EUR 39.e

EUROPEAN ATOMIC ENERGY COMMUNITY - EURATOM

ELECTRON BEAM WELDING OF SINTERED ALUMINIUM

by

M. MEULEMANS, D. TYTGAT, J. VAN AUDENHOVE (C.E.N.)
J. BRIOLA, P. JEHENSON (EURATOM)

1962

ORGEL PROGRAM

Topical Technical Report established by C.E.N.
Centre d'Etude de l'Energie Nucléaire - Mol, Belgium
under Euratom contracts Nos 001-60-4 ORG-B and 022-61-7 ORG-B
in collaboration with the Metallurgy and Ceramics Department
of the Ispra Joint Nuclear Research Center - Italy

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through the liquid state when assembling, in order to maintain the dispersed structure and the favorable properties of the material.

The high gas content of normal SAP (licence AIAG, Switzerland) caused two phenomena which limited the possibilities of welding by electron beam bombardment:

a) ionization

b) metallic projections

and resulting porosity in the welded zone has been observed.

With new sintered and degassed aluminium products (SAP - ISML), manufactured under Euratom contracts by Montecatini Novara, Italy, it was possible to obtain successful closure of tubes grades SAP - ISML 960, 930 and 895.

High temperature testing under pressure has been used to verify the quality of the welds. Use of external pressure on the tube during welding leads to high quality closures equal to or superior to other types of welds because of the very high, localized heating.

Electron beam welding can be systematically used as a quality test for gas content in the material.

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ELECTRON BEAM WELDING OF SINTERED ALUMINIUM

SUMMARY

This research on the electron beam welding of SAP has been done at the C. E. N. (Mol, Belgium) under Euraton contracts, with close collaboration between the C. E. N. team and Euratom personnel of the Metallurgy and Ceramics Service at Saluggia, Italy.

It is generally admitted that sintered aluminium with different oxide contents is difficult to weld and that it must be prevented, if possible, from passing through the liquid state when assembling, in order to maintain the dispersed structure and the favorable properties of the material.

The high gas content of normal SAP (licence AIAG, Switzerland) caused two phenomena which limited the possibilities of welding by electron beam bombardment :

a) ionization

b) metallic projections

and resulting porosity in the welded zone has been observed.

With new sintered and degassed aluminium products, (SAP - ISML), manufactured under Euratom contract by Montecatini Novara, Italy, it was possible to obtain successful closure of tubes grades SAP - ISML 960, 930 and 895.

High temperature testing under pressure has been used to verify the quality of the welds. Use of external pres sure on the tube during welding leads to high quality closures equal to or superior to other types of welds because of the very high, localized heating.

Electron beam welding can be systematically used as a quality test for gas content in the material.

1 - INTRODUCTION

1.1

Sintered aluminium products (the trade-mark is SAP* or Frittoxal** in Europe, APM*** in the U. S. A.) offer interesting possibilities for use as structural and canning materials in organic-cooled or organic-cooled and moderated reactor systems. Their high temperature strength, high thermal conductivity, low neutron absorption and excellent corrosion resistance in organic coolants make them attractive for operation at temperatures up to 450°C.

The improved elevated temperature strength is due to the dispersion strengthening effect of submicroscopic particles of aluminium oxide (Al_2O_3) in a matrix of aluminium. The strengthening effect is retained at elevated temperatures owing to the insolubility and high melting point of the dispersed phase, which blocks the movement of dislocations in the structure and opposes recrystallization.

1.2

The manufacturing process of sintered aluminium products has been reviewed in some recent papers[3, 4, 5, 11].

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* SAP - Protected trade-mark - A. I. A. G. , Neuhausen, Switzerland.

** Frittoxal - Protected trade-mark - Tréfileries et Laminoirs du Havre (TLH) Paris, France.

*** APM - Protected trade-mark - Alcoa, U. S. A.

1.3

It is generally admitted that sintered aluminium with different oxide contents is difficult to weld and that it must be prevented, if possible, from passing through the liquid state when assembling, in order to maintain the dispersed structure and the favorable properties of the material.

