, but it should be realized that the composition of the material has a great influence on its weldability, and each job must be treated on its own merits.

GENERAL APPLICATION

In the Engineering Department of the Navy welding is, or can be, used in :—

(i) The fabrication of pressure vessels of all types
(ii) General fabrication for structural requirements
(iii) Pipe welding
(iv) Repair work on all pressure parts, including castings
(v) Reinforcement of worn parts
(vi) Reinforcement of propeller shafts
(vii) Hard facing valve seats, etc.
(viii) General structural repairs.

There are two grades of welding as far as the engineer is concerned (Grade ' A ' and Grade ' B '). The former is for welding pressure vessels and highly stressed structures, while the latter is for general work. The specifications for these particular requirements have been issued by the Engineer-in-Chief and it is not proposed to remark on them in this paper.

The fabrication of new items is mainly the responsibility of the design departments and technical sections of the purchaser and contractor and, as the unit is generally supplied complete to the ship, it is proposed to illustrate only one or two items to indicate the possibilities of fabrication, for interest, and to concentrate mostly on the use of welding in repair work.

The drawing in FIG. 1 illustrates the fabrication method of part of a steam manifold used in the steam range of catapults and gives a general indication of constructing a unit without a casting. FIGS. 2 and 3 show the methods used in the manufacture of a catapult cylinder. FIG. 4 shows an ' S ' Class submarine engine frame fabricated by welding and FIG. 5, the completed fabrication of the support beams, with the torque box, for the two Deltic engines in a coastal minesweeper. This last is produced in 5 per cent magnesium aluminium and was welded by the argon arc process. In each of the items illustrated, in addition to ensuring that the material is of sound quality, a great saving of weight is effected over the cast counterpart.

Welding has been universally adopted for pressure vessels, and automatic welding is used if at all possible. Each joint has to be specially designed for welding, and multiple runs are preferred to single passes, so that the grain structure of the joint is refined as much as possible. It will be realized that strict supervision is essential and that all defects which affect the strength of the joint must be removed.

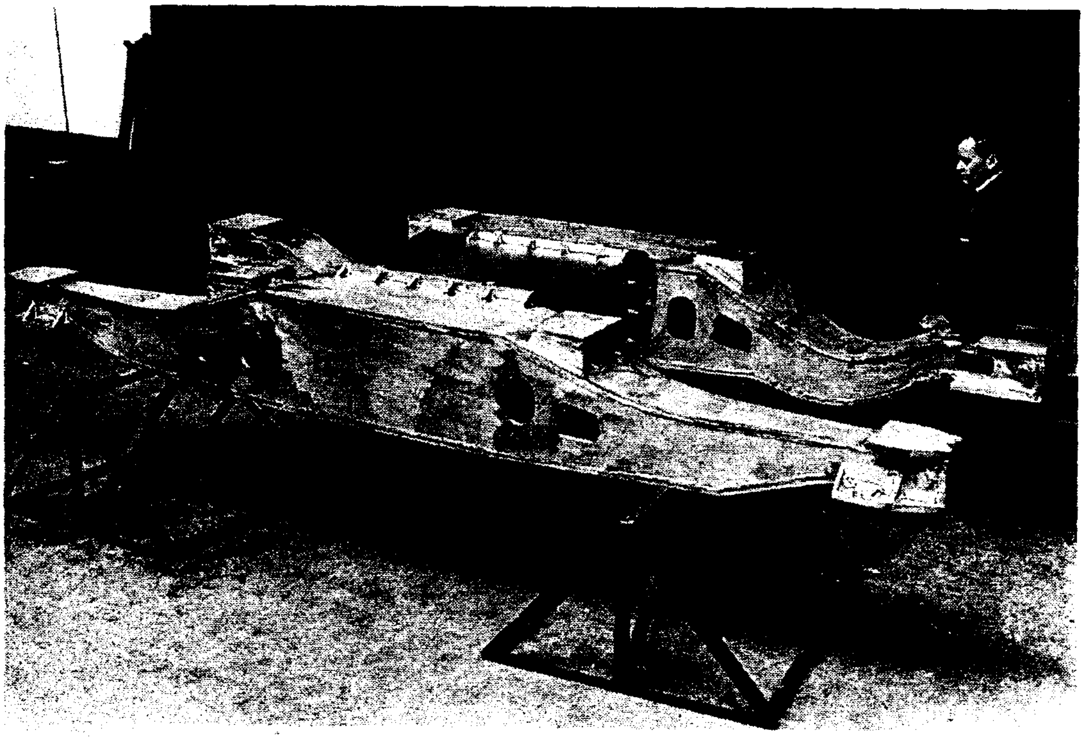


FIG. 5—SUPPORT BEAMS AND TORQUE BOX FOR TWO DELTIC ENGINES
(*Windshields of Worcester Ltd.*)

Pipe Welding

All pipe systems in a vessel now have welded flanges, of one type or another and whereas the plate or ring flange is most in demand, special requirements for steam pressures and temperatures require special types of flanges. There are various methods of attaching flanges but, to date, welding of pipe lines (pipe to pipe, pipe to flange, branches, etc.) has been mainly done by hand. Flash butt welding is used in some instances, but the final section of the weld is not all that is desired. This applies especially to pressure systems. A recent improvement has been the development of the Burton butt welding machine which produces welds automatically to Grade 'A' standard continuously. The machine uses the pressure butt system and produces a plastic and not a fluid weld. The method has proved very successful and nearly all the pipe work in the engineering section for the refit of H.M.S. *Victorious* has been welded by this process.

A future requirement is an *in situ* unit of this machine, and investigations are in hand for its production. With its advent it is envisaged that certain pipe systems in ships may, in the foreseeable future, be of all-welded construction, eliminating flanges wherever possible.

The 'casting-cum-fabrication' technique is a new use of welding by which the casting in one piece of large items like turbine casings can be eliminated. Small intricate portions will be cast individually and the several pieces will be welded together. In this way, casting defects will be greatly reduced. This method shows great promise and indicates the trend in future design.

The items mentioned above are only a small proportion of the type of welded fabrications now being done, but they give a guide as to the possibilities.

REPAIRS

The main consideration of the engineer officer at sea is, however, to maintain the machinery in the highest degree of efficiency. In the field of maintenance, welding can play a most important part but, here again, the material used must be taken into account.

Boilers

With regard to boilers of the water-tube type, such as fitted in most naval vessels, it is not advisable to undertake any repairs involving welding except under extreme emergency and, even then, due consideration must be given to an acceptable method of repair. In any case repairs must be carried out in accordance with B.R.16, Article 183, and B.R.1988, Article 0415. Repair of pressure vessels by welding can only be permitted at present if the material is mild steel.

Under no circumstances must welding be attempted on the new type of pressure vessel for boilers now in operation in the latest design destroyers, frigates, etc., because the drums are manufactured in alloy steel and any attempt at welding would cause cracking. It must be realized that, although welding can be used for repairs to boiler drums, it should only be undertaken after approval has been obtained from the Admiralty.

With regard to cylindrical boilers, extensive repairs have been carried out in various parts of the boilers and the methods adopted have saved a great deal of time and have enabled the repairs to be carried out *in situ*. Examples of this type of repair are :—

(*a*) The removal of stress cracks in various parts of the boiler, such as in the roots of front and back end flanges, Gourlay ends of furnaces, and the reinforcement of the excavated portion to bring the area to the original thickness.

(*b*) The reinforcement of corroded parts which have been worn by steam or water leakage.

