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Report

REMOTELY OPERATED WELDING MACHINE

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Abingdon Oxfordshire
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ABSTRACT

This paper outlines the design of a remotely controlled welding machine used to automatically weld together segments of a large stainless steel torus.

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SUMMARY

This paper outlines the design of a remotely operated welding machine which can be used to automatically weld together segments of a large stainless steel vacuum vessel into a complete torus.

The design parameters were that the machine must be capable of being controlled from a remote position outside of the vacuum vessel and to be of a folding construction in order that it may pass through a 250 mm access port. Interchangeable work heads were designed to enable the machine to perform a pre-welding machining function. The machine is driven via a centrally mounted shaft by a variable speed DC motor through a 15:1 worm reduction gear box.

The welding process is by "argon arc" (Inert Gas shielded non-consumable tungsten electrode - TIG). The welding head is operated at a predetermined fixed arc length and with a fixed current setting.

The material to be welded is EN 58E stainless steel of 0.5 mm thickness. To make a successful weld which was mechanically sound and vacuum tight a welding current of 12 amp and an arc length of 0.5 mm was required. The welding speed being 600 mm/sec with an argon flow of 8 litres per minute. No filler material was used. A misalignment of up to 0.1 mm between plates can be tolerated.

The machining head consists of a small air driven milling unit mounted on a sliding work head. A suction unit was fitted beneath the cutter to suck away swarf and chippings to prevent contamination of the vacuum vessel. The tool is a small high speed steel milling cutter so angled that the cutting is by rolling action which eliminates chatter.

This machine has been in use for several months and repeatedly produces good quality welds.

CONTENTS

(1) INTRODUCTION

1.1 One of the main components in some of the fusion research experiments is the toroidal high vacuum vessel which, generally, has to be bakeable to 200°C as a completed vessel and compatable with vacuum techniques capable of giving a base pressure of 10^{-8} - 10^{-9} torr. As the research has progressed the requirements for larger toroidal vessels has increased up to the present size of some 1170 mm major radius and 270 mm minor radius. In the past the vessels have been pressed from stainless steel plate in annular form to produce half tori and then welded together but now due to size a modular approach has been adopted which gives many advantages such as flexibility, fabrication and machining requirements within the capacity of many more contractors and is generally cheaper. However the main disadvantage is the number of large diameter (600 mm) vacuum seals which must be made and as yet there are no reliable seals which can meet the baking and vacuum requirements without very special techniques being employed.

1.2 The solution adopted is to weld the modules together internally during the assembly procedure of the torus but due to the restricted access and requirements for removal at a later stage the weld is made automatically by a purpose built electrically driven machine. This paper describes the requirements, design and operations of this remotely operated automatic welding machine.

(2) DESIGN REQUIREMENTS

To operate successfully the machine had to fulfil the following requirements.

2.1 It must be capable of being fully automatic in operation and controlled from a remote position.

2.2 It must be of modular or folding construction to enable the largest component to pass through a 250 mm access hole.

2.3 The weight to be kept to a minimum so that it may be handled and fitted into position at arms length by an average man.

2.4 The machine must have interchangeable work heads so that it is capable of performing a machining operation as well as welding.

2.5 The power source must have a variable speed output to suit the varying requirements of 2.4.

(3) DESIGN

3.1 Trolley

The two sections of the torus to be joined were finished with a flange of 600 mm diameter. On each flange a shoulder was accurately machined to act as a guide both radially and axially as shown in Fig 1. The trolley - Fig 2 was designed as a 3 limb structure in aluminium for weight considerations with one of these arms pivoted to allow the overall size to be within the 250 mm diameter access hole. The trolley is located in the area to be welded on the flange shoulder and then the third arm raised into position and the slack in the 3 point location is taken up by pressurizing a pneumatic cylinder mounted on the pivotting arm. The second arm of the trolley is used for mounting either the machining head or the welding head, these are bolt-on assemblies with radial movement provided on the fixing via a worm and wheel. A removable counter balance weight is mounted on the third arm. To support the two edge weld rings during the cutting and welding operation two pinch rollers are mounted adjacent to the work area which can be adjusted to suit the work piece. The trolley as set up in a vacuum module is shown in Fig 5..