Various welding techniques have been described in the literature (flash-, spot-, pressure- and ultrasonic welding). Electron beam welding has been used in our laboratory. It is a fusion welding method but the study of this process is interesting for two reasons :

1) this technique has high energy concentration in comparison to other welding methods

2) the electronic welding stresses out the quality of the base material and especially the gas content.

Experience with such equipment existed at C. E. N. [9].

1.4

This research, done under Euratom contracts, has been conducted with close collaboration between the C. E. N. team and Euratom personnel of the Metallurgy and Ceramics Service at Saluggia, Italy.

2 - ELECTRON BEAM WELDING WITH C.E.N. GUN

2.1 DESCRIPTION OF THE EQUIPMENT

Preliminary tests were made using equipment built at our laboratory and already used to weld other types of materials, such as Al, Cu, Ni, stainless steel, Mo, Nb, Ti and Zr [9] .

This equipment is shown in fig. 1. A sketch of the electron gun is presented in fig. 3. The cathode has a hair-pin form and the electrons are electrostatically focused. The gun is shown in fig. 2. The specimen to be welded forms the anode.

2.2 EXPERIMENTS WITH UNDEGASSED MATERIAL

2.2.1 Material used :

Manufactured by Otto Fuchs, Germany (licence AIAG, Switzerland). SAP 865 (13% oxide). Tube 13/15 mm.

2.2.2 Welding experiments

The high gas content (up to about 40 ml/100 g) [6] caused two phenomena which limited the possibilities of welding by electron beam bombardment :

a) ionization (it leads to switch-off of the power supply)

b) metallic projections..

The weld bead has a dark outlook and shows many pits. The micrographic examination shows that the dispersed structure of SAP is no longer present. The aluminium shows many inclusions and porosity (see fig. 4).

2.3 EXPERIMENTS WITH DEGASSED MATERIAL

2.3.1

The degassing conditions were obtained by systematic tests conducted at 500°, 600°, and 625° C. Analysis of hydrogen in the gas was not possible. Degassing of Otto Fuchs material was considered sufficient when no blistering or porosity occurred upon welding the SAP in the electron beam. This result was obtained by heating at 625° C for 24 hours under a vacuum 1 x 10^{-4} mm Hg (heating and cooling rates : 100° C / hour).

2.3.2

The welding conditions were : 25 kV, 20-25 mA, 1.5 turn in 20 seconds.

2.3.3

It has been possible to weld SAP by electron beam without formation of internal porosity and without complete transformation of the structure, as shown on fig. 5. The welds were leak-tight when tested using a helium leakdetector; but often the weld penetration is only 0.4 mm in a 1 mm thin can, due to insufficient thermal concentration of the gun used.

3 - ELECTRON BEAM WELDING WITH A GUN MANUFACTURED BY "B. PRECIS" IN FRANCE

3.1 THE TEST COMBINED TWO NEW FACTORS

3.1.1

A new gun was put at our disposal by Euratom (J. Briola). This electron gun is a PIERCE type gun of 3 kW, in which the electrons are focused by a concentric electric field that is generated by the concentric arrangement of a spherical anode in a spherical cathode [13, 15, 16].

With this arrangement, the work piece is not the anode. This gun, with added magnetic focalization, permits a higher thermal concentration than the C. E. N. gun.

3.1.2

The sintered aluminium was manufactured by Montecatini in Novara, Italy, under Euratom contract [11] . Aluminium powder prepared by A. I. A. G. in Switzerland is used as a base material and a degassing step at 600° C, after the cold compacting operation, is included in the fabrication procedure, which eliminates the necessity for degassing the finished product before welding. The SAP 960, 930 and 895 were welded.