(*c*) The removal of a defective plate from the combustion chambers, etc., and the replacement of the part by butt welding a new plate in position.

A recent example of the repair to a combustion chamber of a cylindrical boiler which was done in place, is the removal of the tube plate of a combustion chamber, which was cracked in several positions, and its replacement by a new plate. Repairs of a similar kind in earlier times would have necessitated the removal of the front of the boiler, but in this repair, a portion of the front plate was removed of sufficient dimensions to allow the width and flange depth of the tube plate to pass through. The furnace was repaired while it was removed from the boiler, and on replacement of the new tube plate, the slot cut in the front plate was filled by a patch, welded in with butt welds. The welds were X-rayed, and the furnace replaced. The repair was carried out by the Engineering Department of H.M. Dockyard, Sheerness, and proved a great success. A sketch showing the method is given in FIG. 6.

Recent designs of boilers tend towards welded fabrication, and all branch pipes are now welded in position. This applies especially to the superheater tubes in water-tube boilers. The stubs are a fixture in the drum and the tubes are welded to the stubs. Any replacement necessitates cutting the joint and welding the new tube to the stub.

It must be pointed out, however, that all welding repairs of whatever class in the repair of boilers is a specialists job, and should only be undertaken by approved welders.

In recent designs, the boiler casings will be found to be of stainless steel, seal welded to make the unit pressurized. If any repair has to be carried out, the

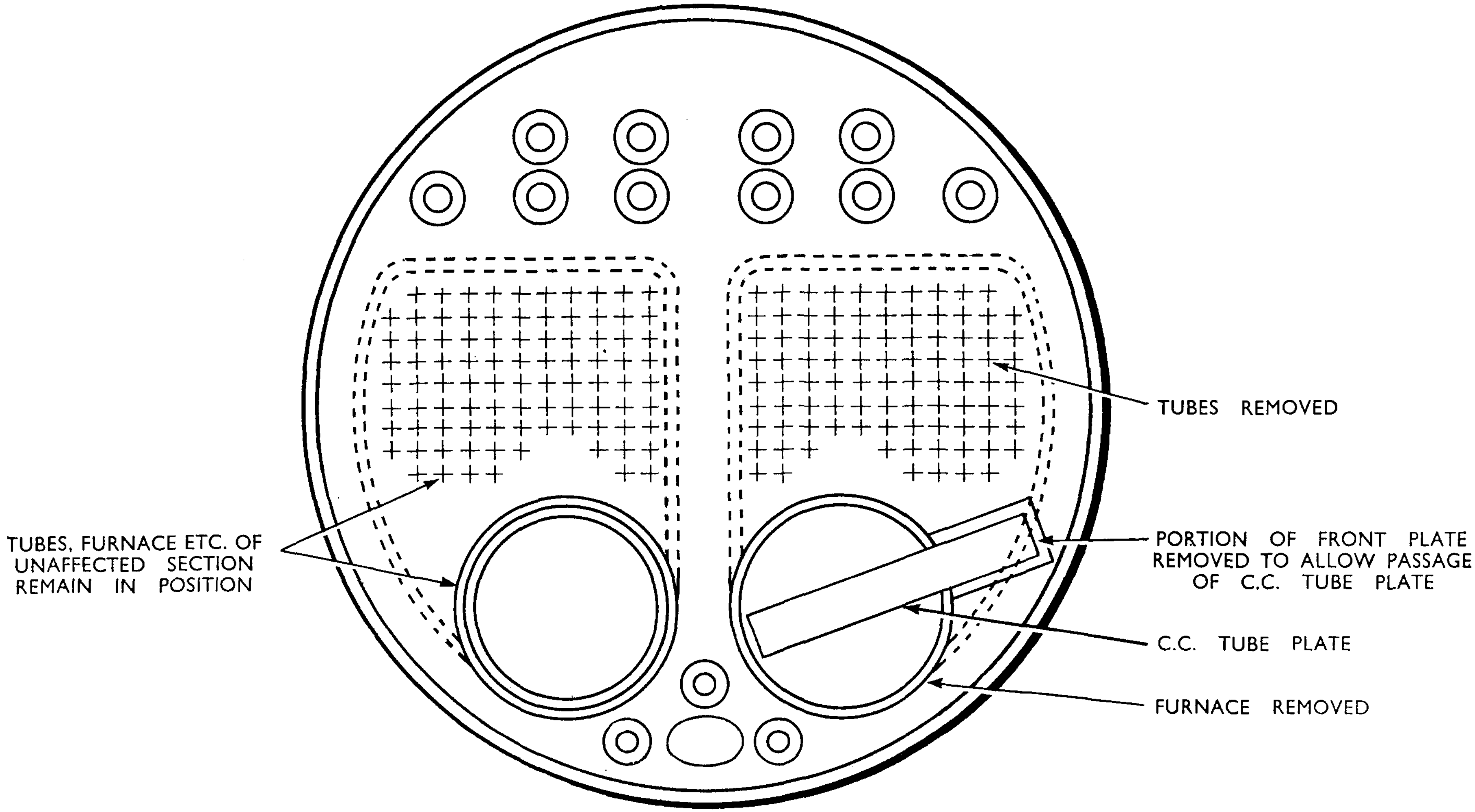

TUBES REMOVED
TUBES, FURNACE ETC. OF UNAFFECTED SECTION REMAIN IN POSITION
PORTION OF FRONT PLATE REMOVED TO ALLOW PASSAGE OF C.C. TUBE PLATE
C.C. TUBE PLATE
FURNACE REMOVED