3.2 The trolley is driven through a centrally mounted shaft by a 0.25 HP DC motor with a speed controller, via a 15:1 worm reduction gear box. This motor gear box unit is mounted on a table inside the vacuum modules and aligned with the trolley as shown in Fig 6. This assembly also has to be mounted within the 250 mm diameter access hole.

(4) MACHINING ASSEMBLY

4.1 Weld Preparation

Prior to welding it is necessary to machine both edge weld rings to the same height and concentric with the welding trolley axis. This requirement together with a possible later requirement to part the completed weld was tackled as a common design problem. Several solutions were tried, the two most successful were:-

4.1.1 Static Tool

A single point tool fitted to the trolley mechanism gave some measure of success. A high speed steel bit was ground into shape similar to a lathe parting off tool with a positive rake. It was aligned on the trolley directly above the weld preparation and was of sufficient width that when fed into the metal was able to machine the insets concentric without the need for axial travel. The main disadvantage of this method was the rigidity required in the tool post within the limited strength of the trolley however this method provided swarf in long chips which was easily collected in a tray and did not contaminate the vacuum torus.

4.1.2 Milling

An end milling cutter was attached to the work arm of the trolley and driven by a ½ HP pneumatic rotary drive. A suction head was fitted around the cutter backed by an industrial vacuum cleaner to remove the swarf. The trials proved unsuccessful mainly due to the cutter teeth picking up the thin edges of the rings and opening up a gap between them requiring yet another process before a welding operation could take place. To overcome this the mounting of the cutter was changed to give a rolling action. This maintained the intimate contact of the two weld preparations and once again the swarf was produced in small spirals which was easily removed by the suction device. Using low radial cutting depths of 0.15 mm and a feed rate of 300 mm/min and providing the support rollers are correctly adjusted the weld preparation is machined virtually burr free, whilst the machine itself operates with little judder. This method will also be used to machine away the welds should it become necessary at any time to remove a modular section of the torus.

The depth of penetration of these welds is in the order of 1 mm hence some 7 or 8 complete revolutions of the trolley are necessary to completely remove the weld and leave parent metal ready for the next rewelding operation.

(5) WELDING ASSEMBLY

5.1 The welding process is "argon arc" (Inert gas shielded non-consumable tungsten electrode - TIG). (Fig 8) It is operated at predetermined fixed arc length and with a fixed current setting. Previous bench trials had established that the two stainless steel inserts (specification EN58E) of 0.5 mm thickness could be successfully edge welded by using a welding current of 12 amps, an arc length of 0.5 mm, a welding speed of 600 mm/sec and an argon flow rate of 8 litres per minute. The welding electrode must be positioned directly above the joint line of the two mating inserts. A varying gap of up to 0.1 mm between inset can be tolerated without detriment to the quality of the finished weld.

5.2 The final trials were carried out on a module using full size dummy flanges to assimilate welding conditions on site. This is illustrated in Fig 6. The starting procedure which gave consistent results was to set the trolley in motion and ensure that it rotated freely and without judder, then strike the arc and commence welding. It is advisable to over run the start of the weld by approximately 10-12 mm to ensure complete homogeneity.

5.3 Various sections of the weld were cut out, polished and etched and examined for flaws. A typical specimen is illustrated in Fig 7.

(6) CONCLUSION

This welding unit has been in use for several months and has repeatedly made good quality welds which have successfully passed a stringent vacuum testing procedure. It is felt that this remotely controlled welding unit could have applications in many other fields on plant and equipment which necessitates argon arc welding.