3.2 TEST EQUIPMENT

3.2.1 Description

Equipment which simulates the pressure and thermal conditions of the can in a reactor has been designed. A welded tube is internally pressurized and heated, and a helium leakdetector is used to detect any failure.

The equipment consists of two parts :

- an enclosure in which a helium pressure can be maintained
- a chamber where a residual pressure of 10^{-2} to 10^{-3} mm Hg can be obtained; this chamber is connected to a CEC helium leakdetector (Fig. 6, 7, 8).

The two enclosures are independent and are interconnected by the tubular sample which penetrates the first enclosure with its unwelded end, and the second with the welded end. A thermocoax type heating element is placed inside the tube, close to the weld. The section of tube between the two enclosures is water cooled to protect the rubber joints. The temperature of the tube is always measured 3 mm from the weld, by a thermocouple pressed against the tube by means of a small spring.

3.2.2 Test procedure

a) Evacuate the second enclosure to 10^{-3} mm Hg;

b) Pressurize the tube to 20 kg/cm2 (value given by Euratom staff);

c) Heat the welded end of the tube at a constant rate, 12° C/minute until the leakdetector indicates a break in the weld or in the tube.

3.3 RESULTS

Two types of end-plugs have been used : type a and type b (see fig. 9).

3.3.1 Type a end-plug

The welding conditions were : 30 kV, 25 mA, 1.5 turn in 20 seconds.

A series of tests has shown that with precise mechanical positioning, it is possible to weld

SAP 960, 930 and 895 end-plugs to tubes. The failure of the sealed tubes will occur at the side of the tube and not at the weld for shortterm rupture tests at temperature. Temperature reached is, on the average, 500° C, with 20 kg/cm^2 internal pressure. The metallograph of different SAP materials in degassed and undegassed conditions is shown in fig. 10, 11, 12, 13 and 14.

It must be noted that SAP 930 and 895 have still to be degassed at 625° C for 24 hours or more, to avoid any blistering or porosity in the structure, mainly in the end-plug.

3.3.2 Type b en-plug

The welding conditions were : 20 kV, 18 mA, 15 turns in 5 minutes.

The results indicate some improvement over the type a end-plug (fig. 15 and 16). The combination of pressure and lower temperatures provide stronger joints.

The procedure was the principle of a technique as described in reference 20, p. 51 : " ... the successful procedure will involve sealing in a plug at the end of the tube followed by welding around the exposed bond line. The former should provide strength and the latter might ensure leaktightness". The report added : "This solution of the problem does not seem to have been selected at this time by any of the organizations in this field".

In fact, it was selected and is used applying a localized external pressure on the tube during welding (14) (see fig. 17). Two zones are obtained in the weld : one with untransformed SAP, welded by diffusion which provides strength, the other with transformed SAP which ensures leaktightness. Temperature reached in the pressure test is, on the average, 565° C with 20 kg/cm^2 internal pressure.

4 - CONCLUSIONS

4.1

Successful closure of SAP tubes using an electron-beam welding technique has been possible for SAP 960, 930 and 895. High temperature testing under pressure has been used to verify the quality of the welds.

4.2

Combination of pressure and welding leads to high-quality closures equal to or superior to other types of welds because of the very high, localized heating.

4.3

Electron beam welding can be systematically used as a quality test for gas content of the material.

Acknowledgements

The authors thank G. Musso for the very fine metallographic work done, and P. Groeseneken for his technical help.

The collaboration with J. Briola and P. Jehenson of Euratom has been a permanent source of discussions, suggestions and stimulation.

