EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

ISR-VAC/67-23

AUTOMATICALLY AND REMOTELY WELDED AND REMOVABLE WELD FLANGE VACUUM JOINT

by

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Submitted to the 1967 U. S. National Particle
Accelerator Conference, March 1 - 3, 1967,
Shoreham Hotel, Washington, D. C.

Geneva - 22nd March 1967

PS/5863

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SUMMARY

This paper is a discussion of the development, testing and evaluation of a welded vacuum flange, capable of being automatically welded, and then removed and rewelded at least 4 times.

1. INTRODUCTION

The advent of enormous vacuum chambers (2-4 km), with their large number of seldom removed individual vacuum joints, in high radiation fields and with high or ultra-high vacuum requirements, leads one to search for an alternative to the high cost metal-gasket bolted vacuum joint.

A weld, once leak tested, is the most reliable alternative vacuum joint. And in the form of a weld flange, or simple butt weld of tubes, it has extremely low cost ($\not>$ 8 SFr./joint).

A vacuum joint in the form of a welded flange joint has been proposed on the 200 GeV[2] accelerator, and is presently in use at SLAC[1,3]. However, until now, no flange has been developed tested and proven that can be remotely-automatically welded and removed. This type of joint has been studied on the 1.5 km length beam transfer vacuum system between the existing Proton Synchrotron (PS) and the Intersecting Storage Rings (ISR) at CERN and also at specific places on the Storage Rings themselves.

2. DESIGN CRITERIA

The design and development of a weld joint involves three separate components: the joint itself, a welding mechanism and a removal mechanism. The desired criteria for these three items are as follows:

For the joint:

1. Reliable vacuum joint
2. Low in cost
3. Removable and reweldable at least 4 times
4. Able to serve as transition piece
5. Radiation, temperature and environment resistant.

For the welder:

1. Automatic-remote installation of the welder; automatic-remote alignment and clamping of mating joints
2. Automatic-remote weld cycle
3. Automatic-remote retraction of welder
4. Failsafe weld cycle
5. Removable and reweldable welds, 4 per joint
6. Fit into allowable space

For the weld removal mechanism:

1. Automatic-remote installation and positioning
2. Automatic-remote weld joint removal
3. Automatic-remote retraction
4. Failsafe weld-removal mechanism
5. To make up to 4 joint-removals per joint
6. Fit into allowable space.

3. FLANGE DESIGN

The weld joint may take either the form of an edge-welded flange, or of a butt-welded tube joint. The weld flange has been studied because the weld flange also serves conveniently as a transition piece between different sizes and shapes of the vacuum chamber sections.

The prototype weld flange form under test is shown in Fig. I. The flange is first blanked from a 1 mm 304 L sheet into a disc with a specific O.D. and I.D. The blank is then stamped to the final shape with no further operations required. The ribs on the flanges keep them from warping and also serve to center them, and to give both the welding and removal mechanisms the same reference to the flanges. The flanges may be easily made sexless, as is shown in Fig. II by having both ribs protruding. Then, however, the weld mechanism must also center the flanges.

The flanges can be welded to the vacuum chambers with the same automatic welding mechanism by merely repositioning the weld-head. The convolution facilitates this edge-welding of the flange to the chamber. The convolution and the straight section of the flange also act as a membrane, affording a certain compliance. The vacuum chamber and flanges are then ready to be installed and welded together.

3.1 Advantages of a welded vacuum joint

1. Vacuum reliability
2. Low cost - a simple stamping
3. Ease of installation - feasible to remote and automate the operation both for weld reliability and for radioactive environment
4. No sealing surface to damage
5. No multiple-part flanges
6. Joint need not be separated or retracted for removal
7. A certain compliance - based on design and shape of flange
8. Space requirement - based on igenuity applied to design of joint and welding and removal mechanisms
9. Ease of corrections - another weld pass
10. Can be sexless or female/male joint
11. No bake-out problems
12. No radiation damage.

3.2 Disadvantages of a welded vacuum joint

Aside from the susceptibility to mal-function of the welding and removal mechanisms, the main disadvantage of the weld flange vacuum joint is that it is only removable perhaps four times. This question of the finite number of removals and reweldings of the flange could be answered in a couple of ways. When the weld flange has been removed for the last possible time, the flange itself could be cut off and a new flange welded to the vacuum chamber in situ. This could be done automatically; the joint would then be ready for another series of removals.

