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Dragon Project Report

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ELECTRON BEAM WELDING EXPERIMENTS FOR BURSTING DISC ASSEMBLIES

by

R. HANSEN

[redacted]

A.E.E., Winfrith, Dorchester, Dorset, England

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ELECTRON BEAM WELDING EXPERIMENTS

FOR BURSTING DISC ASSEMBLIES

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1. INTRODUCTION

Special Bursting Disc Assemblies which have a leak rate $< 10^{-8}$ atmospheric cm^3/s, are required for the Dragon Helium Purification Plant.

The pressure on the secondary side of these assemblies may normally vary between 0 and 3 atmospheres but it is necessary to protect the assemblies against pressures higher than 24 atmospheres on the primary side, i.e., the discs should burst at 24 atmospheres. This system would be unreliable with the secondary pressure varying as it does. Therefore, it is proposed to use two discs in series, as can be seen from the principal assembly design in Fig. 1. As long as the discs are intact and provided there is no leakage, the void in between them will stay at a constant pressure, thereby preventing disc No. 1 from rupturing at any other pressure than the required one. If then, disc No. 1 bursts, the second disc will follow automatically because this one is chosen to burst at a much lower pressure. The disc holder is designed so that disc No. 2 cannot burst the wrong way if there should be any unexpected pressure rise on the secondary side of the assembly. During fault conditions the pressure could rise to 20 atmospheres.

The usual assemblies where the discs are only clamped onto the holder were found to be inadequate for the purpose, because they were not up to the required leak tightness standard.

The Dragon High Temperature Techniques Group was asked by the Dragon Engineering Division, to find out if it would be possible to electron beam weld very thin discs to solid slugs for the purpose of making special bursting disc assemblies.

2. WELDING EQUIPMENT

The welding equipment which was available was a "low voltage" electron beam welding unit, with the following specification:

Maximum voltage:	20 kV
Electron Beam:	Up to 100 m A
Maximum wattage:	2 kW
Spot diameter:	$\geqslant$ .8 mm ∅

The sample to be welded is clamped in a chuck underneath or beside the electron gun, Fig. 2. The chuck is so positioned that the electrons can hit on the right spot and then rotate at any required speed between 2 and 50 rpm.

The gear rotating the chuck, which was only temporary for this work did not run too smoothly. All the weldings were done without using a telescope.

3. DESIGNS

To find a welding method which was likely to be successful, a number of designs were made, Figs. 3, 4, 6 and 7.

The main dimensions of the assemblies are 70 x 40 O.D. x 25 I.D. (mm). The thickness of the discs is .002 in.

The materials of primary interest were monel 400 for the disc holders, nickel for disc No. 1, silver for disc No. 2.

This report gives a survey of the experiments done and of the results obtained.

4. FLAT WELD

4.1 Flat Weld without Ring

In the first experiment it was attempted to flat weld the disc straight onto the disc holder. As seen from Fig. 3, the electron beam impinges vertically on the disc.

As expected, this arrangement was unsatisfactory. Power settings between 50 and 200 watts at voltages between 10 and 18 kV were tried, as well as welding speeds between 14 cm/min and 100 cm/min. If the settings were low the disc just crinkled and no joint was made. At higher settings the discs simply burned away.

4.2 Flat Weld with Ring

Flat welding with the ring on top of the disc, as shown in Figs. 3a and 3b, also failed, for the same reasons as above.

It is possible, however, that these welds could have been made with a "high voltage" gun, because of the higher penetration values of the electrons at higher voltages. A "high voltage" gun has voltages up to 150 kV. Over-heating of the disc would then be prevented.

5. EDGE WELD WITH CHAMFERED RING

Edge welding a disc with a pressed up rim, Fig. 4, in between the holder and a ring so that the three edges are fused together, proved to be a promising method. As seen from the drawing, a vertical beam is needed in this case.

Since monel 400 was not available at the time, stainless steel was used instead for the first trials. Fig. 4a shows a micrograph of a nickel to stainless steel weld. The electrical settings for this weld were: 17 kV - 14 mA - 238 W. The speed of the chuck was 2 revolutions at 4 rpm (50 cm/min).

Fig. 4b shows a micrograph of a silver to stainless steel weld. An interesting fact to note about this particular weld is that underneath the actual weld, molten silver has run down on both sides of the disc and in that way made a brazed joint. This may lead to a special electron beam brazing technique. For example, by placing a silver ring on top of the three edges, Fig. 5, and melting the ring with the electron beam, one should be able to make a brazed joint.

A few complete assemblies of this design, i.e., with disc in both ends, were made and showed that this welding method is suitable for the purpose of making bursting disc assemblies, provided that:

(i) the rim of the disc is undamaged. The local workshop had some difficulties in pressing out these discs; and that

(ii) the ring to be inserted in the disc has a diameter .006 in less than the inside diameter of the turned out groove of the disc holder, so that the disc slide fits in between.

The required leak rate was achieved with the nickel-monel 400 welds. Silver-monel welds with the required leak rate were also made, but only with 50% success. The reason for this was probably that part of the disc edge was burned away before any weld was made. Besides, silver and monel did not seem to mix very well and, therefore, the welds had a bad appearance compared to the nickel-monel welds.

6. EDGE WELD WITH DOMED RING

Edge welding with a domed ring, according to the design shown in Fig. 6, was not successful. The reason for this was that bad alignment between the domed pieces resulted in melting of the disc before any weld was made. Also because of bad fitting it was not possible to melt all three edges at the same time. With more precise machining of the specimens, however, a better result should be obtained.

7. EDGE WELD WITH HORIZONTAL BEAM

Edge welding the disc in between two rings as in Fig. 7, was the design that seemed most promising and, therefore, most time was spent on this type. The three edges are fused together as described in paragraphs 5 and 6, but in this case with a horizontal beam.

A number of specimens were made with grooves and edges of different dimensions. This was done to find the one which was the easiest to weld and also had the required leak tightness.

The sample shown in Fig. 8 has a leak rate $<10^{-10}$ atmospheric cm^3/s. The disc holder is monel 400 and the disc is nickel. The electrical settings were: 17 kV - 10 mA - 170 W. The welding speed was 1 revolution plus overlapping at 4 rpm (50 cm/min). Fig. 9 shows a micrograph of the weld. Fig. 10 shows a complete assembly before welding, and Fig. 11 a complete welded assembly.

The most important measurements of this weld are shown in Fig. 7. These are also the measurements recommended for the bursting disc assemblies.

Due to the fact that silver-monel are not completely miscible, as already mentioned in paragraph 5, these welds were not as good as the nickel-monel either in appearance or in leak tightness. The leak rate varied between 10^{-5} atmospheric cm^3/s and $<10^{-10}$ atmospheric cm^3/s for the different welds. Fig. 12 shows a micrograph of a silver-monel weld. The electrical settings for this weld were: 17 kV - 15 mA - 255 W. The welding speed was 50 cm/min (1 revolution + overlapping at 4 rpm).

Copper as material for the disc holder was also tried with this design. Although, of course, much more power is needed to do the copper welds, good silver-copper welds were made, both in appearance and leak tightness. Fig. 12a shows a micrograph of silver-copper weld. The electrical figures were: 17 kV - 50 mA - 850 W, and the welding speed was 1 revolution at 4 rpm.

On the other hand nickel-copper did not make a good weld for leak tightness. No leak rates better than 10^{-6} atmospheric cm^3/s were achieved.

8. EDGE WELD WITH RECESS

(i) Edge welding with a recess as shown in Fig. 13 was tried. The idea was to install the disc in the recess, thereby protecting it from being hit directly by the electron beam and burning the disc edge before the edge of the disc holder was melted. This worked quite well; leak tight nickel-monel and silver-monel welds were made, but the higher power needed to do the welds caused over-heating of the work-piece, i.e., compared to the welds described in the previous paragraph, where the assemblies could be taken out with bare fingers with ease immediately after the welding was done, without being burned.

(ii) A new method of welding was discovered, while experimenting with the above described weld, which needs more development than done here. If the welding experiment is set up as (i) above, but only employing half the power, the top part can be removed after the welding, and one is left with the disc alone welded onto the top of the disc holder; not as before, in between the disc holder and ring. Fig. 14 shows a silver disc welded onto a brass holder and Fig. 14a a similar silver-copper weld.

(iii) One should also be able to do electron beam soldering with this design by placing the soldering material in the recess as shown in Fig. 15. This was tried once with tin as the soldering material, and it looked promising enough to encourage further work along this line.

9. DISCUSSIONS OF RESULTS

There are a number of questions to be asked when considering the results of the experiments; the most important are:

(i) can the welding be done easily?

(ii) is the design suitable as a bursting disc assembly?

(iii) is the leak tightness up to the required standard?

Our object was to find a way to weld nickel and silver discs onto a monel 400 disc holder. Taking the nickel-monel weld first, the results obtained according to paragraph 7 must be considered the best, see also Fig. 7. With the electrical settings at 17 kV - 10 mA - 170 W, a good weld without over-heating is obtained. A leak rate $<10^{-10}$ atmospheric cm^3/s is also readily obtained.