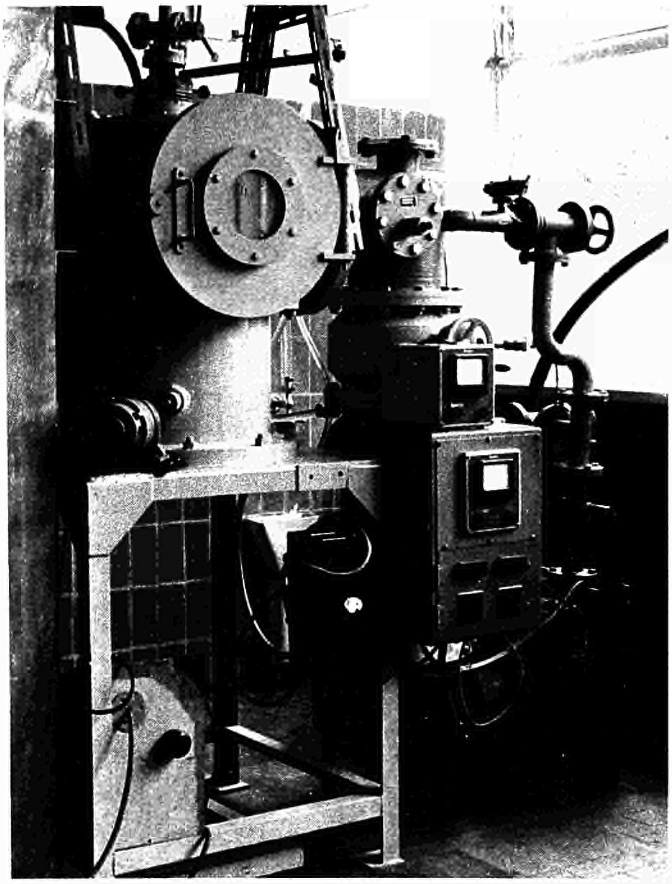


Fig. 1 - Equipment used at the C.E.N. laboratory for welding.

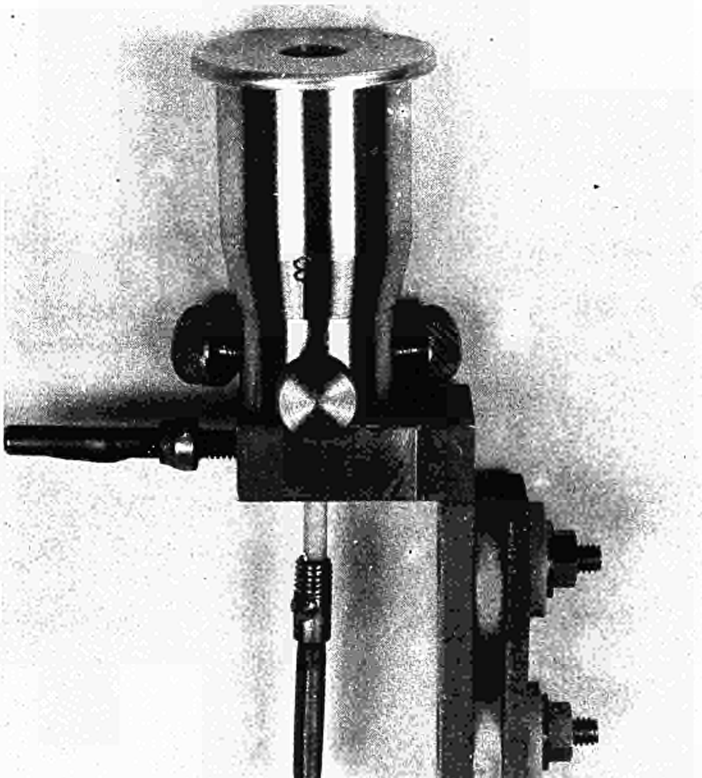


Fig. 2 - Photograph of the electron gun.