A second alternative might be to use a butt-welded joint to join the two vacuum chambers, or transition pieces, directly, as shown in Fig. VII. The bellows on either side would probably exist in any case, and they would thus serve the dual function of allowing for component and chamber misalignment, plus allowing the tube to be cut and then pushed about 1 mm together, for the reweld, after each cutoff. After a number of removals, when a certain length of the chamber had been cut out, like 10 mm, a filler could be doubly welded in, as shown in Fig. VII. This butt-welding procedure could give an almost infinite number of joint removals and rewelds.

4. AUTOMATIC WELDER DESIGN

The automatic welder has been designed both as a clamping fixture and the weld-head drive mechanism. The welder is a simple device, as shown in Figs. II, III, IV, consisting of two nested rings which are both split. The outer ring is hinged and locked and the inner ring rotates in this outer ring. The rings remain true due to the hinge on the outer ring and the locating dowels at the split sections of the rings, as shown in Fig. II. The inner ring contains a groove which matches with the rib on the weld flange. The outer ring contains a set of reaction rollers running against the inner ring and also a set of clamping fingers with rollers. When the welder is positioned against the flanges, the flanges and the inner ring are clamped together between the reaction rollers and the clamping fingers on the outer ring. The inner ring is then held firmly against the flange and is fixed due to friction. The outer ring contains a D.C. motor and drive pinion. These drive the outer ring relative to the ring gear attached to the fixed inner ring.

The motor is powered by a voltage regulated power supply to insure constant weld head speed characteristics. When the outer ring is unlocked and unclamped from the flange, half of the inner ring is held by the drive pinion meshed with the ring gear. The other half of the inner ring is held by a cam actuated by the hinge opening.

The weld head rotates with this outer ring, always keeping the electrode at the center of the flange pair and a fixed distance from the flange edge. The welding process is the standard argon arc process with a tungsten electrode (T.I.G.).

5. AUTOMATIC WELD REMOVAL DESIGN

Several weld removal methods are being investigated. They are:

1. Multiple machined grooves on flanges to facilitate weld bead peel-off
2. Combination cut and weld bead peel-off
3. Cutting off of weld bead.

With the multiple machined groove flange a cut is made on the weld bead and then the weld bead is literally ripped off. This type of flange is shown in Fig. IX. The second method consists of a partial cutting through of the flange in the machined groove to make it easier to rip off the weld bead rim. The third method consists of machining the weld bead off with either a rotating cutter or a fixed cutter that rotates around the flange. A mechanism similar to the automatic welder in design and presently in fabrication will be the basis for tests on methods 2 and 3.

6. TEST RESULTS

An automatic welder has been tested and modified which now gives reproducible and reliable welds.

The typical automatic weld cycle followed in the weld tests is as shown in Fig. VIII. The welder, in the open position, is installed manually on the pipe, and shut. The ribs on the flange serve to rough-locate the flanges, and as the clamps are tightened, the welder centers on the flange rib and also forces the two mating flanges into correct position. This manual procedure takes about 25 seconds. With the addition of pneumatic clamping, the time will be cut to 5 - 10 seconds.

The motor, the argon and an ultra-violet light are turned on, and after a one-quarter revolution, the arc is remotely started, in the presence of the ultra-violet light. After one revolution plus 1 cm, the electrode current is tapered to zero in about 2 cm. This leaves a good weld-runout, as shown in Fig. VI. The electrode current cut-off activates a relay which stops the motor at the next index point for opening the welder.

The use of an ultra-violet light, provides good reproducible electrode starting characteristics. Current taper-off over a 2 cm length eliminates any weld craters. Use of an argon shield over 1/4 of the weld circumference also allows good weld protection and cool down.

The removal of the mechanism is easily accomplished by releasing the clamps on the flange and opening the welder. This is done manually in under 5 seconds. These short manual installation and removal times are important from a radiation standpoint.

Weld tests to date show a wide range of acceptable combinations of weld-head current and speed. The 1 mm 304L flanges have been edge-welded with good results from 25 A and 8 cm/min (9 min weld time) to 52 A and 46 cm/min (1.5 min weld time). A cross-section of a weld at 40 A and 28 cm/min (2.5 min weld time) is shown in Fig. V. The weld penetration, or throat, is about 1 mm, and a good weld structure exists. The weld surface appearance and electrode current taper-off can be seen in Fig. VI.