On the other hand the results with silver-monel were not as good as was hoped on either of the designs described. However, the design in paragraph 7, Fig. 7 was the best with three quarters of the welds giving a leak rate $< 10^{-10}$ atmospheric cm^3/s and the rest being $< 10^{-5}$ atmospheric cm^3/s.

Regarding copper as a material for disc holders, one will see from paragraph 7 that the silver-copper weld is a "good one", but that the nickel-copper one is not. A remedy for this could be to make the assembly body in two halves, one of monel and the other of copper, and to weld them together before connecting the discs.

9.1 Leak Testing

Leak testing the welds is usually done by evacuating through a hole in the body, using a helium mass-spectrograph leak detector, spraying the discs and welds with helium, Fig. 16. This leaves the problem how to seal the hole afterwards because, as mentioned, the volume in the assembly must keep a constant pressure. Two other methods to check the leak rate of the welds are:

(i) The Pirani Method, where one can use the assembly itself as a Pirani head with filament built in, Fig. 17. This has the advantage that the pressure in the assembly can be checked at any time, also when they are in use, if wanted.

(ii) The Palladium Method, Fig. 18, where a small Palladium tube is welded into the side of the assembly. Hydrogen may, when the Palladium tube is heated, be put into the assembly or taken out according to wish. Using a hydrogen mass-spectrograph leak detector, leak testing can be performed in several ways. Also a modified Edwards Palladium leak detector may be used. Heating of the Palladium tube can either be done by HF-induction coil, or by resistance heating.

10. CONCLUSIONS

It can be seen from paragraph 8, for example, that more development work could be done. But, as a result of the experience gained so far, the High Temperature Techniques Group would recommend the bursting disc assembly design as in paragraph 7, with the dimensions given in Fig. 7, as a suitable solution for electron beam welding.

As regards material for the disc holders, it is recommended that nickel discs should be welded to monel 400, and silver discs to copper. But, if some rejects could be allowed for after the welding the silver discs, we would advise monel 400 to be used as holder both for the nickel discs and for the silver discs, as a second alternative.

Since the work was finished, however, it has been thought that thinner nickel discs (.0005 in) could be welded in the manner indicated in paragraph 7, in which case such discs could replace the silver ones recommended for the copper disc holder. Any work carried out to test this notion will be reported later.

11. ACKNOWLEDGMENTS

To Messrs. T. A. J. Jaques, G. Coast, J. F. G. Condé, B. Aarset and A. Thomson for their co-operation and interest.

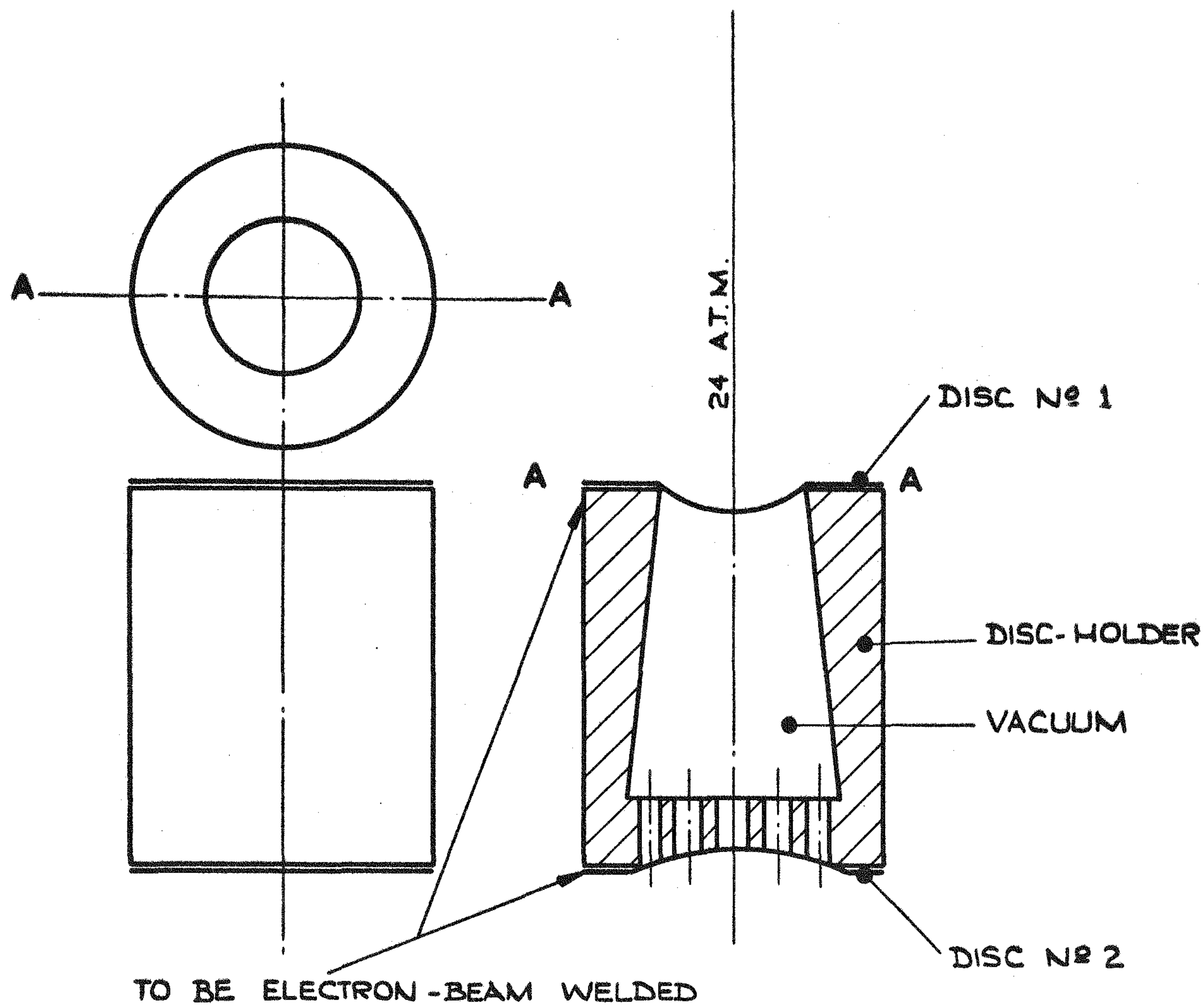

FIG. I THE BURSTING DISC ASSEMBLY

THE DISCS ARE ELECTRON BEAM WELDED TO THE HOLDER.
IF Nº I DISC BURSTS, DISC Nº 2 WILL FOLLOW AUTOMATICALLY.

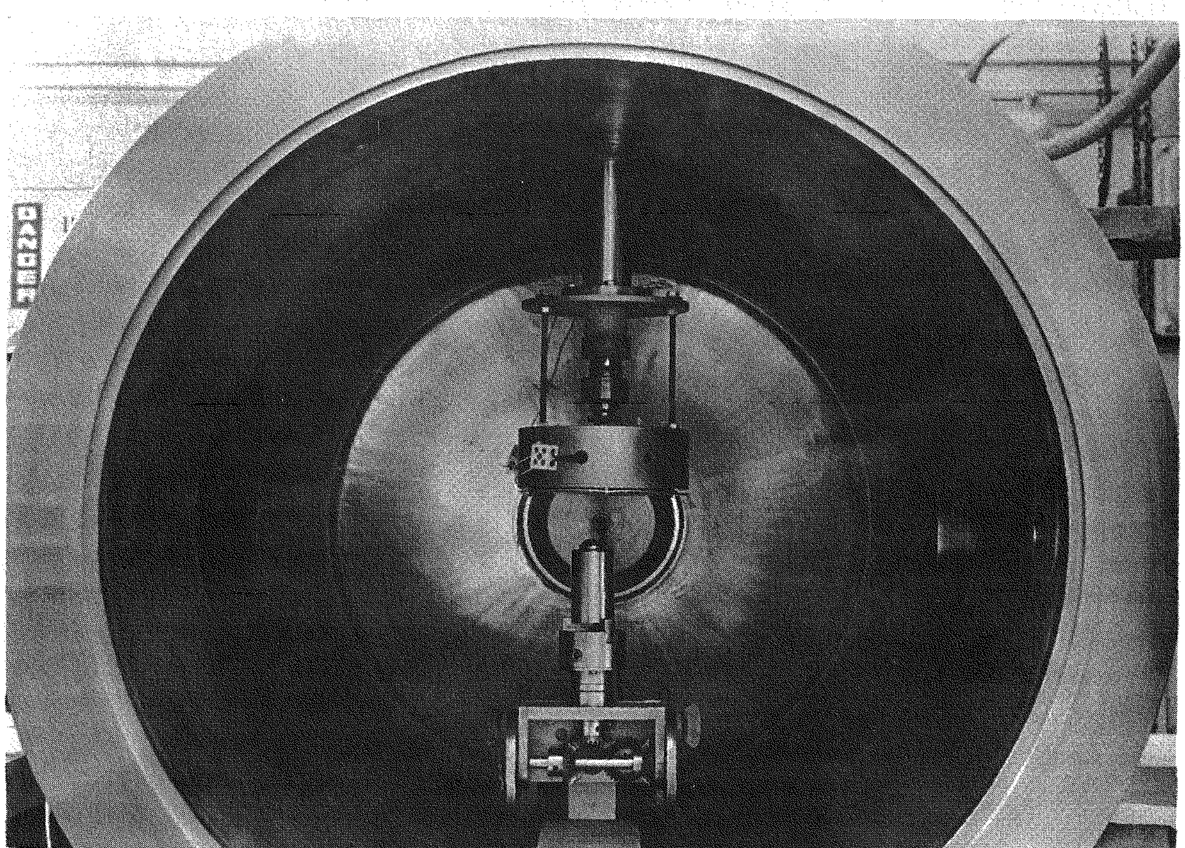

FIG. 2   THE ELECTRON GUN

Showing the lower part of the gun and
the chuck assembly inside the chamber.