FIG. 6

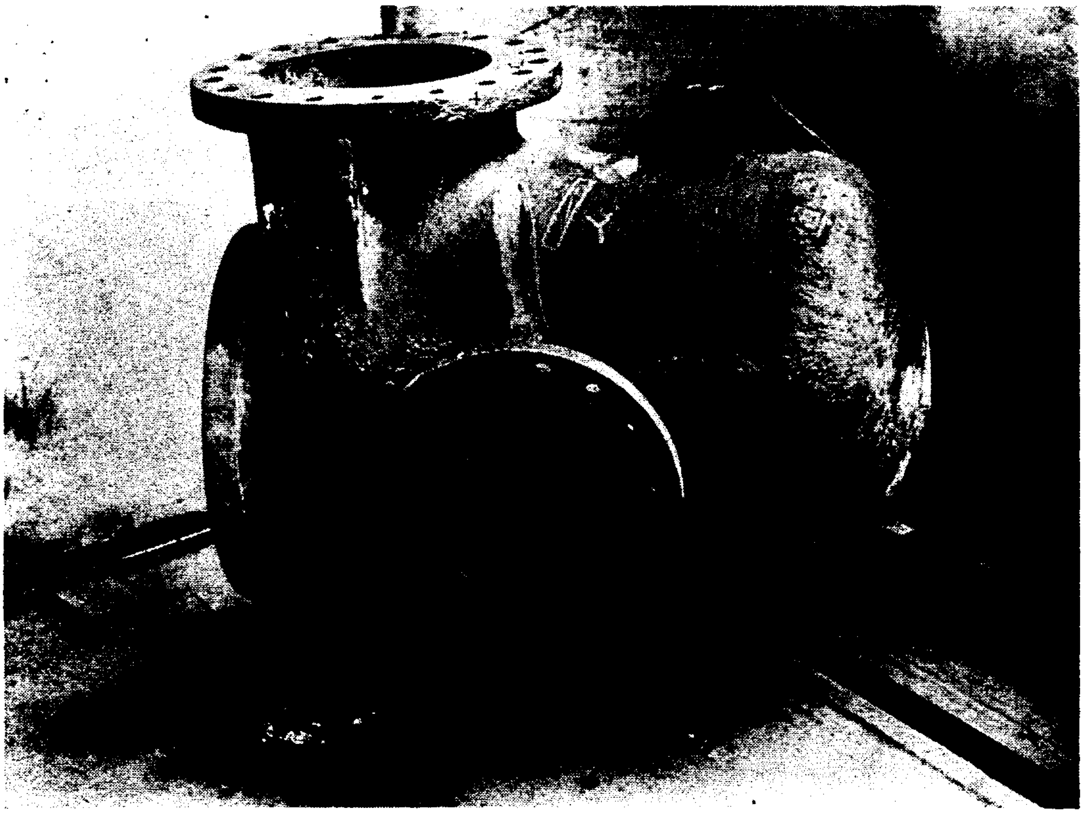


FIG. 7

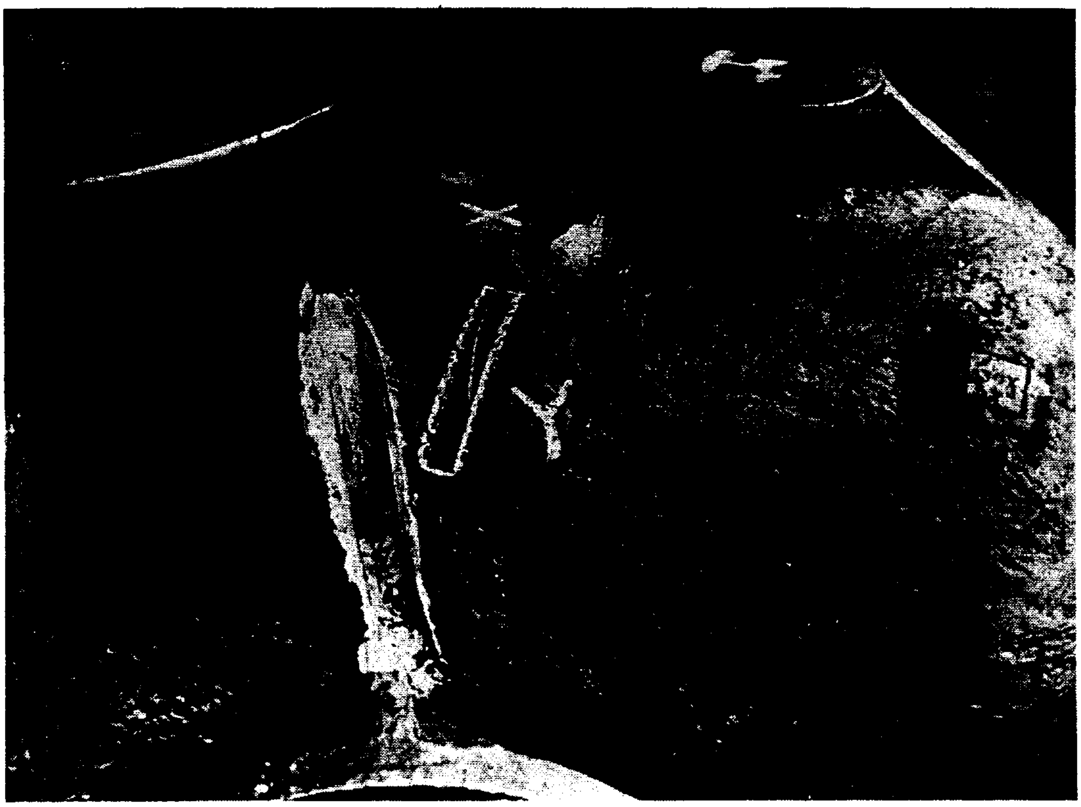


FIG. 8

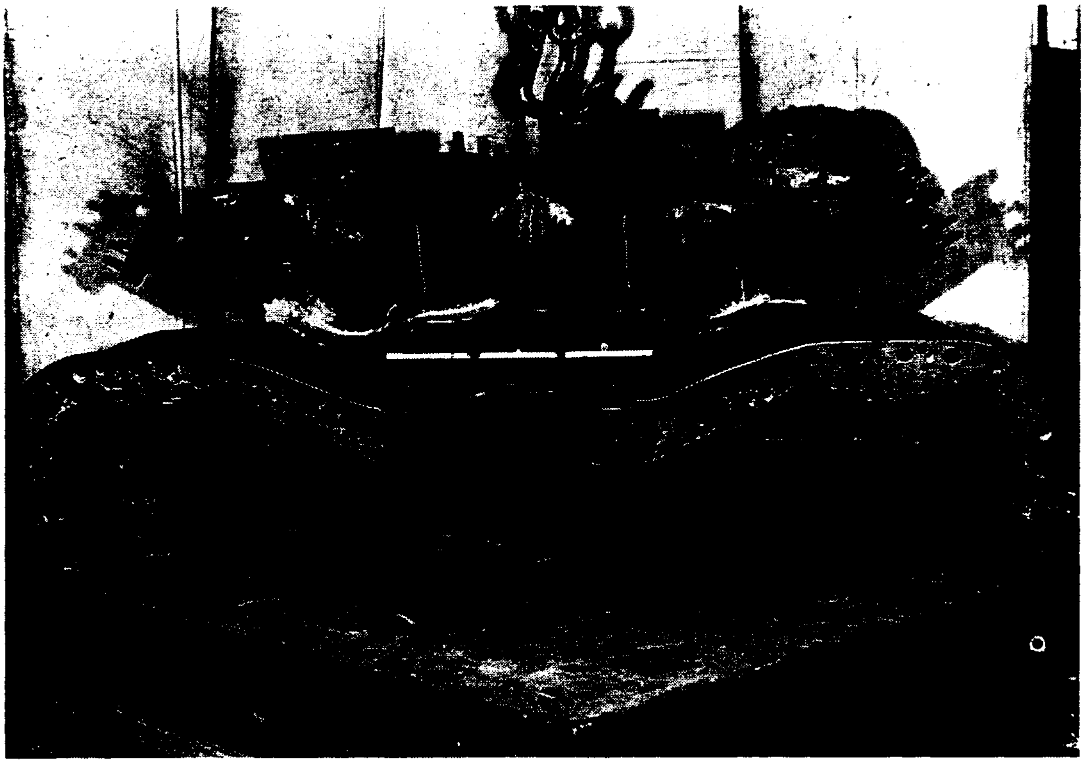


FIG. 9—ASTERN NOZZLE BOX OF H.M.S. ' CAMBRIAN '

seal weld will have to be broken, the repair made, and the casing replaced and re-welded. This may involve possible spot welding of strips, etc., and the use of the argon arc process to seal the casing finally. Provision has been made in dockyards for spot welding machines, and the welding of the casing has to be done on site.

Valves

In the case of stop valves, safety valves, etc., defects have been found, after service, in the castings. They have included cracking due to original hot tears, blow-holes, and scouring by the passage of steam. Welding has been used as the method of repair. The defective portion is first removed and the position is X-rayed to ensure complete removal of the defect. The area is then reinforced, using the appropriate preheat, the correct welding rod and the proper technique. The unit is then stress-relieved as far as practicable and, if found satisfactory after X-ray, is tested and replaced. An example of such a repair is shown in FIGS. 7 and 8. In this type of application it is essential that correct welding sequence and a judicious application of preheat is employed so that the casting is not distorted.