(7) ACKNOWLEDGEMENTS

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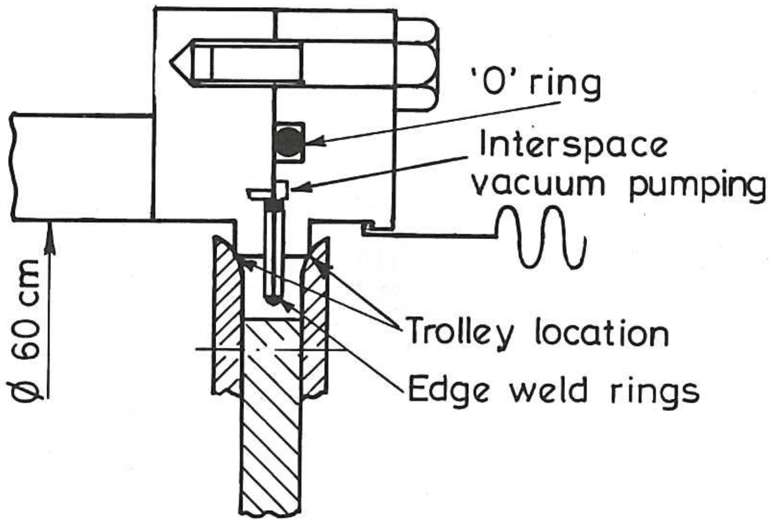
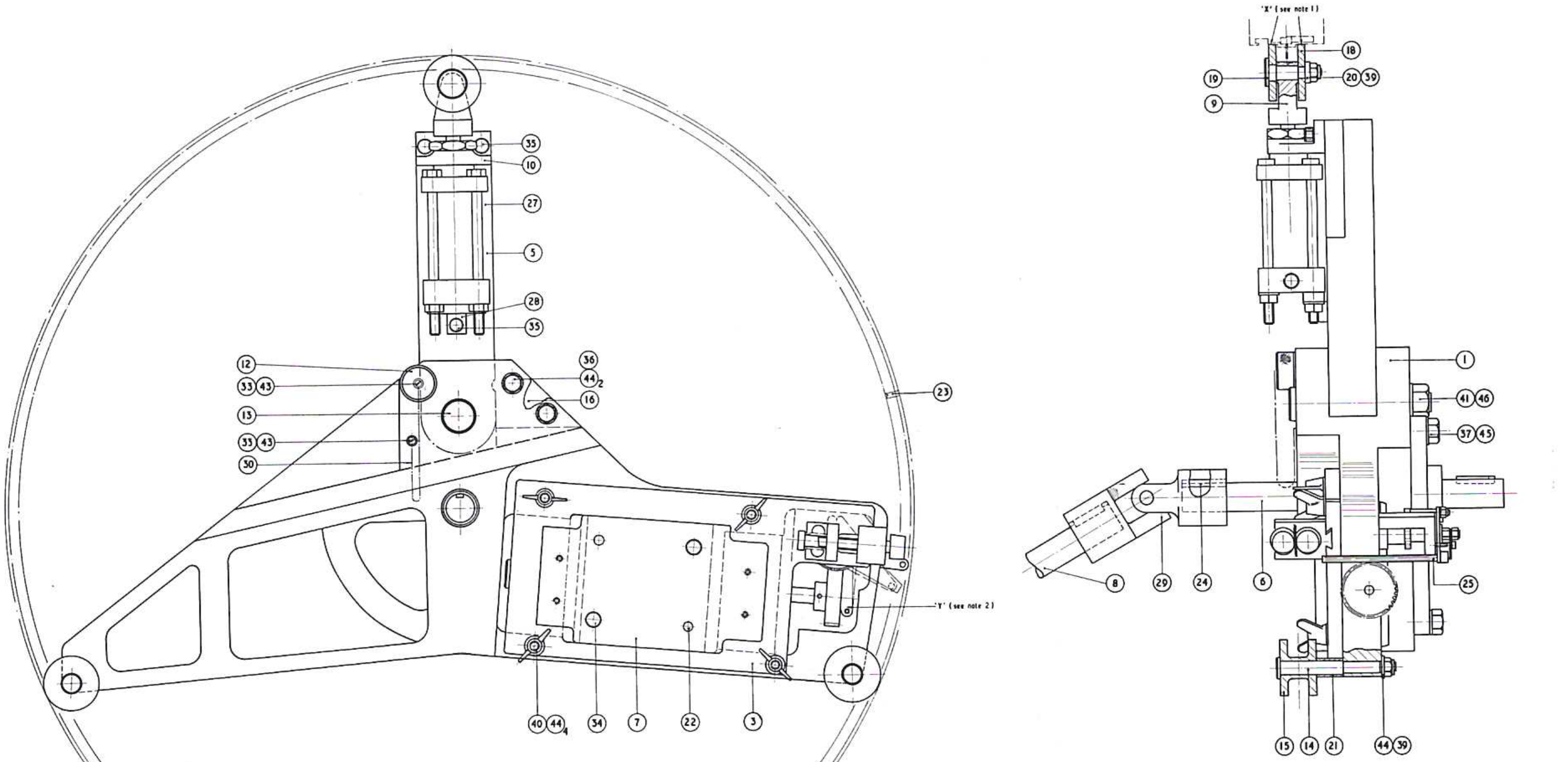


Fig. 1 Machined location guides in module



NOTES.