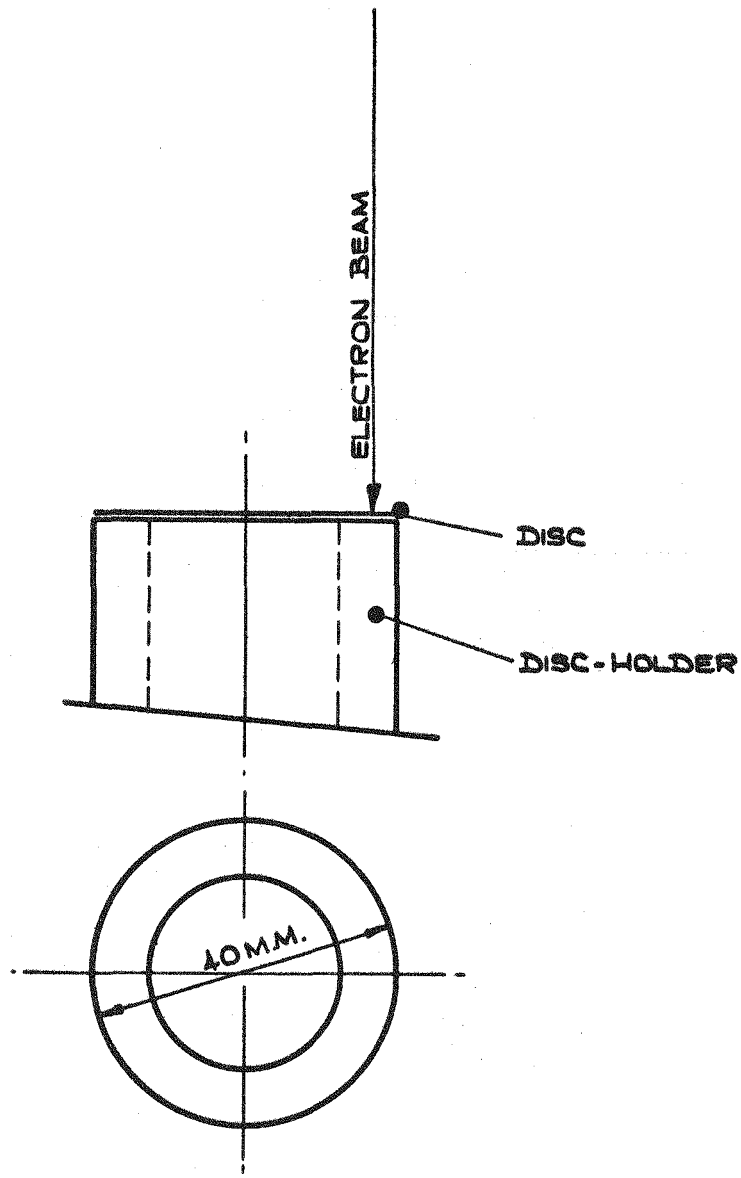

FIG. 3 FLAT WELD

SHOWING ONE HALF OF THE ASSEMBLY ONLY.

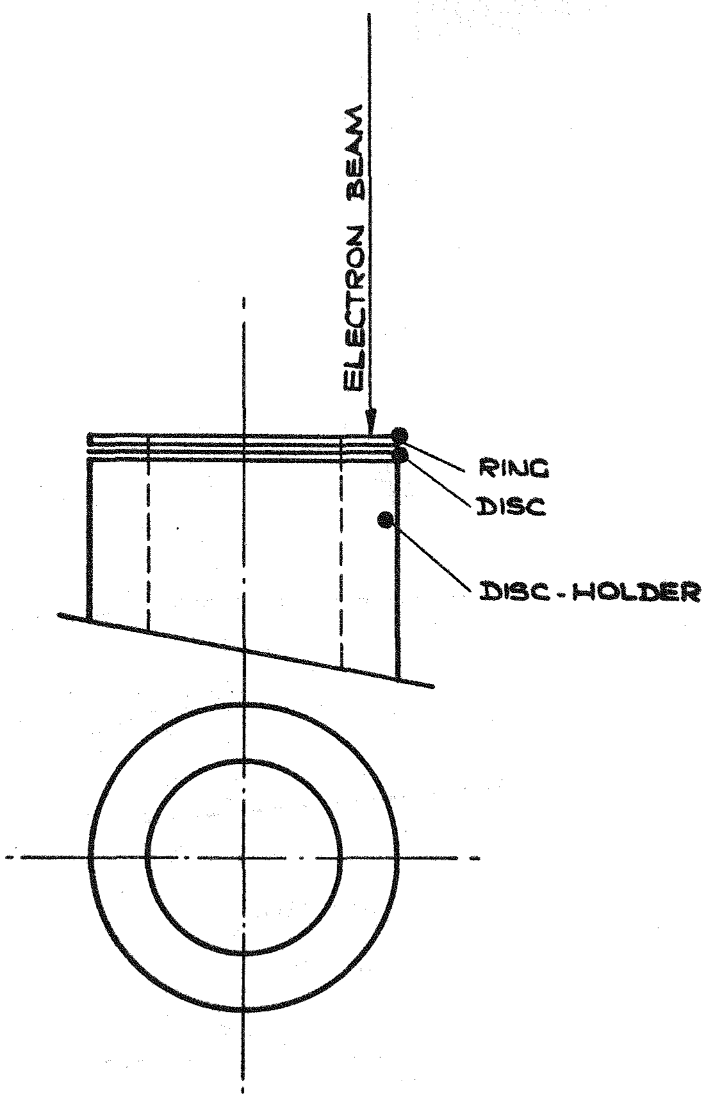

FIG. 3a FLAT WELD WITH RING

THE DISC TO BE WELDED IN BETWEEN THE RING AND THE HOLDER.

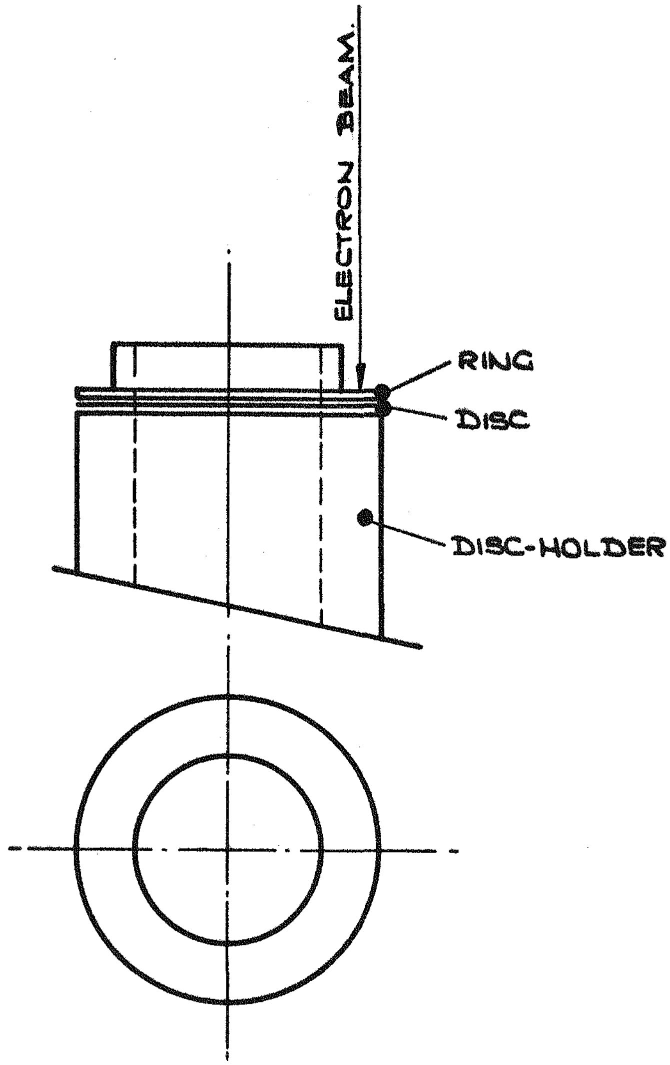

FIG. 3b FLAT WELD WITH RING

HERE THE RING HAS A RIM TO MAKE IT MORE RIGID.