The seal welding of valve seats into the casting to stop leakage is a recognized practice. This matter is now under review and further instructions, based on recent experience, will be issued in due course.

All welding of valves should be carried out by the arc process, and the material must be analysed before welding is undertaken, so that the appropriate welding procedure can be adopted.

Pipe Lines

Repairs to pipe lines may be undertaken by welding, but cover patches must be avoided. If a pipe is damaged, it is better that the defect is removed by

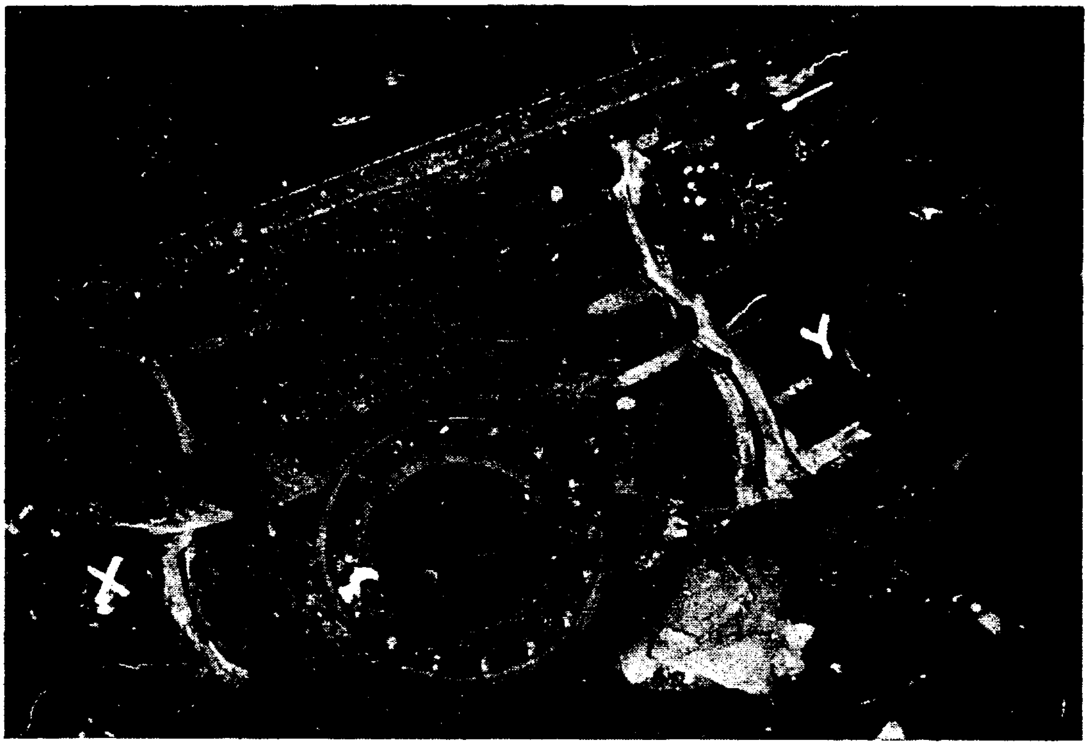


FIG. 10—ASTERN TURBINE CASING, H.M.S. 'SCORPION': TYPICAL EXCAVATION
(*C. M. L., Portsmouth*)

cutting out the portion of the pipe, and replacing by a new section. Pipe welding is a specialist job and should only be undertaken by experienced operators.

Turbines

During service, many cracks have been found in main turbine casings due to original defects, etc. Some examples of welding repairs carried out on such items to keep the units in service are illustrated. FIG. 9 shows the weld repair carried out on the astern nozzle box of the turbine of H.M.S. *Cambrian*. The initial defect was only noted by a small crack of approximately 3 in. in length under each valve box, but on removal to the shop and examination by X-ray, the final excavation extended as shown to approximately 4 ft 6 in. in length, $1\frac{7}{8}$ in. deep and $2\frac{5}{8}$ in. wide. The unit was jigged, preheated, and welded. After the final weld, the unit was stress-relieved, and finally machined. On replacement the item slipped over the fitted positioning bolts without trouble.

Other turbine repairs of a similar nature have been effected on the Weapon Class destroyers. A typical example of the excavation to the astern casting of *Scorpion* is shown in FIG. 10. The defects were caused by the presence of support brackets for the regulating valves. These were removed and, after X-ray examination, the defective portions were removed, and the whole area reinforced. The unit was finally X-rayed to ensure a perfect weld, stressed relieved and replaced.

It is essential that when undertaking the repair of castings the following general rules should be observed :—

(i) Take the chemical analysis of the casting material.
(ii) Free the casting as much as possible to give freedom of movement without endangering the final shape of the unit by distortion.
(iii) Chip out the crack until the defect is no longer visible by examination by crack-detector, or if possible X-ray, examination.

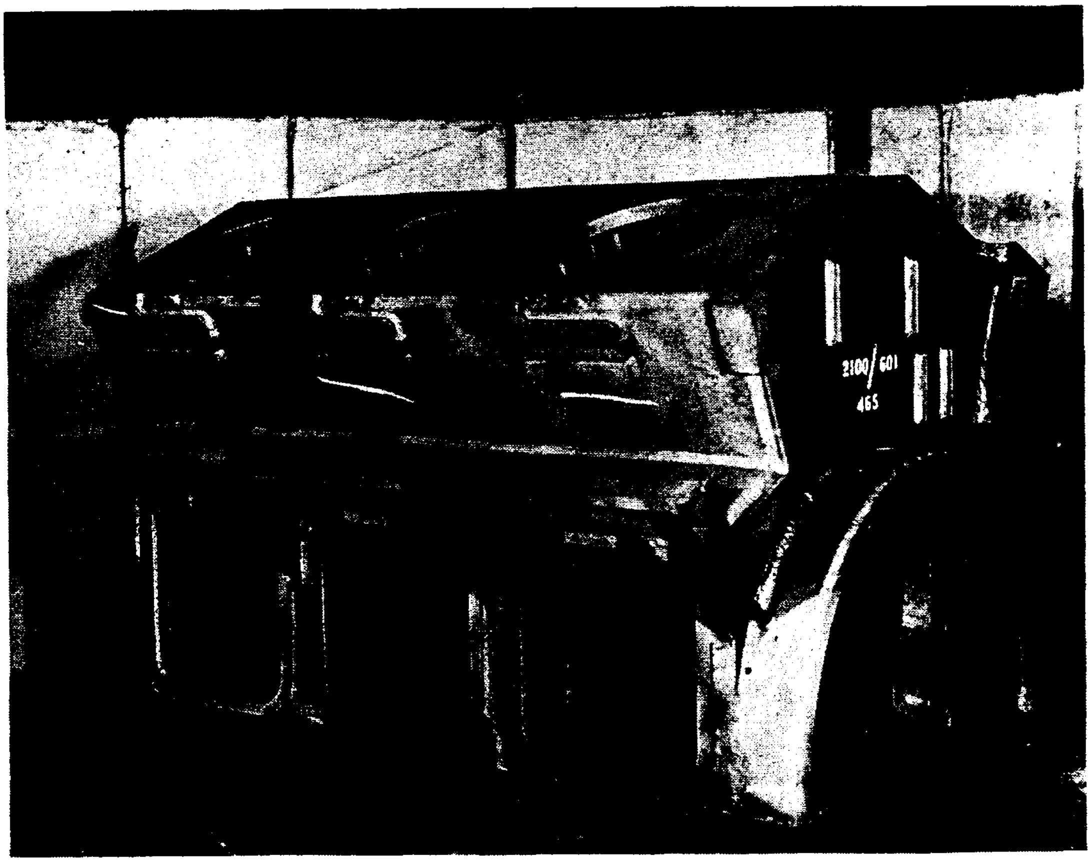


FIG. 11—FABRICATED A.S.R.1. FRAME
(*M. L., Chatham*)

(iv) Ensure that no possible traps for slag are in the excavation, by smoothing off the weld section.
(v) Preheat to the required temperature, which depends upon the class of material and the thickness of the unit wall.
(vi) Welding can now be started, but stepped welding may have to be undertaken depending on the nature of the repair.
(vii) On completion of welding, dress the weld and examine by X-ray if possible, to ensure that no defects are present in the weld.
(viii) Stress relieve to the required temperature.