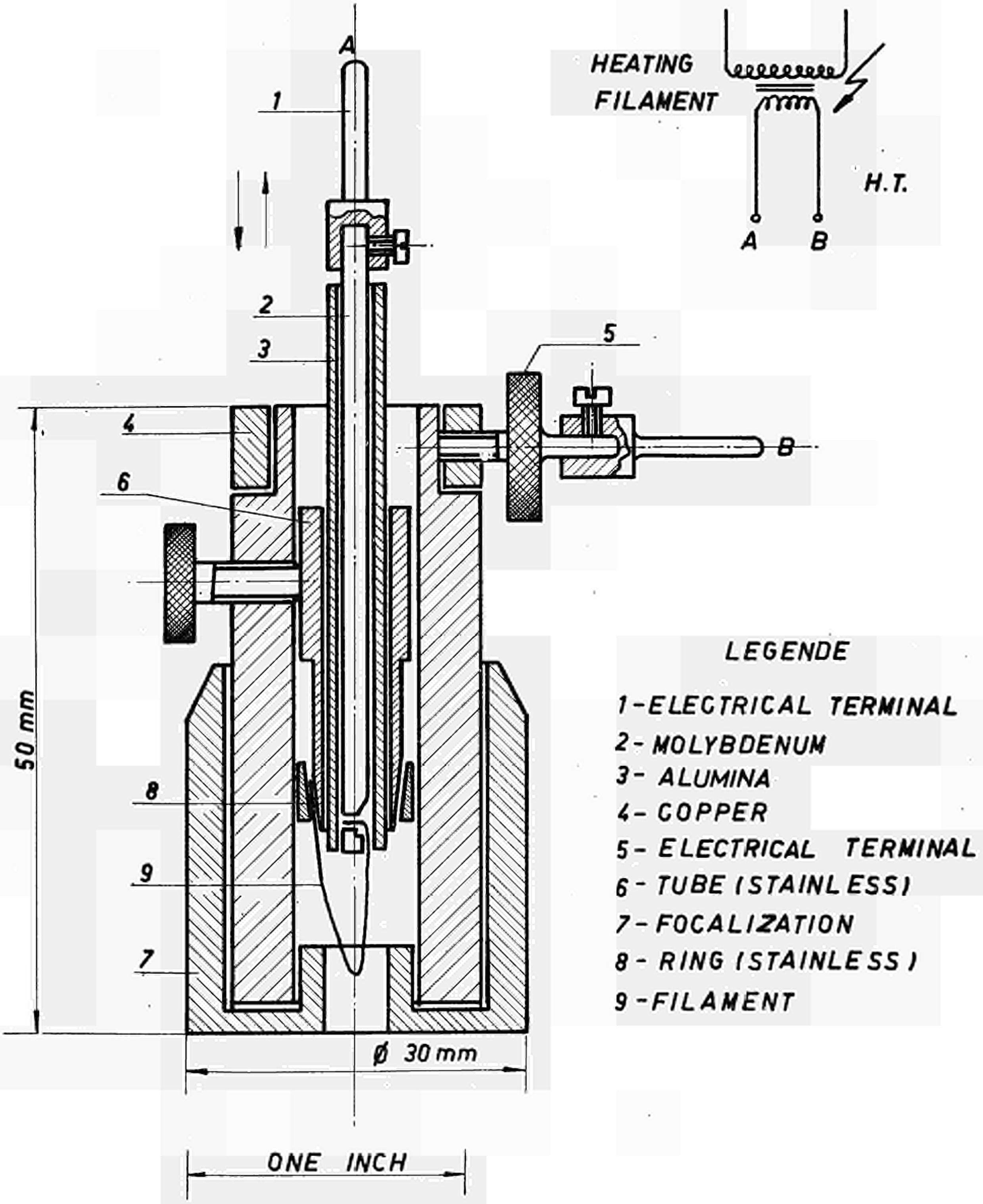


Fig: 3 SKETCH OF THE ELECTRON GUN

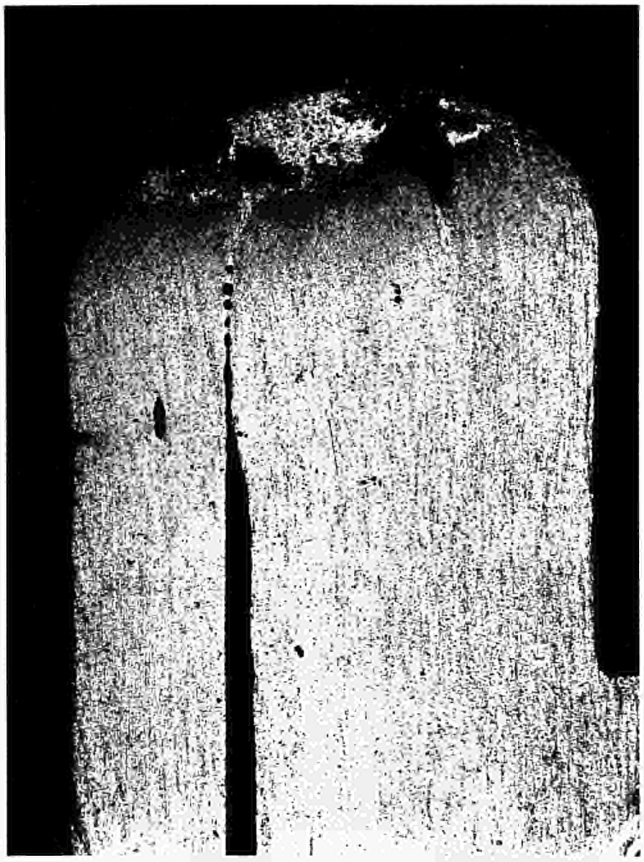


Fig. 4 – Undegassed S.A.P. after electron beam