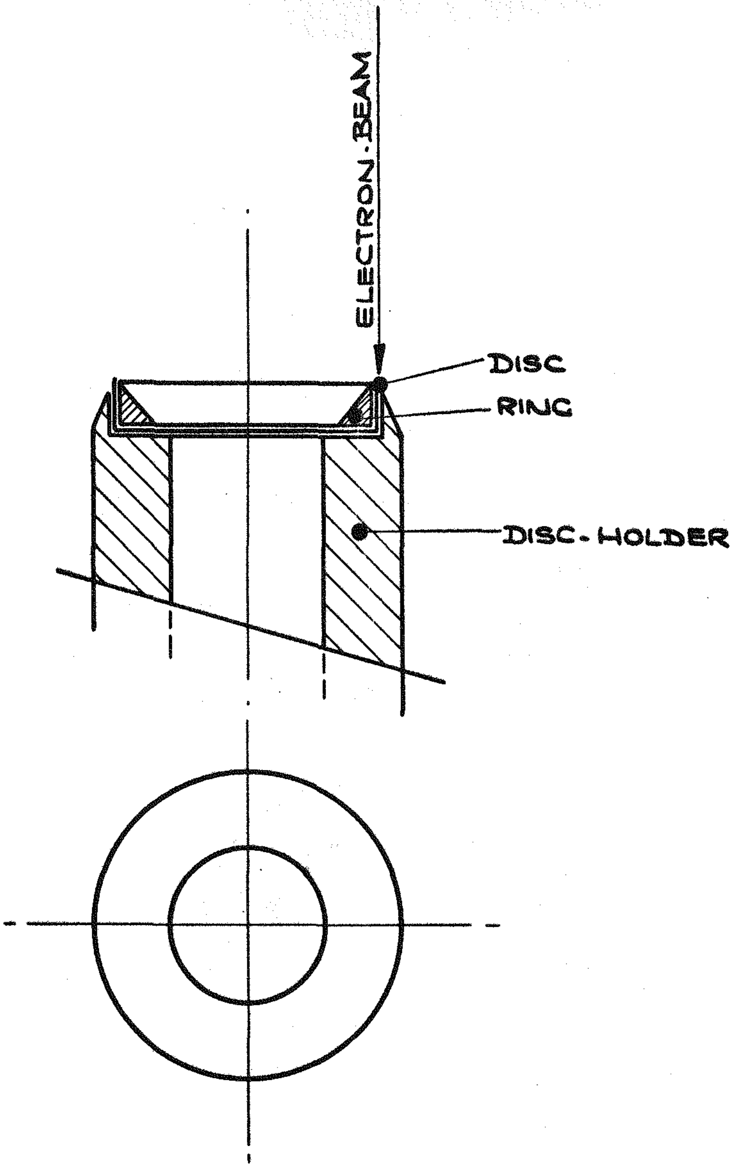

FIG. 4 EDGE WELD WITH CHAMFERED RING

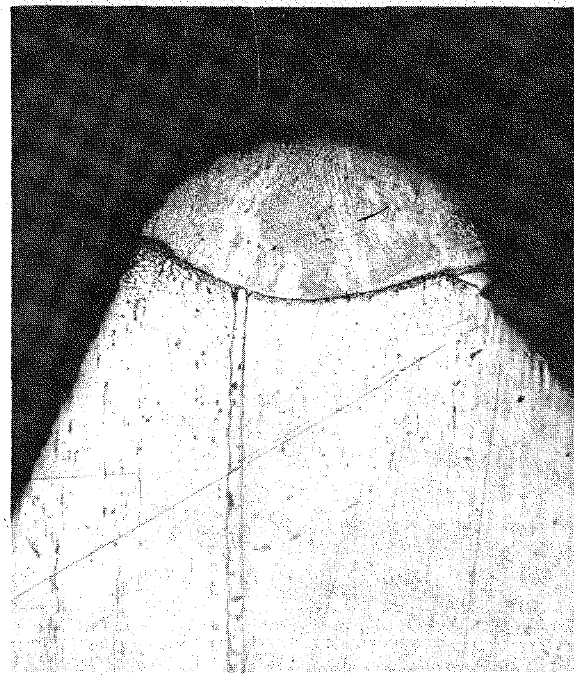

FIG. 4a NICKEL STAINLESS STEEL WELD X 60

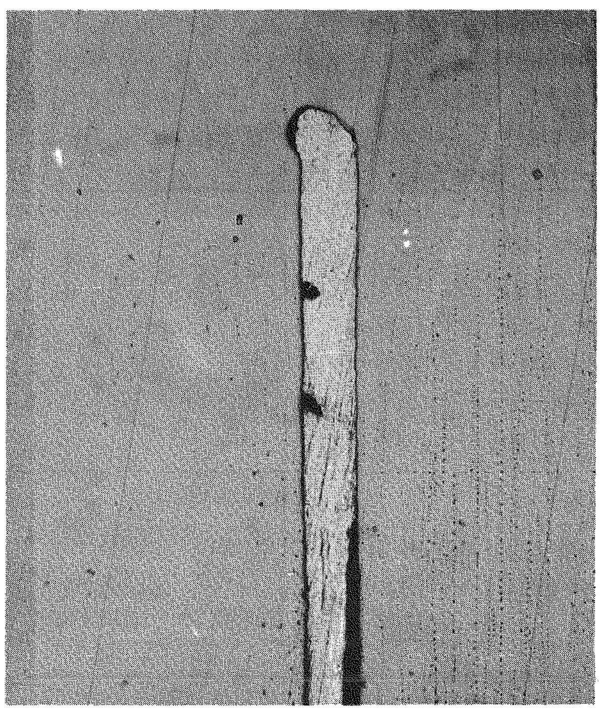

FIG. 4b SILVER STAINLESS STEEL WELD X 150

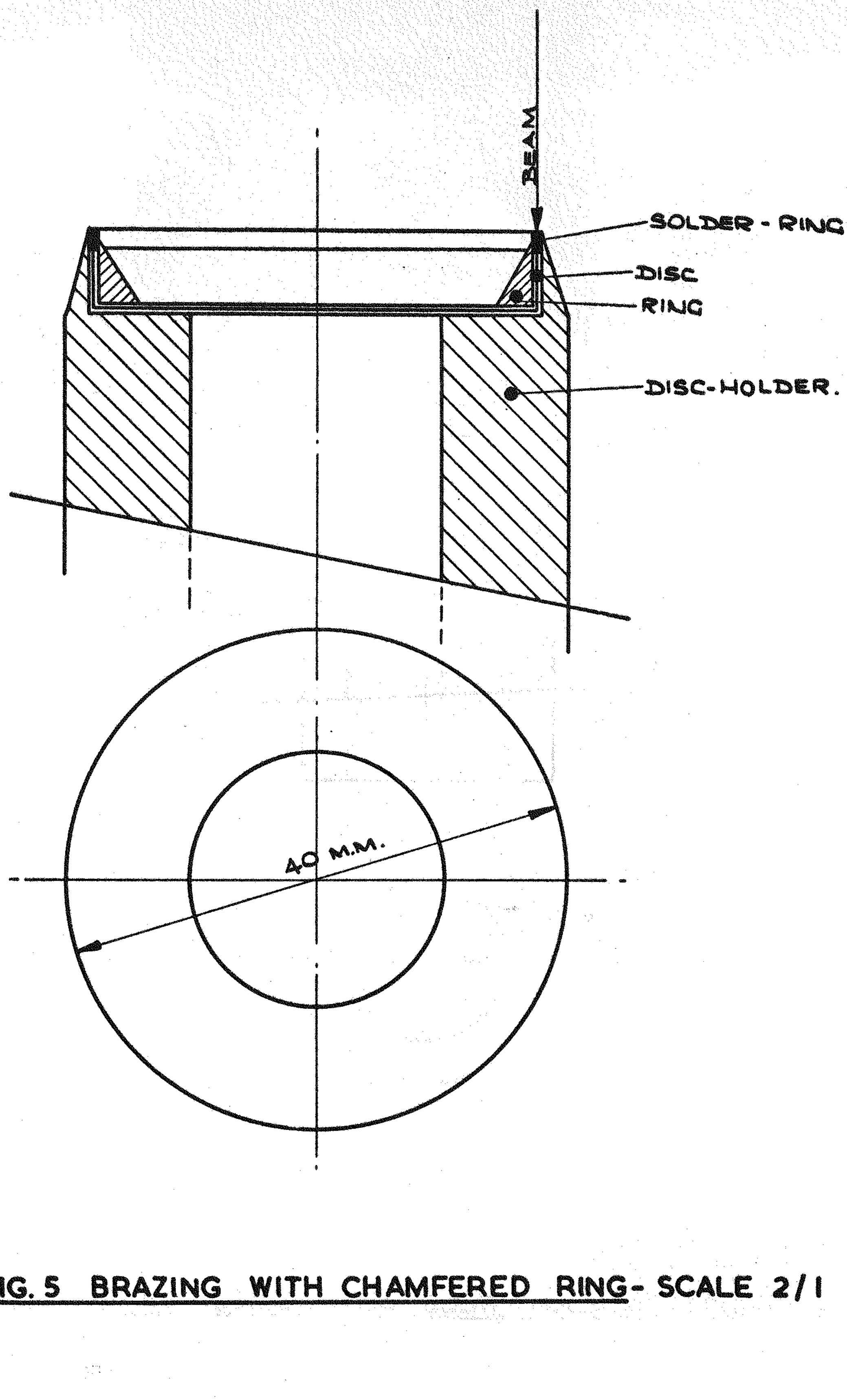

FIG. 5 BRAZING WITH CHAMFERED RING - SCALE 2/1

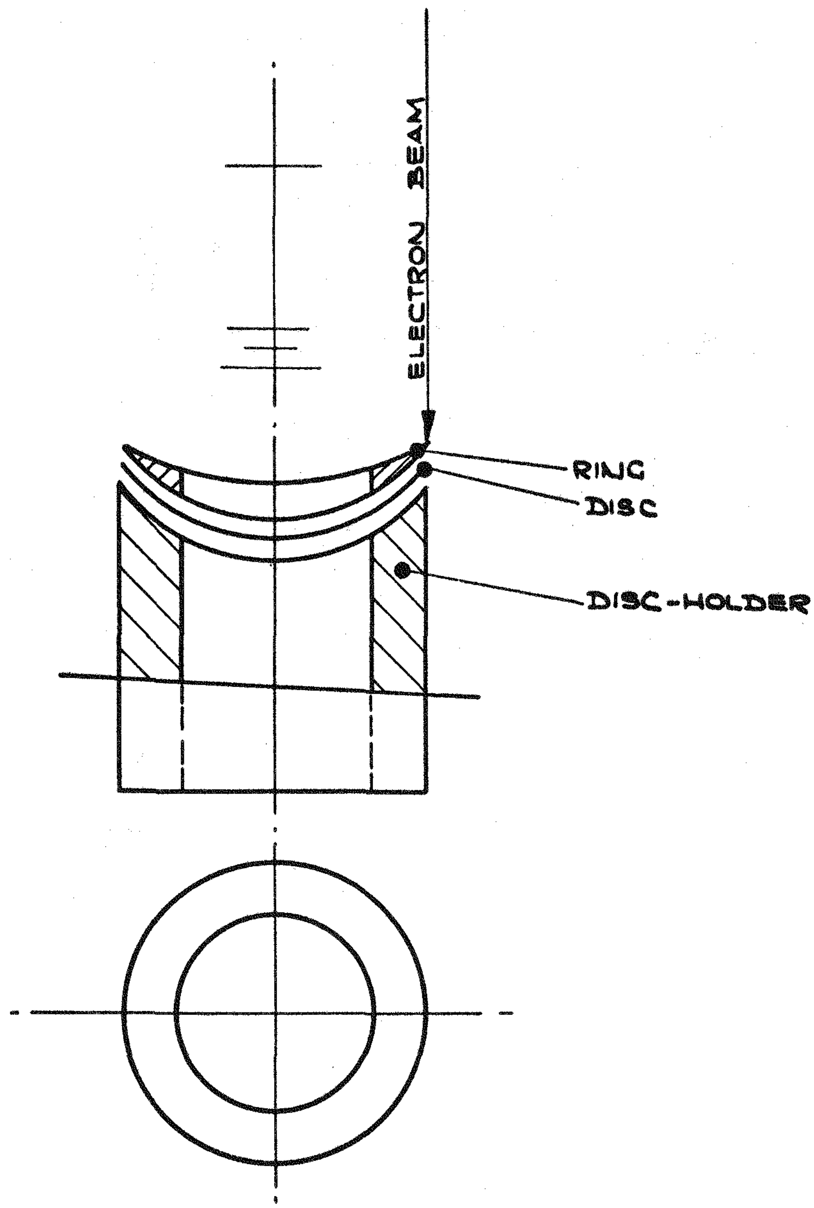