It will be seen that welding offers a wide field for repair work in all classes of turbine work, and enables repairs to be carried out *in situ* with the minimum removal of engine-room fittings and in the minimum of time.

Diesel Engines

All submarine engine frames are now fabricated, and this method has developed into a highly specialized undertaking. Cracks often occur in service, however, and such cracks are usually found in the vicinity of the bottom bolt plate of the fabrication. In all cases, repairs have been carried out in place, removing the crack by chipping out, and re-welding the area with suitable electrodes. Preheating is applied as required, but the temperature is in most cases very low because the material is ordinary mild steel of low carbon content. As X-ray examination cannot be carried out on these welds, crack detecting is undertaken to ensure freedom from cracks, as far as possible.

FIG. 11 illustrates the general fabrication of an A.S.R.I. frame, and the type of welding is fully illustrated. Welding repairs are also carried out on all types of I.C. engines, but care must be exercised in selecting the correct technique.

General Fabrication

This type of welding fabrication applies to all classes of engineering requirements, such as tanks, gearcases, condensers, engine beds. An item of interest recently produced is the main support beams together with the torque frame for the installation of the Deltic I.C. engine in the C.M.S.s. FIG. 5 illustrates the beams after manufacture at the maker's works, and it will be seen that the unit is in three pieces, the torque box being in the centre. The interesting point is that the material used is 5 per cent magnesium-aluminium alloy, which gives strength with lightness. This unit was welded by the argon arc process.

Most fuel tanks for the coastal and inshore minesweepers are of aluminium alloy, and the welding of this material is becoming of great importance in the naval field.

Propeller Shafts

Under normal working conditions these shafts become so badly pitted by corrosion that, in many cases, repair by reinforcement, and thus the employment of welding, has become necessary. Various methods have been devised and these are set out in D.E.T.M.33, quoted in B.R.1988 : 0230. It is highly specialized work and should only be undertaken in a suitable repair yard. Distortion of the shaft may occur and great care must be exercised during the straightening process to avoid over-stressing the material. Similar repairs can be done on steel or bronze shafts but approval must first be obtained, because such repairs to a highly stressed shaft may be dangerous. Welding repairs to steel shafts in the vicinity of the propeller cone should not be undertaken, and any repairs to journal positions should be stress-relieved on completion.

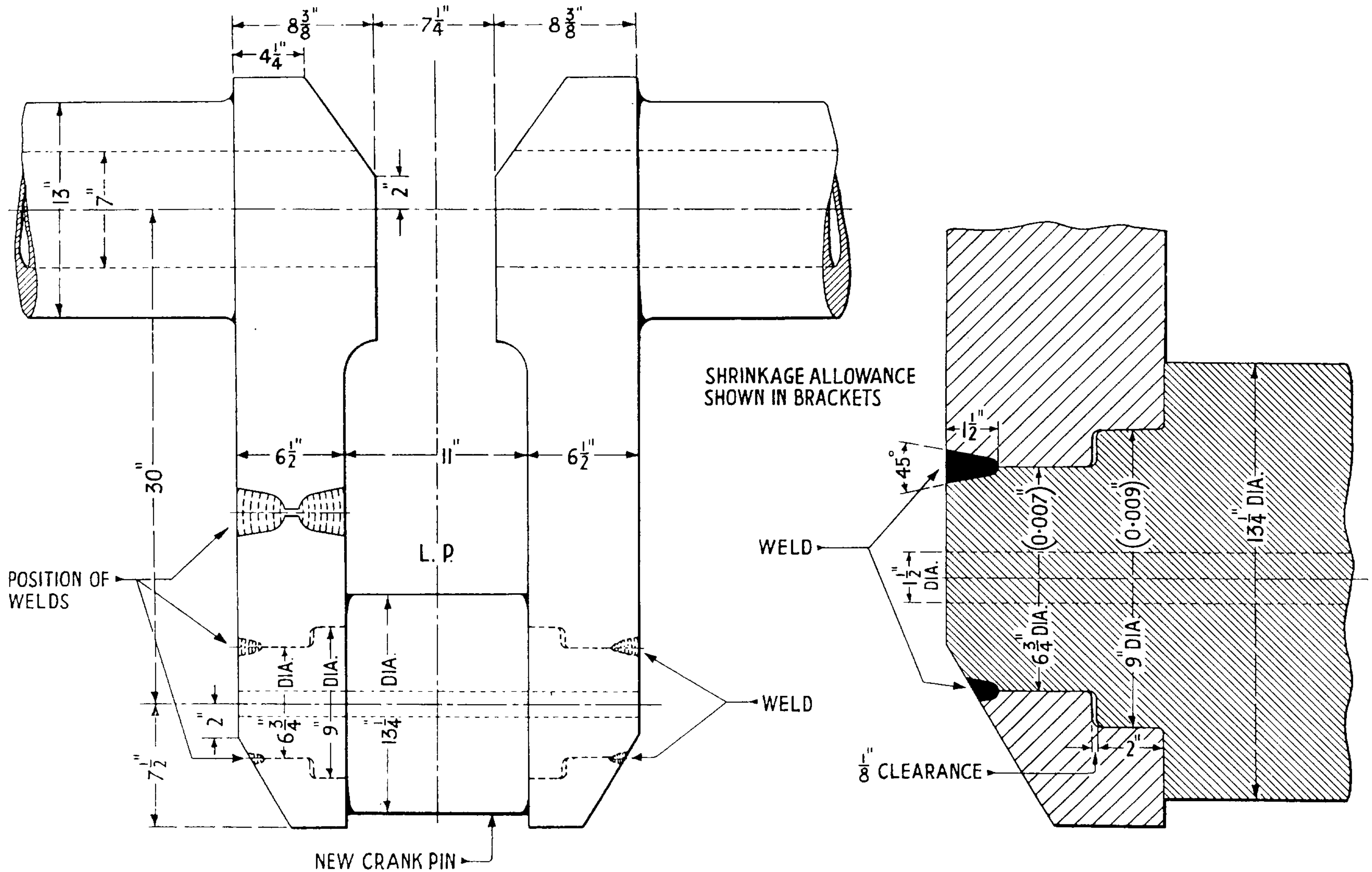
Crank Shafts

Some crank shafts of recent design are being fabricated, but the majority of shafts of all sizes are generally solid forged. Cases have arisen where repairs by welding have been a necessity.

Two Examples

A 'visiting' vessel suffered a fatigue fracture to the crank shaft of an auxiliary engine and a repair was urgently needed. The material was a low nickel-chrome steel alloy and it was decided to attempt welding. It was preheated to 200 degrees C. and tempered, on completion, to 650 degrees C. The crank shaft was replaced and has apparently given good service since. Distortion problems gave a good deal of trouble at first but were eventually satisfactorily solved.