1. To position cylinder (item 27) on swing arm, attach brackets (items 10 and 28) and roller ass'y (items 17, 18, 19, 20 and 39) to cylinder. Then clamp complete cylinder ass'y to swing arm (item 5) so that, with 1/8" of stroke applied, rollers contact rolling die on rings (at 'X' position in R.H. view.) mark through from 3 holes in brackets, tap 3 holes 1/4" B.S.F. med. fit thread x 1/2" deep, in swing arm.
2. Mechanism block ass'y (item 3) is installed in-situ with ratchet arm in position 'Y' in L.H. view, then rod (item 25) is added separately
3. Motor mounting sub-ass'y (item 4) is not shown

Fig.2 General arrangement drawing of welding machine

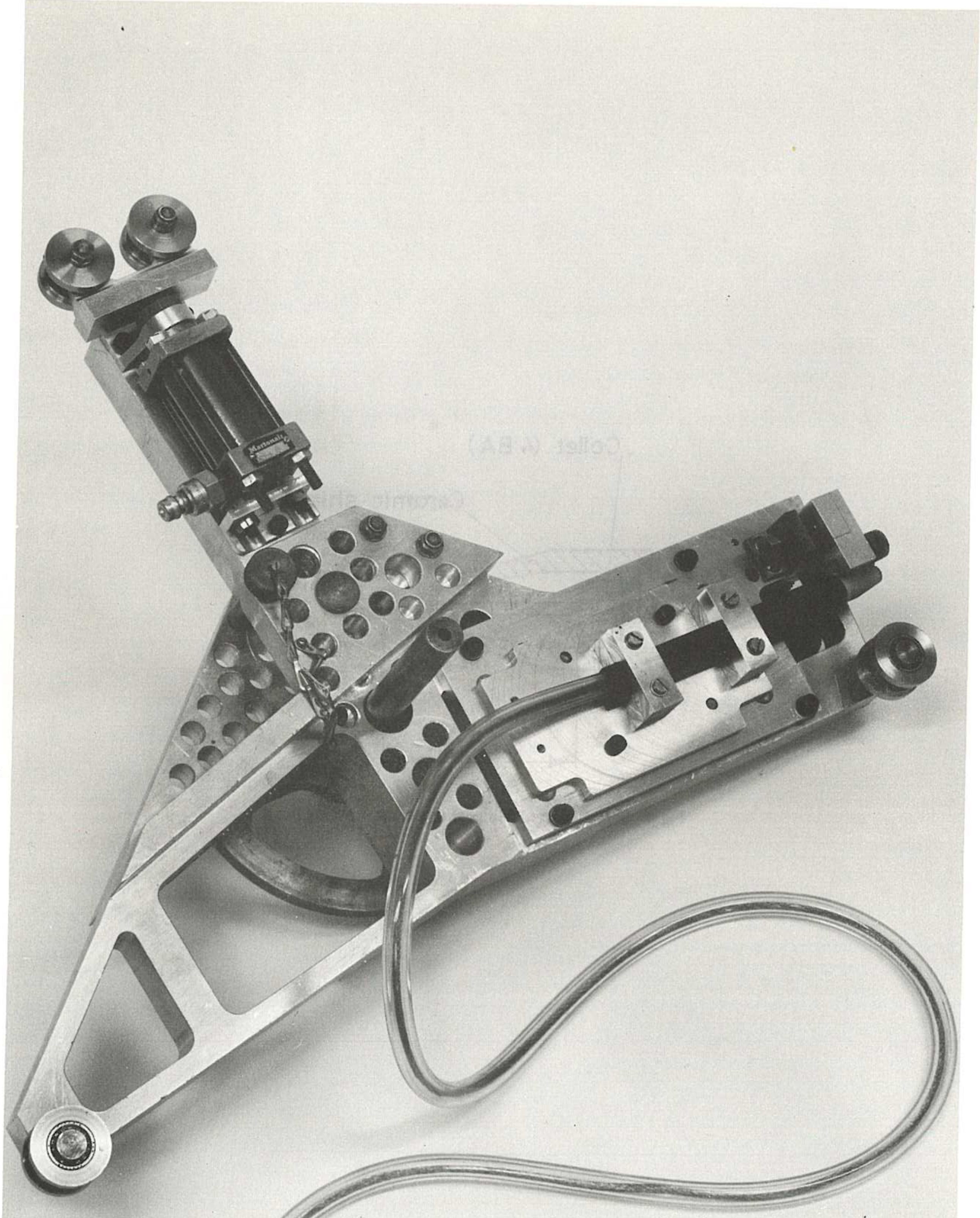


Fig.3 General photograph of welding machine