Multiple welds have been tried on flanges in which 1.5 mm (including the weld bead) has been machined off the radius - in a lathe - and then the flanges rewelded for several such weld-removals. No welding difficulties nor vacuum leaks were encountered. It is encouraging that the previous weld zone did not seem to effect the reweld or the vacuum integrity of the succeeding rewelds. Weld joints, with and without machined grooves, have been cycled 10.000 times at an axial deflection of 2 mm, with no fatigue or vacuum problems evidenced.

The second phase has been the study of weld removal methods. Two different concepts of weld removal are being studied. One is the rip-off weld bead, and the other is the cut-off weld bead. Initial weld rip-off tests run on flanges with machined grooves are promising. (A flange with a machined groove for weld bead rip-off is shown in Fig. IX.) More tests are underway on this method.

For the weld bead cut-off tests, both a rotating tool and a fixed tool rotating around the circumference of the flange will be investigated. Certainly the rip-off weld bead is much simpler. However, the cut-off weld may offer a more reliable removal and reweld capability. Further tests will be conducted to study the removal and reweld capabilities of each system.

7. CONCLUSION

The weld flange and automatic welder are both proving to give a reliable and sound vacuum joint. Further investigation is now being conducted on two different types of weld removal methods, i.e., the weld-bead rip-off and the weld bead cut-off. Both of these methods will be studied and tested in hopes of achieving the desired reliable weld flange with the capability of being removed and rewelded four times.

Not much emphasis has been placed on the question of remoting the flange mounting and removal because it is really only a question of remote installation and removal of the automatic welder and cut-off mechanisms. The automatic tools are being designed so that once they are in rough location, they can both center themselves and clamp the flanges automatically. No remote manipulation will be necessary.

Certainly the welded vacuum joint has many characteristics, such as vacuum reliability, low cost, and feasibility of remoting and automating the mounting and demounting procedures, which warrant its application in many accelerator vacuum systems being proposed or designed today.

ACKNOWLEDGEMENTS

The development to date of the weld flange, automatic welder, and automatic cut-off tools, their design, fabrication and tests, would not have been possible without the contributing ideas and efforts from Messrs. E. André, B. Bruggeman, J. Brunet, R. Mercier, R. Stierlin and W. Thomi.

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2. 200 GeV Design Study, LRL, Vol. I, p. VII-4.

3. D. Robertson, Private communication, SLAC.

FIGURE CAPTIONS

Fig.	I	Weld flange prototype
Fig.	II	Automatic weld flange welder assembly
Fig.	III	Automatic welder shown in situ - on ISR beam transfer prototype vacuum system
Fig.	IV	Automatic welder in open position - ready for installation, and weld flange pair
Fig.	V	Cross-section of weld flange weld (1 mm flange thickness)
Fig.	VI	Surface of weld bead and current taper at finish - with automatic welder
Fig.	VII	Schematic of butt-weld tube joint
Fig.	VIII	Graph of weld cycle
Fig.	IX	Flange with machined groove for rip-off weld bead.