One of the larger repairs made on a crank shaft was to the welded section fabricated on the main shaft of the paddle tug *Firm*. This vessel was required for a special service when the L.P. crank pin fractured from the web, badly affecting the web itself. A replacement would have had a delivery interval of approximately two years, and so a repair had to be made. The pin was drilled out of both webs in such a manner as to provide a shouldered recess as indicated in FIG. 12b, and the damaged web cut at position shown by the weld in FIG. 12a. A new portion of the web was made, shaped to facilitate welding, and secured to the old portion by approximately 180 runs of weld. The welding procedure was arranged to avoid, or counteract, distortion and after final stress relieving the web was machined to the required dimensions. A new pin



A B

Fig. 12—Details of new Crank Pin for the Paddle Tug 'Firm'

was made slightly larger than the holes in the webs, and after fixing the whole shaft in a shaft lathe, aligning the webs correctly, the pin was soaked in dry ice for three hours, while the webs were heated by torches to a black heat. A cradle was set in position to accommodate the pin in the correct position, and, on a pre-arranged signal, the pin was removed from the ice, placed on the cradle, and the webs brought together. On shrinking the pin was securely fixed in the webs, and after a period, seal welds were placed in position as indicated. The work was done in approximately 6 weeks, and the shaft is still giving satisfactory service.

Propellers

These are generally of phosphor-bronze but experiments are now being carried out with stainless steel, and these may be fabricated by welding.

Non-ferrous propellers, however, are generally cast, and at intervals suffer from corrosion and damage to the blade tips. In the case of re-tipping, welding has become prominent, replacing the older method of burning on. Both carbon arc and metallic arc methods have been employed, but the present day trend is to use metal arc with appropriate electrodes.

Chemical Welding

The main advantage of this method is the actual fusing together of two fractured sections by a chemical reaction and it is suitable only for a specific type of repair.

The required shape of the finished section is first made in wax and the fractured portions are prepared to ensure good fusion at the fracture. A mould is built round the wax section and allowance is made for pouring ramps, uprisers and preheating holes. The wax is then melted out and the area is preheated with flame torches until the ends are at a ' red ' temperature, the drain and heating holes being plugged. Above the mould is a container with the chemical mixture in it (usually iron oxide or aluminium). The mixture is ignited by an ignition powder and a violent chemical reaction takes place, ending in the production of aluminium oxide and iron or steel, according to the mixture. This melt is then poured into the mould and allowed to solidify, when the mould is dismantled leaving the weld.

This type of repair is most suitable for castings but is used on small units only in exceptional circumstances.

Stud Welding, etc.

Stud welding of boiler tubes is a general feature in boilers of present-day design. This work can be done in dockyards, but the method has to be very minutely controlled to ensure good welds. It is not a job which can be done on site, and replacements of tubes have to be taken from stock. Stud welding, other than the above, is not generally adopted for engineering purposes.

Spot, seam and stitch welding are not generally used for engineering work except of a special nature.

General

Most ships are now provided with welding equipment in accordance with policy. With the advent of special materials like aluminium and stainless steel, special plant is necessary, and this is being provided to repair and depot ships. It will be realized that each material has its own welding technique and, whereas A.C. can be used with advantage on some materials, D.C. is required for others. With argon arc welding A.C. and D.C. is a necessity.

Electrodes suitable for the respective material must be obtained, and at present these items are patternized in the *Rate Book* under the minimum functional requirements, and each gauge is given a separate pattern number. This arrangement was set out to assist storekeeping and reduce the number of different electrodes maintained in the store. It is essential, however, that, when welding a particular item of machinery, the same make of electrode must be used throughout the repair and, to ensure this, arrangements have been made whereby the same type of electrode can be demanded.

Automatic welding is now becoming more and more advantageous especially in fabrication, because it eliminates the human factor. The first-class welder, however, will always be required for pressure work, and skilled operators will have to be trained to produce the best possible welds at all times.

First-class welding cannot be rushed and, because of this, such schemes as piece-work are not used in industry where pressure welding is done. Any attempt to scamp the work will lead to many defects, such as porosity, piping, slag inclusion, undercut, lack of fusion, cracks, etc., and whereas very slight defects of, say, porosity may possibly be accepted, a combination of slight porosity and small slag inclusions would lead to fracture in service. The acceptable dimensions of such defects have been laid down in the Admiralty Grade ' A ' Specification, and an attempt has been made to create a standard.

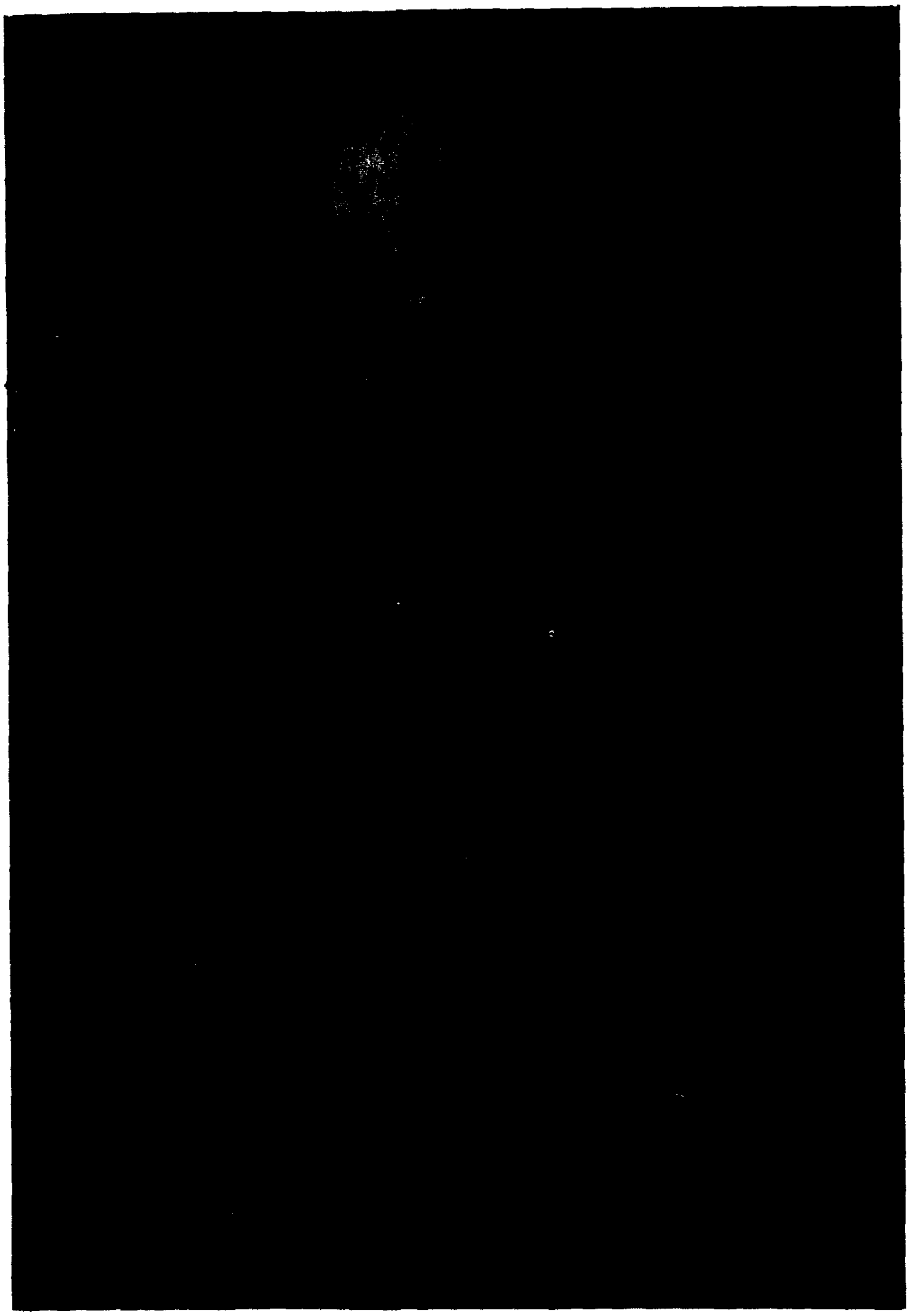
This matter of an acceptance standard for weld faults has been the subject of many discussions in committee both in this country and abroad, but owing to the numerous combinations of defects, and their specific contribution to the strength of the joint, no satisfactory solution of the problem has as yet been found. Thus the acceptance of a weld depends on the skill and knowledge of the inspection officer who thus has a very responsible job in identifying the various defects, summing up their respective value with regard to the position in the joint and the effect on the strength in service, and deciding upon the possibility of partial repair, re-welding or acceptance.