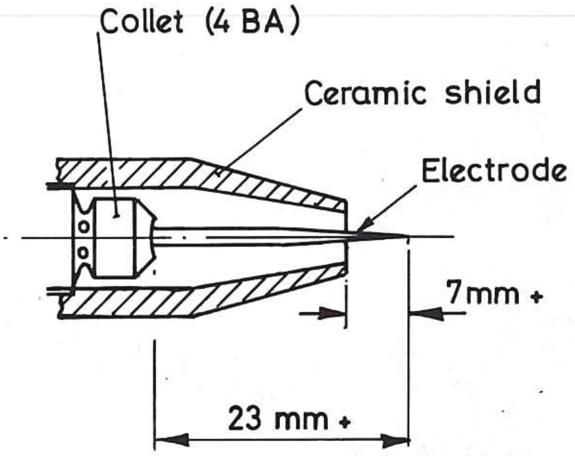


Fig.4 Setting dimensions for argon arc welding head

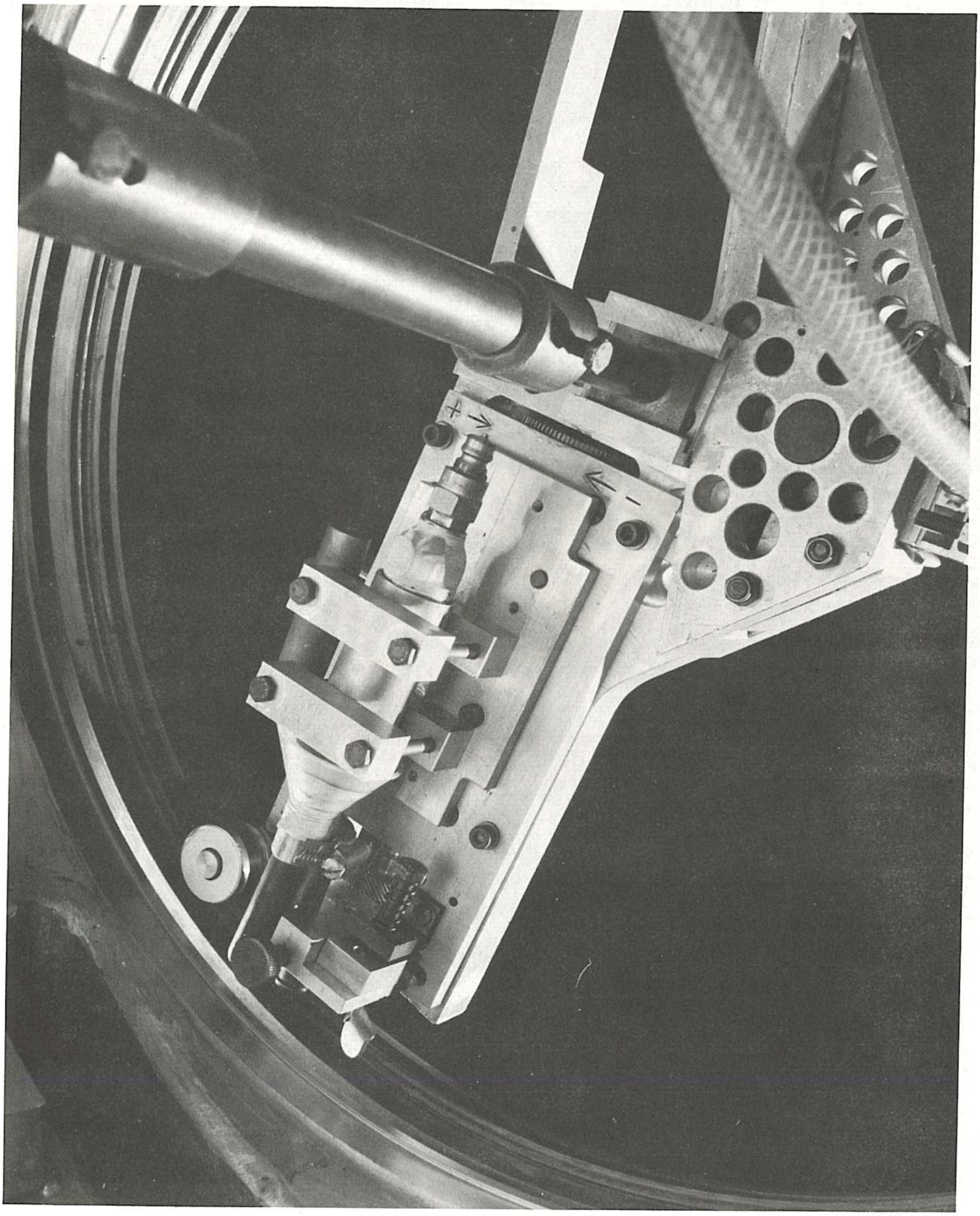


Fig. 5 Machine set up in a module in preparation to machine inserts concentric

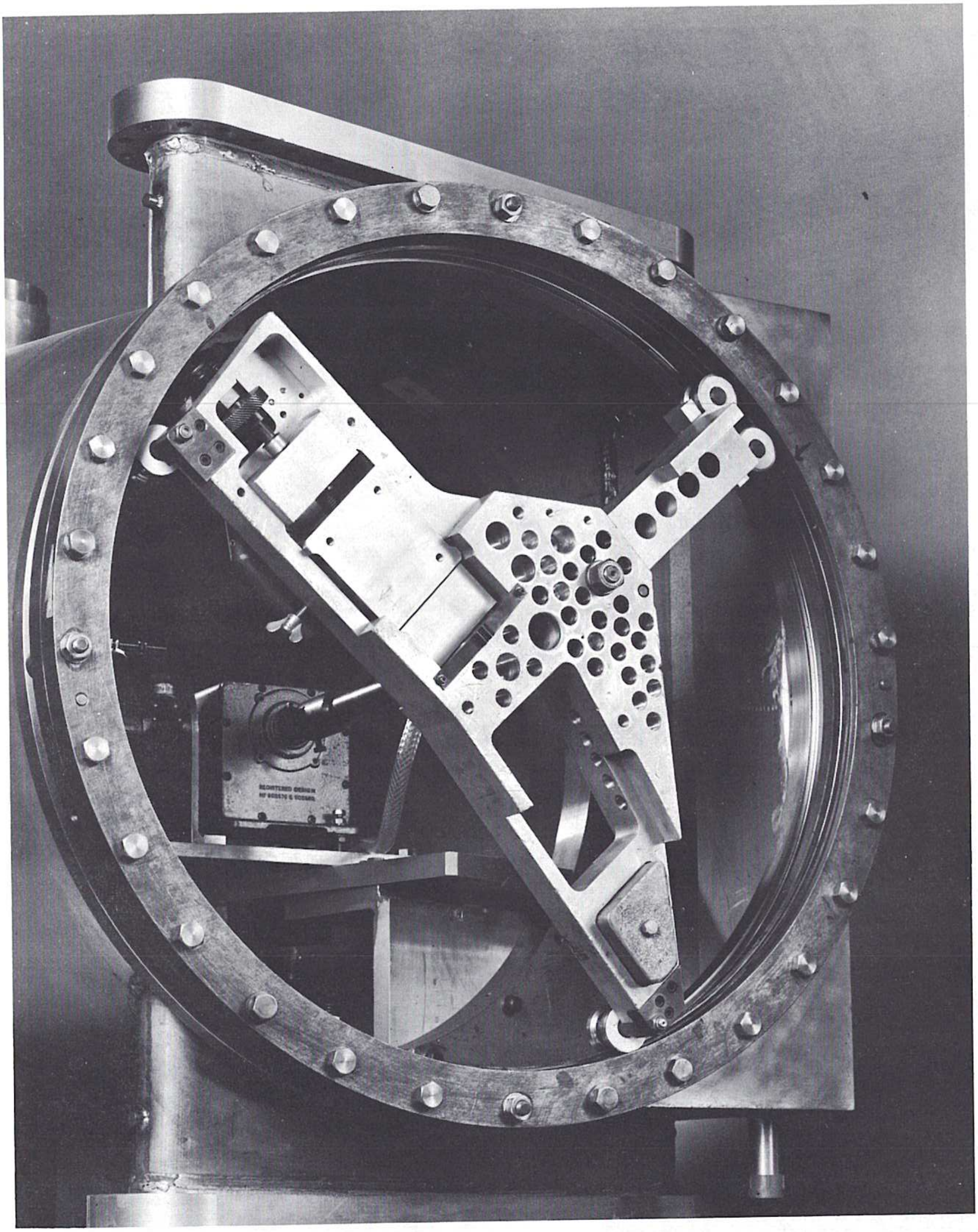