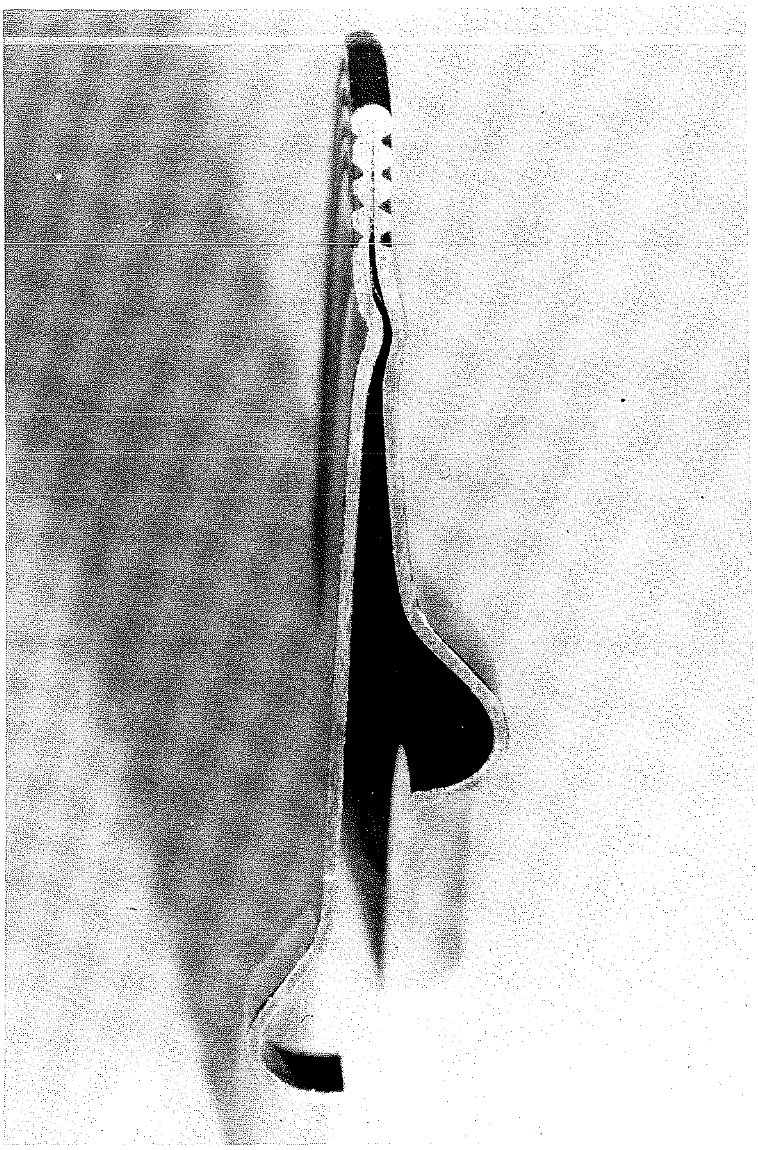
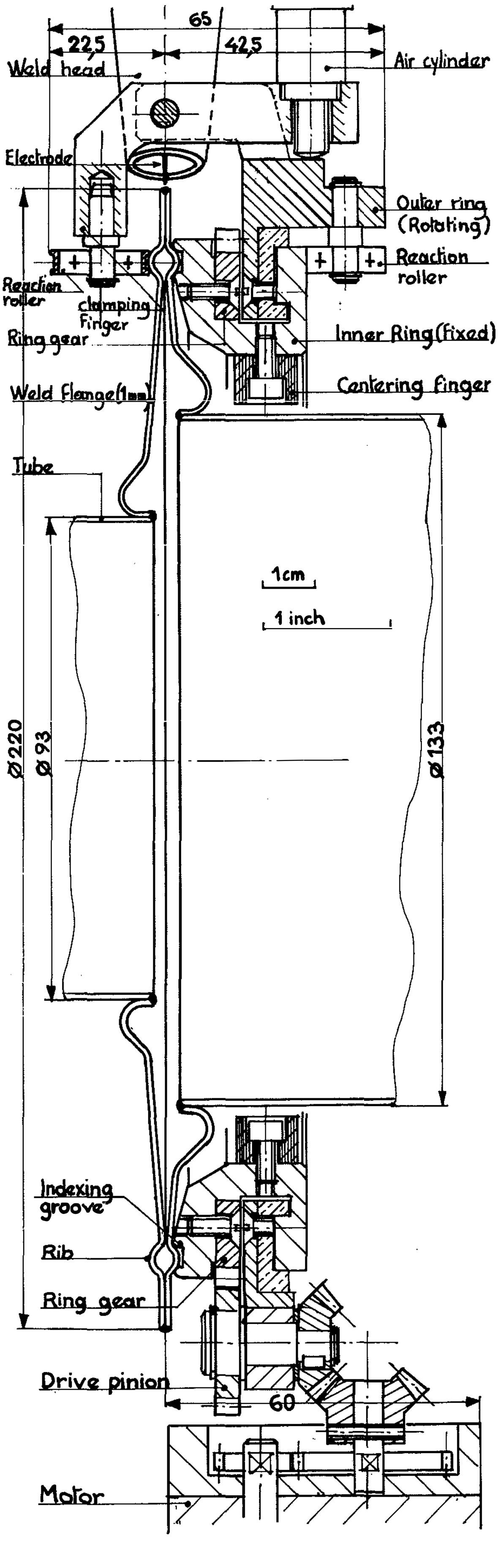


Fig. I



65
22,5
42,5
Weld head
Air cylinder
Electrode
Outer ring
(Rotating)
Reaction
roller
Reaction
roller
clamping
Finger
Ring gear
Inner Ring (fixed)
Weld Flange (1mm)
Centering finger
Tube
1cm
1 inch
Ø220
Ø93
Ø133
Indexing
groove
Rib
Ring gear
Drive pinion
60
Motor