FIG. 6 EDGE WELD WITH DOMED RING

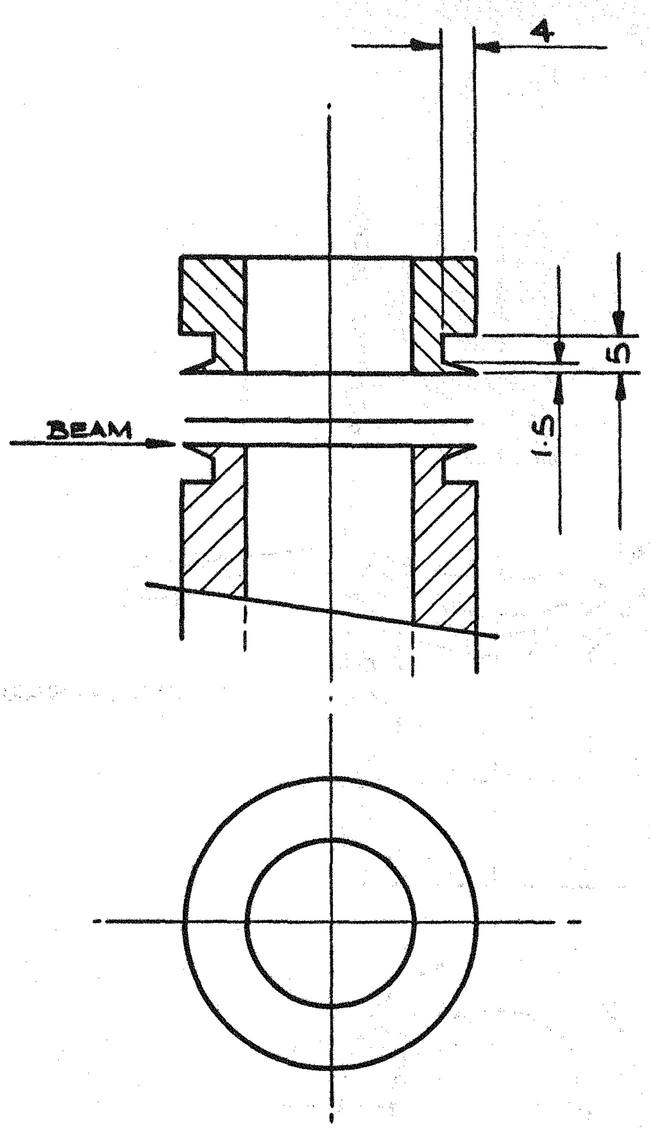

FIG. 7 EDGE WELD WITH HORIZONTAL BEAM

THE MOST IMPORTANT MEASUREMENTS ARE GIVEN.

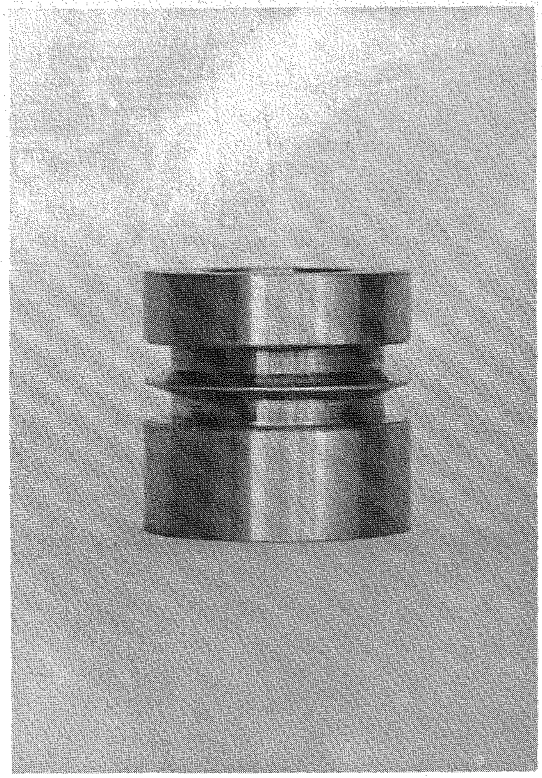

FIG. 8 NICKEL-MONEL 400 WELD

The electrical settings:	17 kV - 10 mA - 170 W
The welding speed:	50 cm/min (1 revolution at 4 rpm)
The leak rate:	$<10^{-10}$ atmospheric cm^3/s