CONCLUSION

It is hoped that the foregoing gives some information on the value of welding in repair and constructional work. In spite of the great possibilities of the use of welding, it is not the answer to all problems and must be used with care and discrimination.

To obtain successful welding, the material must be, to some degree, of weldable quality and due precautions must be taken to ensure the appropriate preheat where necessary, to provide the appropriate electrode to suit the material, to guard against distortion, and to use the correct welding technique. The welder must be made fully aware of the conditions under which the weld is to be made.

A short paper can, of necessity, contain only a small fraction of the requirements for welding, but it is safe to say that welding has become an essential tool in the engineering world and one which, if properly used and developed, will prove a valuable method both of repair and manufacture in the Navy.



INSPECTOR OF MACHINERY J. A. SMITH, R.N.

E.A.P. TO D.O.A.(E)

BY

COMMANDER I. J. LEES-SPALDING, R.N., A.M.I.MECH.E.

Joseph Andrew Smith, born in 1847, was promoted to the rank of Inspector of Machinery in 1898 and appointed '*President* for service at the Admiralty' on 25th October, 1898. His duties were not specified and he did not relieve anyone. He became a Chief Inspector of Machinery and was relieved in April, 1899, by W. H. Riley who had ' undergone a course of instruction at Kensington and was entered as an Acting 2nd Class Assistant Engineer ' in September, 1874.

Having risen through Acting 1st Class Assistant Engineer, Assistant Engineer, Engineer, Chief Engineer, Staff Engineer, Fleet Engineer, Inspector of Machinery and Engineer Captain, W. H. Riley became an Engineer Rear-Admiral in 1907. He was relieved at the Admiralty in December, 1902, by Chief Inspector of Machinery W. W. Chilcott, C.B., who became an Engineer Rear-Admiral in April, 1903, with seniority of April, 1898 !

It was W. W. Chilcott who was first appointed '*President* additional for service at the Admiralty in connection with engineering personnel and other duties ', and can thus be positively identified as the first E.A.P. It is, however, clear that J. A. Smith and W. H. Riley actually preceded him in the job.

Engineer Rear-Admiral Charles Lane was the next E.A.P. and he reigned for 7 years as captain and admiral from December, 1905, to November, 1912, when he was relieved by Engineer Captain (later Engineer Rear-Admiral) W. T. Hocken. Admiral Hocken was on duty in his office only a few days before he died suddenly on 28th August, 1914, at the age of 54.

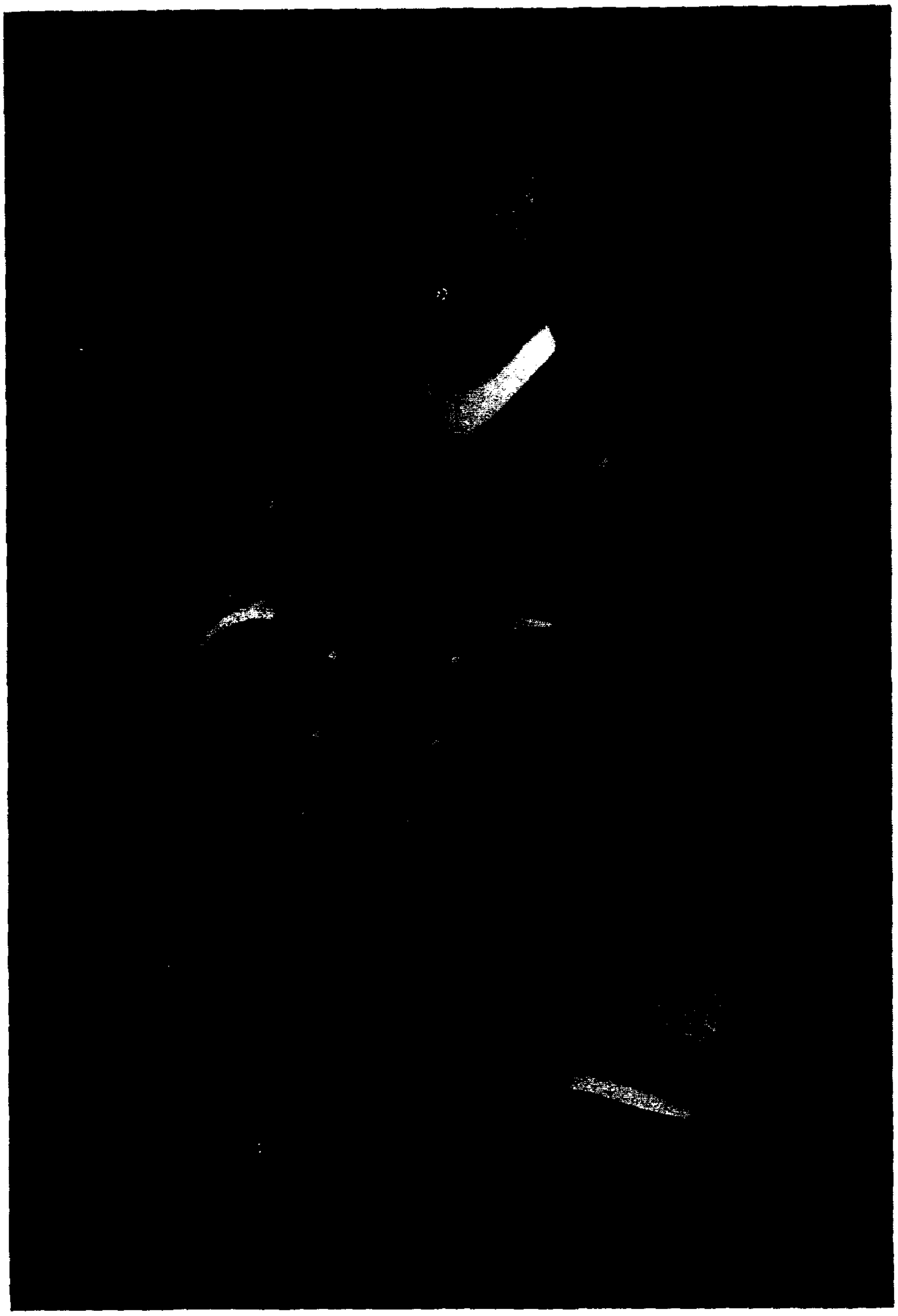
The pendulum now took its first swing and his successor, Engineer Rear-Admiral W. J. Anstey, C.B., was appointed ' *President* additional for service in E.-in-C. Department, Admiralty, for duties in connection with engineering personnel ', thus putting the (E) appointing authority under E.-in-C. When his successor, Engineer Captain (Engineer Rear-Admiral, 18.1.20) William Toop took over, the pendulum swung the other way and he was appointed ' . . . as Extra Naval Assistant to the Second Sea Lord for engineering personnel duties ', so changing allegiance back to the Second Sea Lord. I believe it must have been at this stage that the short title E.A.P. was coined.