Fig. II

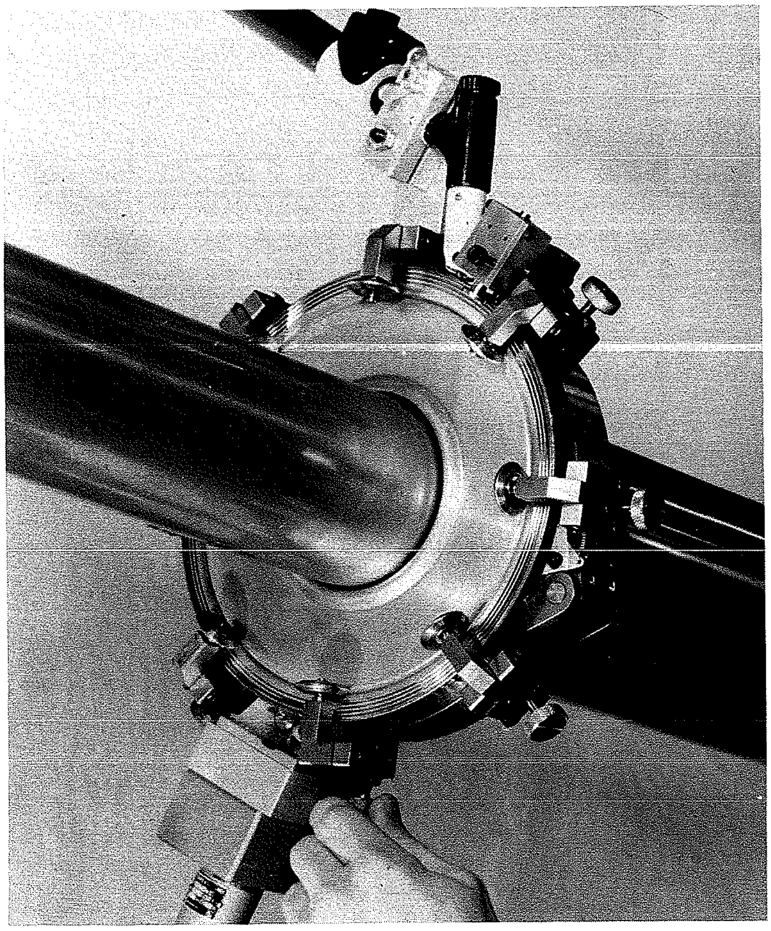


Fig. III

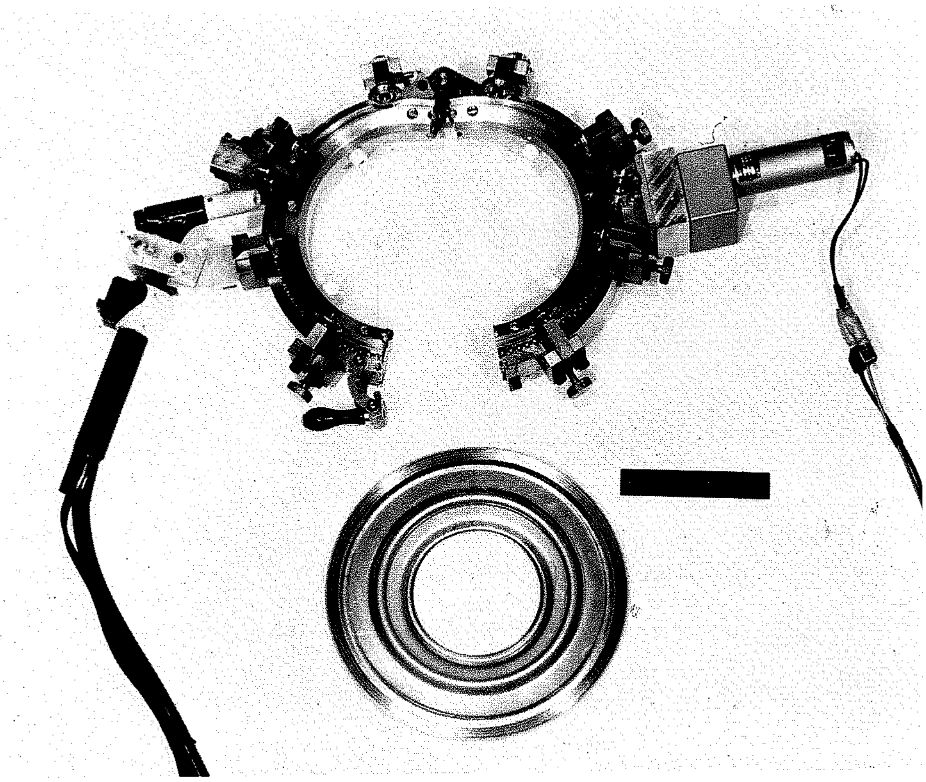


Fig. IV

Fig. V