welding – Otto Fuchs material. (× 25)

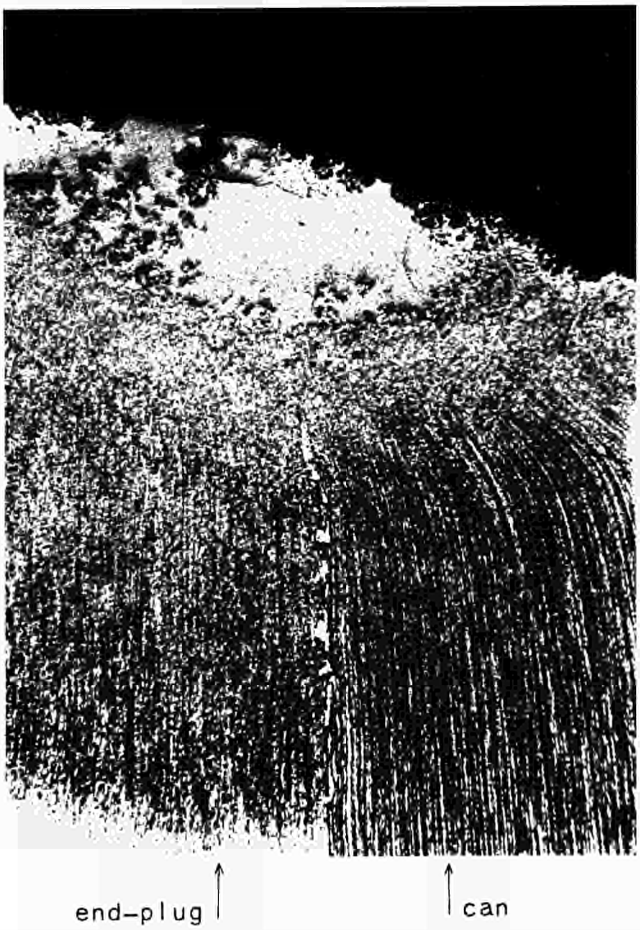


Fig. 5 – Degassed S.A.P. after electron beam welding – Otto Fuchs material. (× 100)