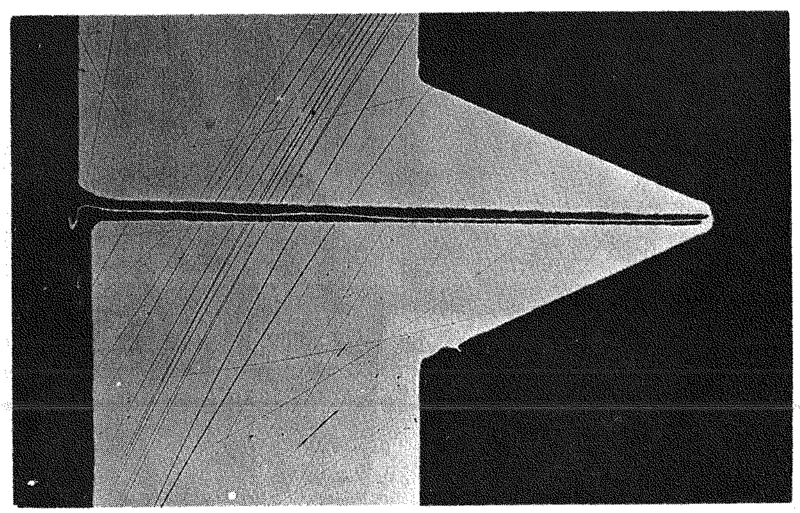

FIG. 9 MICROGRAPH X 10 OF THE WELD SHOWN IN FIG. 8

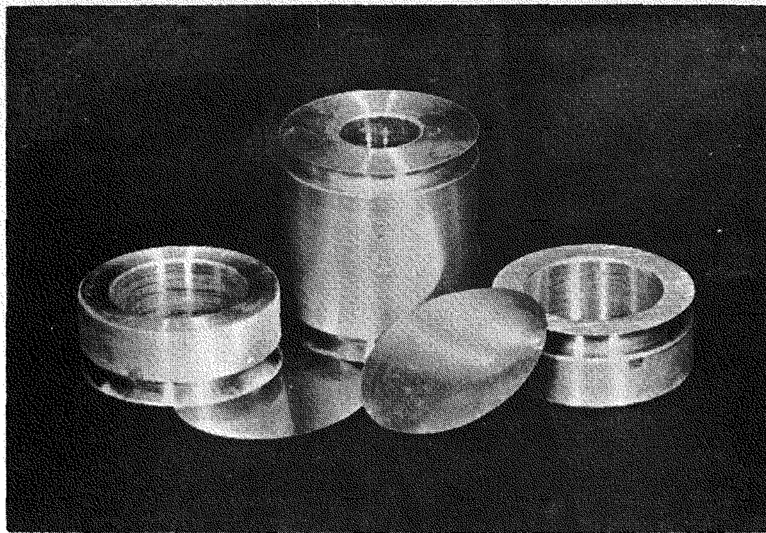

FIG. 10 COMPLETE SET OF UNWELDED COMPONENTS

FIG. 11 COMPLETE WELDED ASSEMBLY

The electrical settings:	Top weld, 17 kV - 12 mA - 204 W
	Bottom weld, 17 kV - 28 mA - 376 W
The welding speed:	Top weld, 50 cm/min (3 revolutions at 4 rpm)
	Bottom weld, 50 cm/min(2 revolutions at 4 rpm)

Both welds have a leak rate $<10^{-10}$ atmospheric cm^3/s.
For both welds the settings were higher than necessary.

Materials: Nickel and Monel 400.

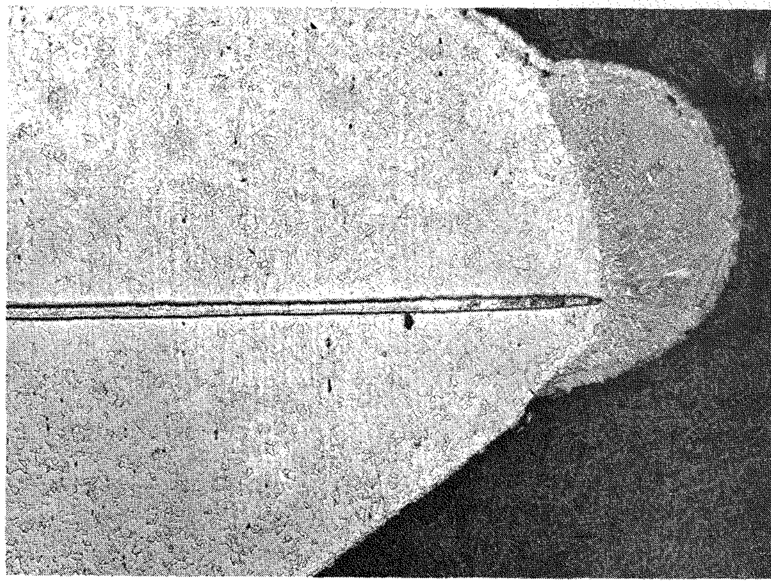

FIG. 12 SILVER MONEL WELD X 40

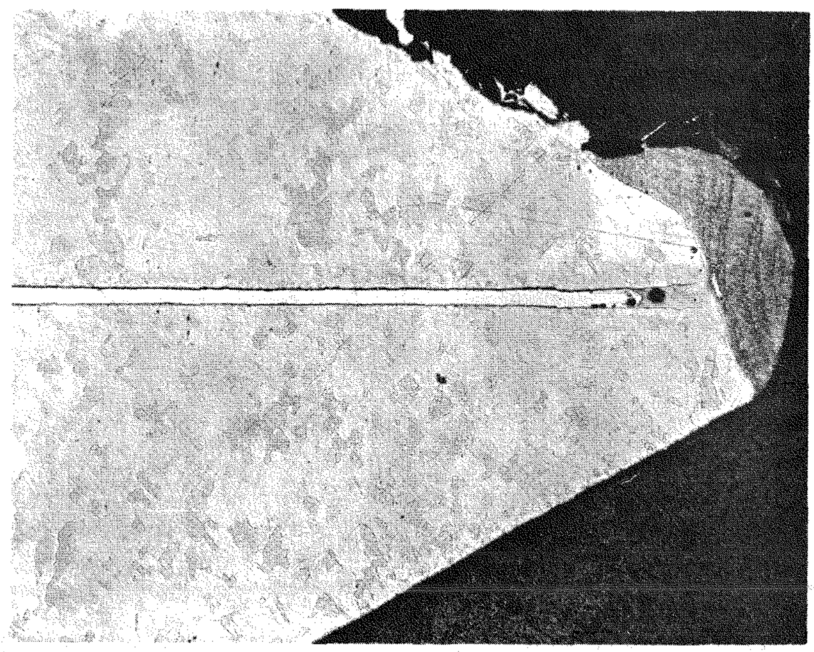

FIG. 12a SILVER COPPER WELD X 40

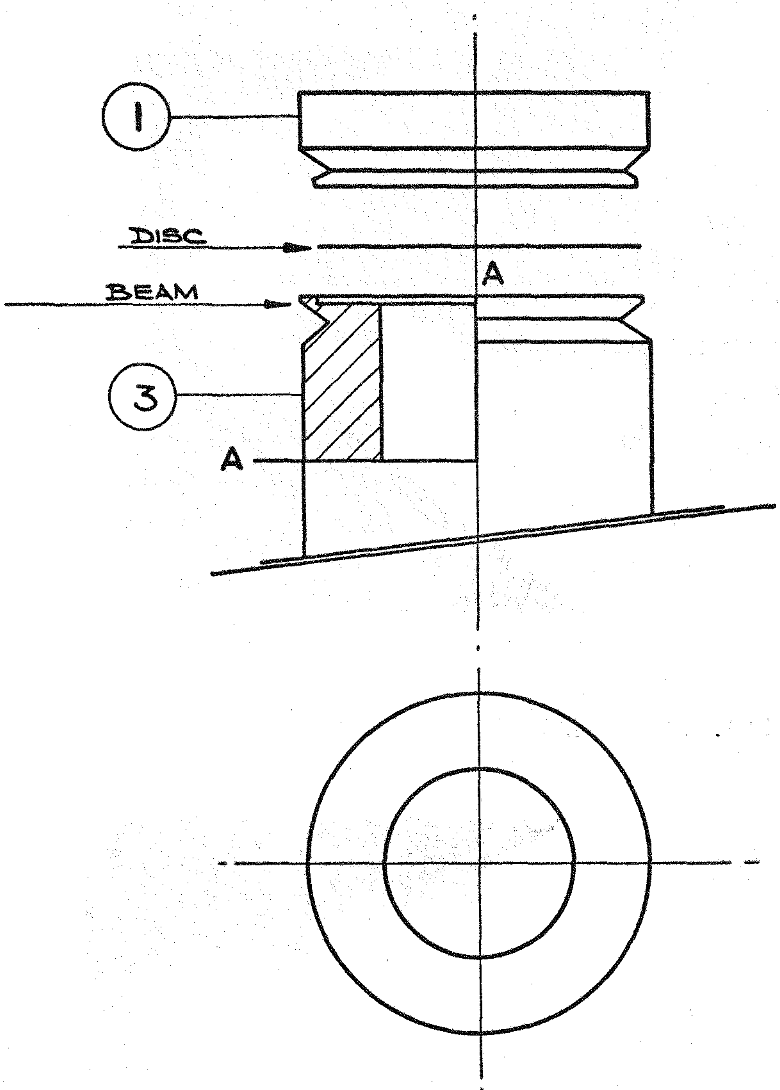

FIG. 13 EDGE WELD WITH RECESS

(1) GOES ON TOP OF THE DISC INTO THE RECESS IN PART (3)