Fig. VI

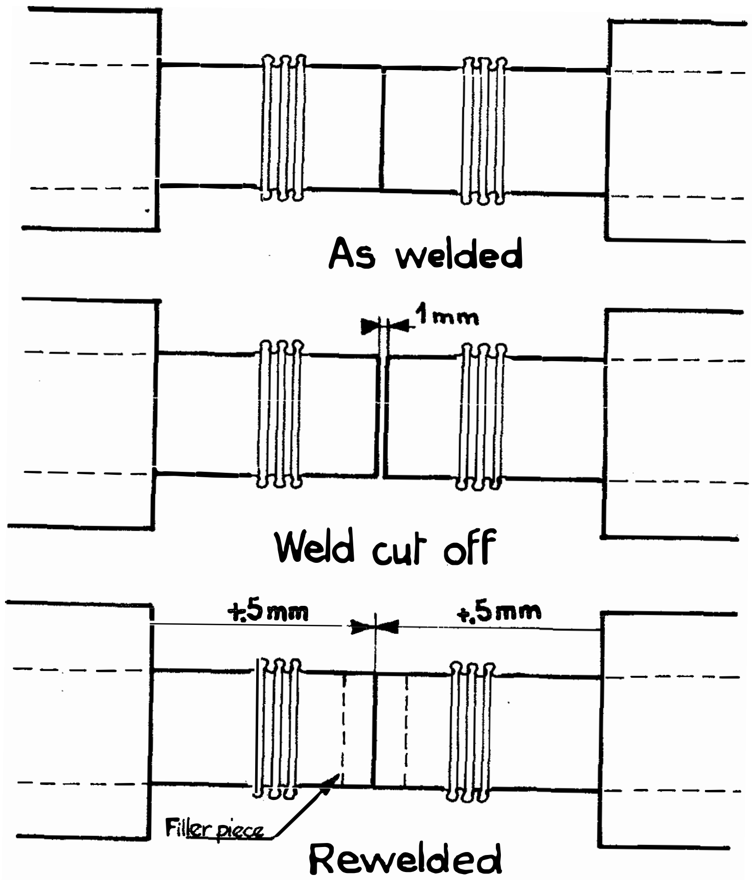


Fig. VII

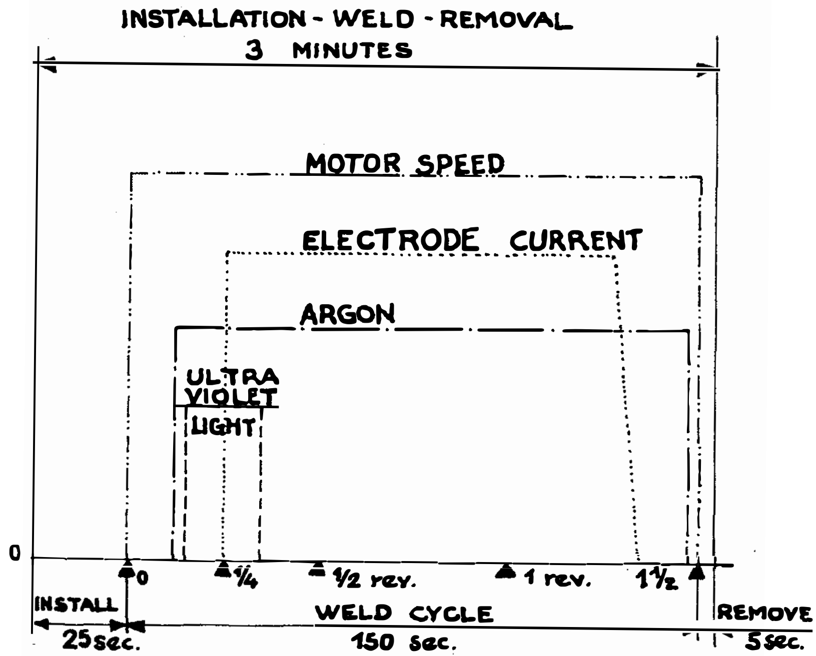


Fig. VIII

Fig. IX