Fig.6 Dummy flange bolted to module

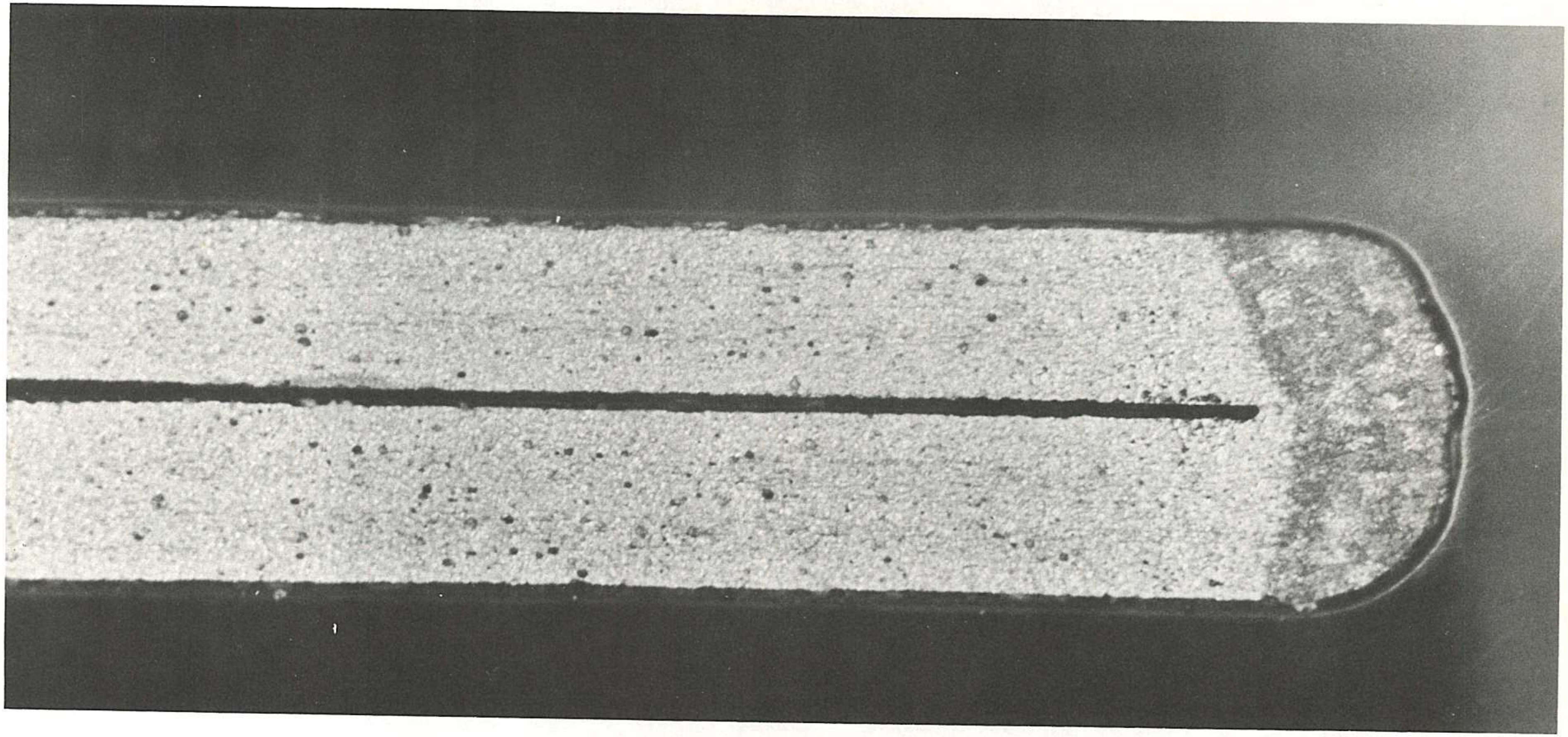


Fig.7 Polished and etched weld specimen

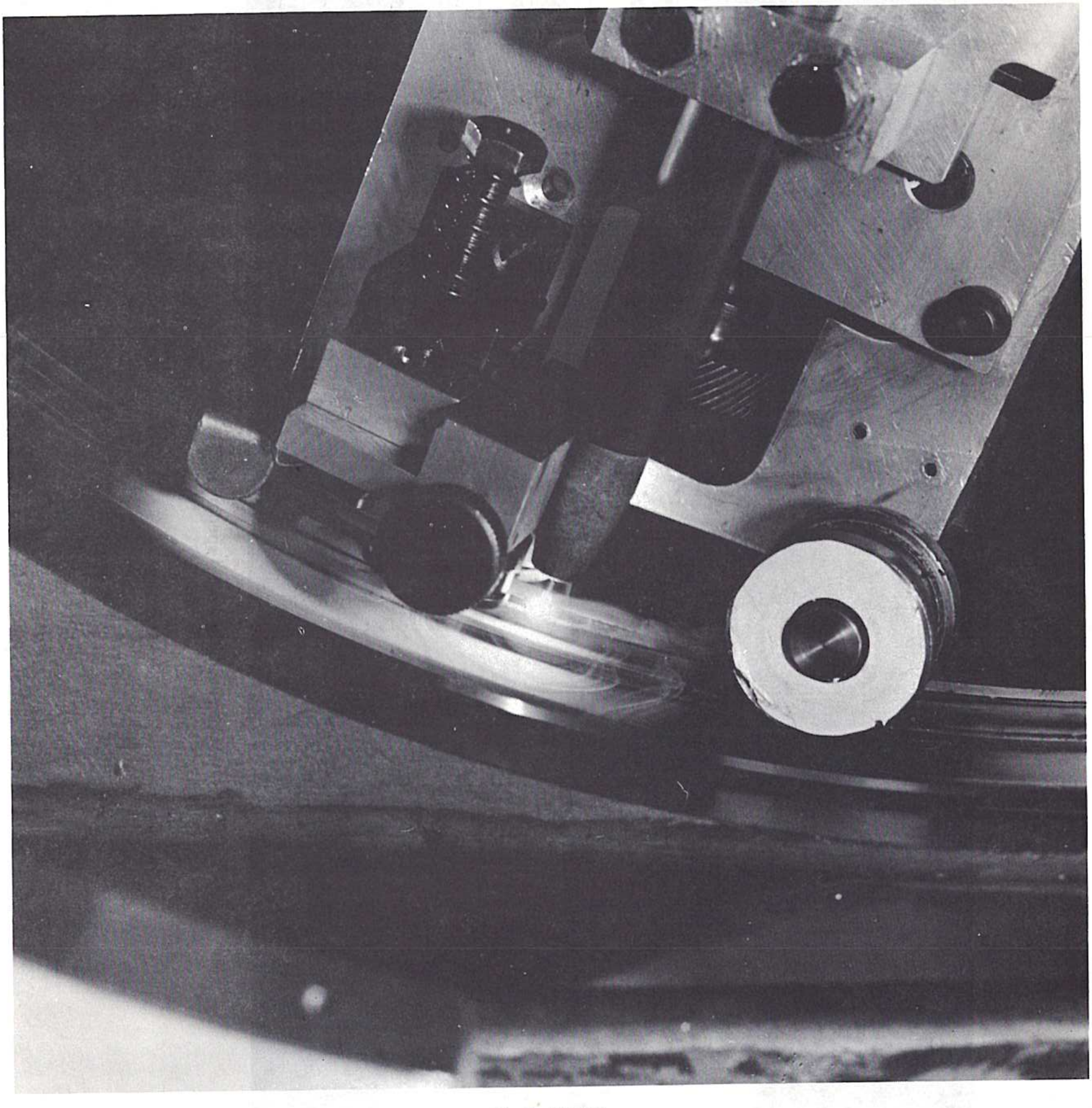


Fig.8 Welding

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