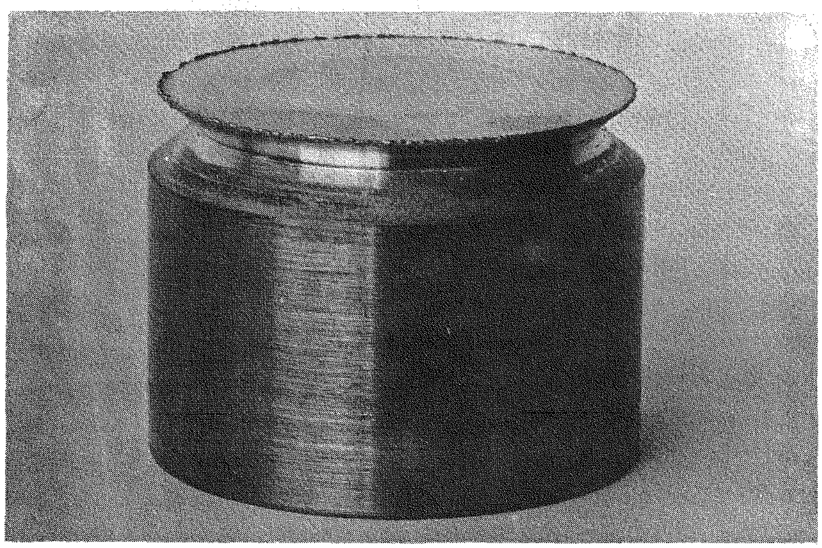

FIG. 14 SILVER BRASS WELD

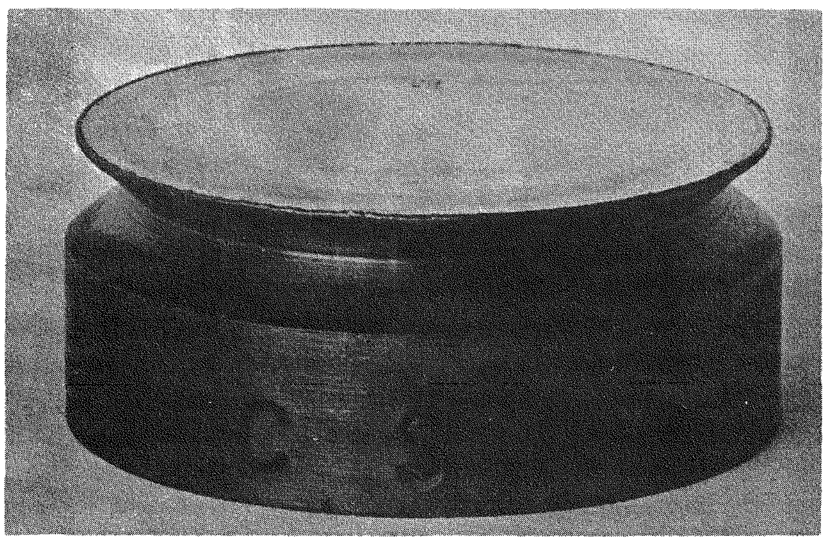

FIG. 14a SILVER COPPER WELD

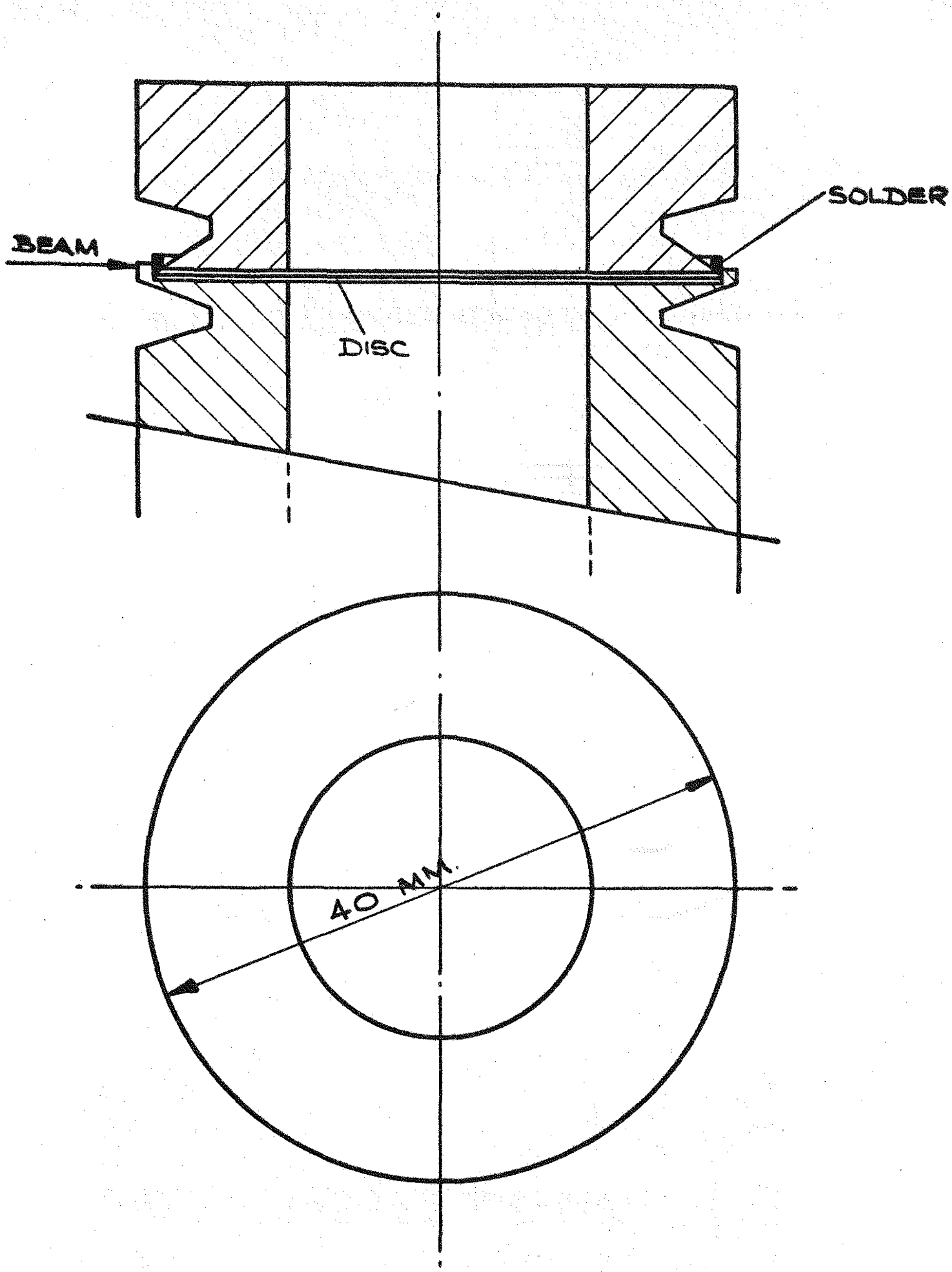

FIG. 15 BEAM SOLDERING WITH RECESS

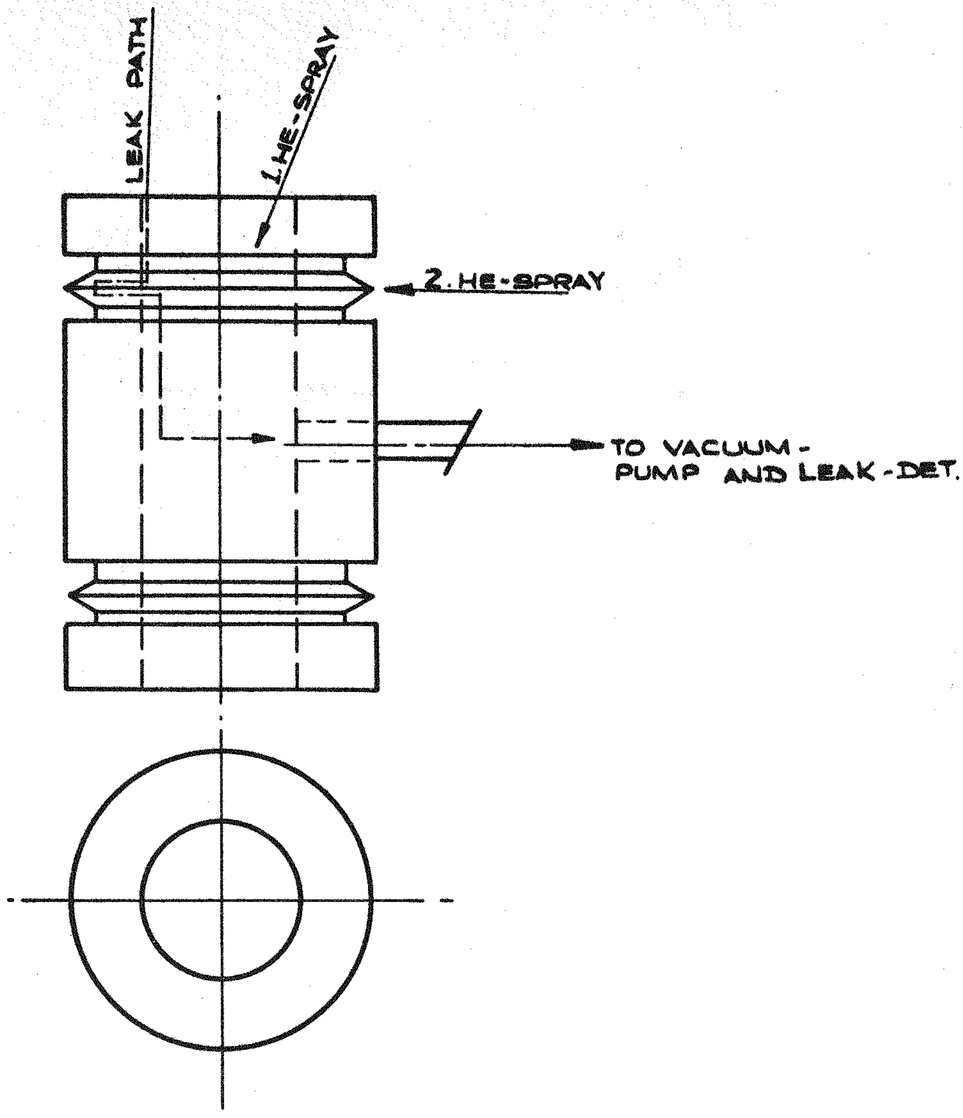

FIG. 16 HELIUM MASS-SPECTROGRAPH LEAK DETECTION

THE LEAKS, WHICH WERE FOUND WITH THE SILVER DISCS, WERE ALWAYS WITH 1 HE-SPRAY, SEE DRAWING. THE LEAK PATHS WERE PROBABLY AS SHOWN ON THE DRAWING. THE REASON FOR THESE LEAKS WAS PROBABLY THAT THE SILVER DISC WAS MELTED TOO FAR IN, BEFORE A PROPER JOINT WAS MADE.