Engineer Rear-Admiral Toop set the fashion, which has been followed to the present day, of serving as E.A.P. clean shaven, his predecessors having all been bearded. He died only seven years ago at the age of 82.

Engineer Rear-Admiral William Rattery, C.B., O.B.E., was E.A.P. from February, 1923, to May, 1928, when he was relieved by Engineer Rear-Admiral H. L. Parry, C.B., O.B.E. In September, 1931, H. L. Parry was in turn relieved by Engineer Rear-Admiral E. W. Roberts, O.B.E. Admiral Roberts had had an interesting career, including appointments to '*Britannia* additional as instructor of cadets in steam and the steam engine ', as an engineer sub-lieutenant, and to ' *President* additional for service at the Admiralty, as Assistant Director of P. and R.T. and Secretary of the Sports Control Board ', as an engineer commander. It is about this time that one notices that senior officers were spending more and more time ashore, most of Admiral Roberts' predecessors having spent almost all their careers up to and including their captain's time at sea.

Admiral Roberts actually became E.A.P. as an engineer captain and was promoted to engineer rear-admiral in December, 1932. He had been captain of the Royal Navy Rugby XV and captain of England and was still an England selector in 1933. He died in his sleep on 19th November, 1933, having only that afternoon watched the final England trial.

Rear-Admiral T. Gurnell, C.B. (who was awarded the Order of St. Anne, Third Class, with Swords, by the Russians for his services in the Battle of Jutland in the *Termagant*) was appointed as his relief but only remained in office for ten months before retiring voluntarily in September, 1934. From September, 1934, until January, 1948, two officers only held the post of



ENGINEER REAR-ADMIRAL W. TOOP, C.B.

E.A.P.—first Engineer Rear-Admiral T. H. Warde, C.B., and from November, 1940, Rear-Admiral (E) C. H. Nicholson, C.B., C.B.E.

Captain (E) Sydney Brown became E.A.P. in January, 1948, but went to hospital seriously ill in August, 1948. When it was clear that he would be sick for a long period, Engineer Rear-Admiral Sir Sydney Frew, K.B.E., C.B., was appointed *in lieu,* and remained until Captain Brown became fit and was promoted to rear-admiral in November, 1949.

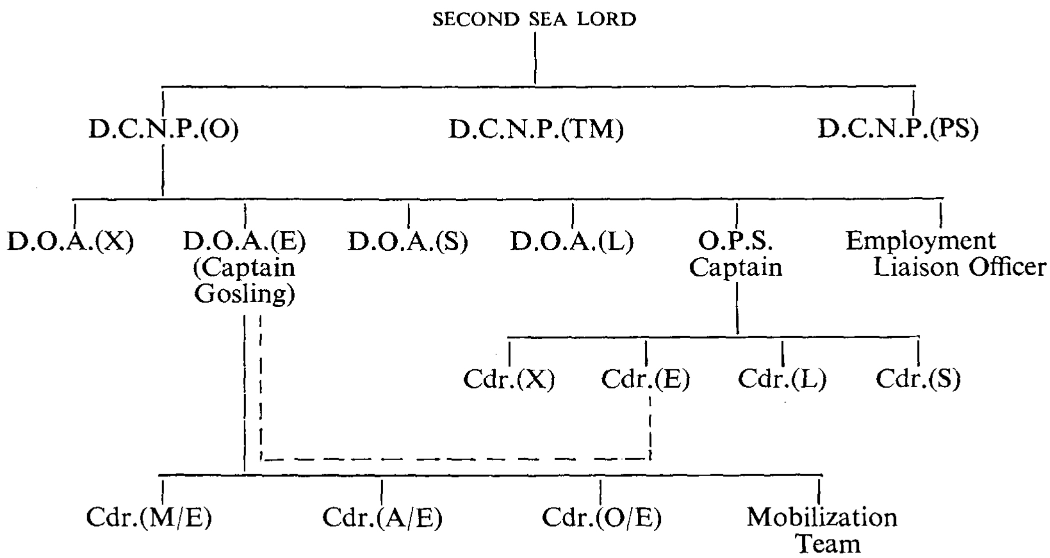
In October, 1953, Admiral Brown was relieved by Rear-Admiral P. C. Taylor, C.B. During the latter's term of office, the pendulum swung back again with his appointment as Deputy E.-in-C. (Engineering Appointments and Personnel), so preserving the popular title of E.A.P., and making him responsible to the Engineer-in-Chief for appointments of commanders and below, instead of to the Second Sea Lord. The Engineer-in-Chief was in tu responsible to the Second Sea Lord for all (E) officers' appointments.

From November, 1956, until the post was abolished on 18th February, 19! Rear-Admiral R. T. Sandars was E.A.P. On the latter date, the Directorate Officer Appointments was created, and Admiral Sandars became Depu Chief of Naval Personnel (Training and Manning).

The portrait gallery which used to adorn the walls of Room 945 in Que Anne's Mansions, one of the loveliest of offices, will in due course be hung the lobby of D.O.A.(E)'s suite, (Rooms 327, 328, 329) but at present it sto short at Admiral Frew. It is hoped to bring it up to date soon.

As announced in A.F.O.1/56, ' the responsibility for advising the Board (appointments of General List officers of the rank of commander and belc will be assumed by a single authority under the superintendence of the Secoı Sea Lord ' (A.F.O.1/57, paragraph 22). This authority is the Directorate Officer Appointments, with the Deputy Chief of Naval Personnel (Officers)- at the time of writing Rear-Admiral Sir Charles E. Madden, Bt., C.B., but d to be relieved by Rear-Admiral D. E. Holland Martin, D.S.O., D.S.C.—as i head. Under him there are four sections (X, E, S and L) with a captain of t status of a Director in charge of each, and responsible for the duties previous carried out by N.A.2 S.L., D.E.-in-C. (E.A.P.), D.D.G.S. and D.N.L.D. The is also a planning staff with a captain in charge and four commanders formiı the Officer Planning Section. These Sections, together with the Mobilizati(and Employment Liaison Officer, are all housed in the Directorate on tl third floor of Queen Anne's Mansions.

Diagrammatically, detailing only the D.O.A.(E) and the O.P.S., it can l shown thus :—



A certain number of common services, such as a typing pool and registr are combined, and it is hoped that the organization will become more close knit as time goes on. This physical contiguity has a far greater co-ordinatir effect than might be imagined, for although little cross-appointing in the low(ranks can be achieved at present, one at least feels that we are all acting i concert.

D.O.A.(E) and his assistants are as approachable as E.A.P. always has beeı and it is intended that the same personal relationship shall continue betwee them and the officers of the Fleet.

' What's in a name ? that which we call a rose
By any other name would smell as sweet '.