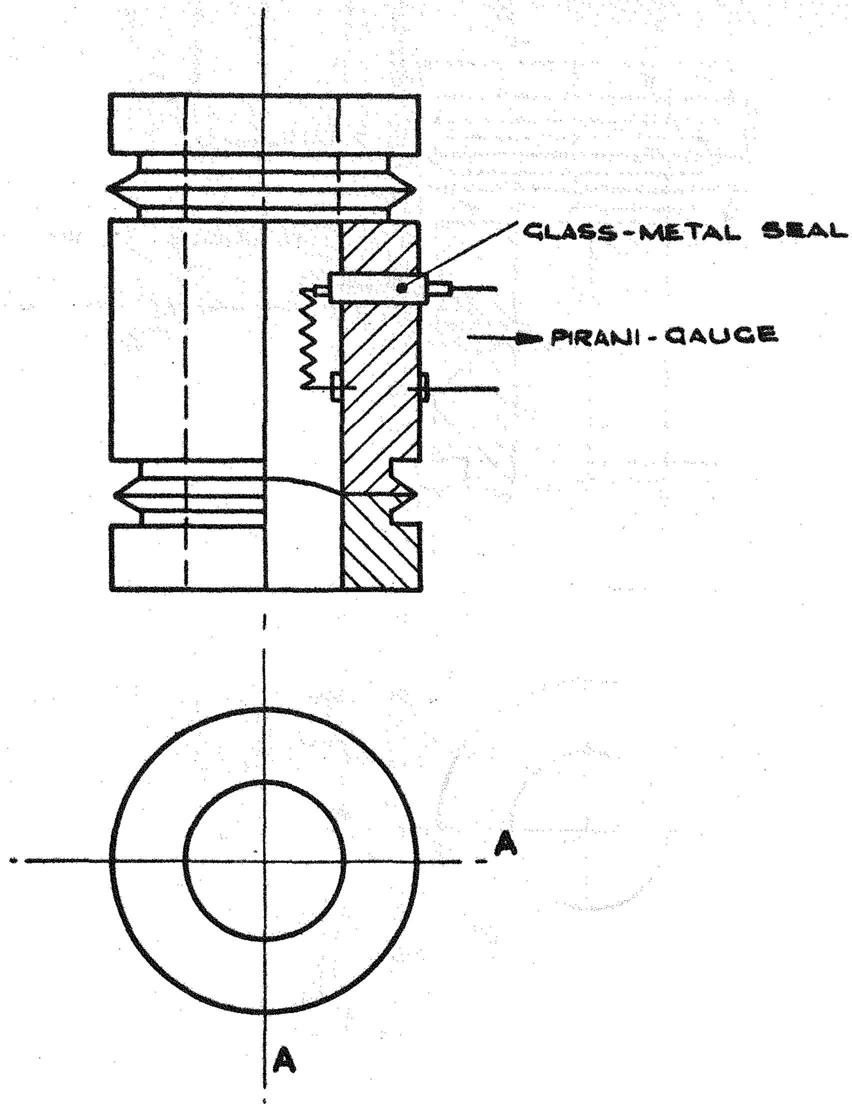

FIG. 17 PIRANI LEAK TEST

THE ASSEMBLY ITSELF ACTS AS THE GAUGE HEAD.

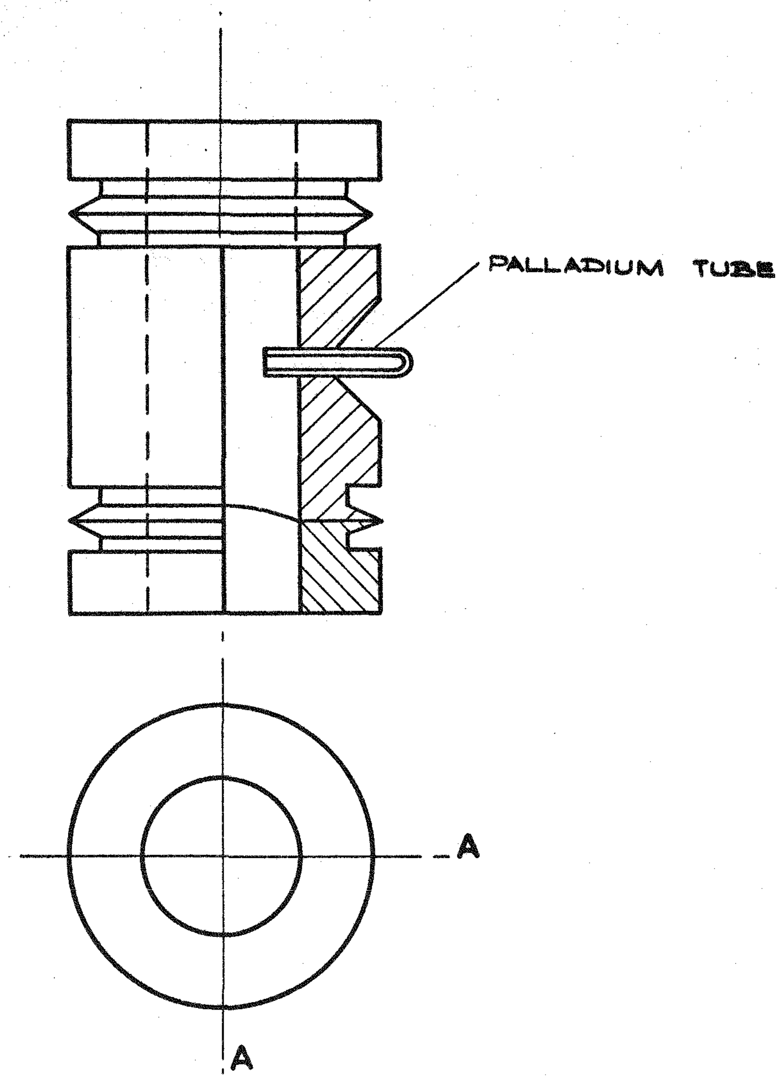

FIG. 18 PALLADIUM LEAK TEST

BY HEATING UP THE PALLADIUM TUBE, OR DISC IF USED, HYDROGEN WILL DIFUSE FREELY THROUGH, EITHER WAY. THIS FACT MAY BE USED IN CONNECTION WITH SEVERAL WAYS OF LEAK DETECTION WITH THE USE OF EITHER A HYDROGEN MASS-SPECTROGRAPH LEAK DETECTOR OR AN EDWARDS PALLADIUM LEAK DETECTOR.