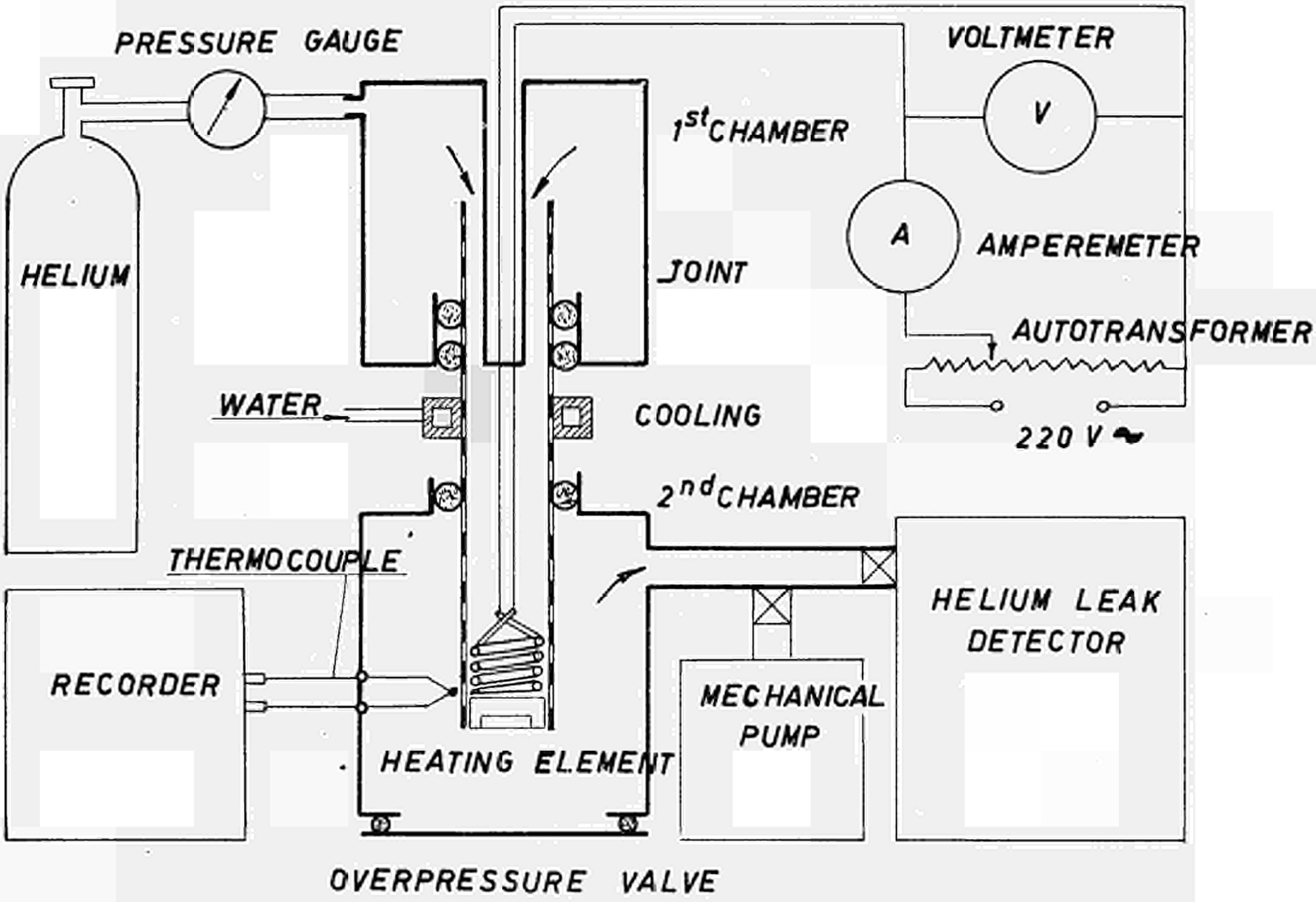


Fig. 6 TESTING EQUIPMENT OF WELDED TUBES (SKETCH)

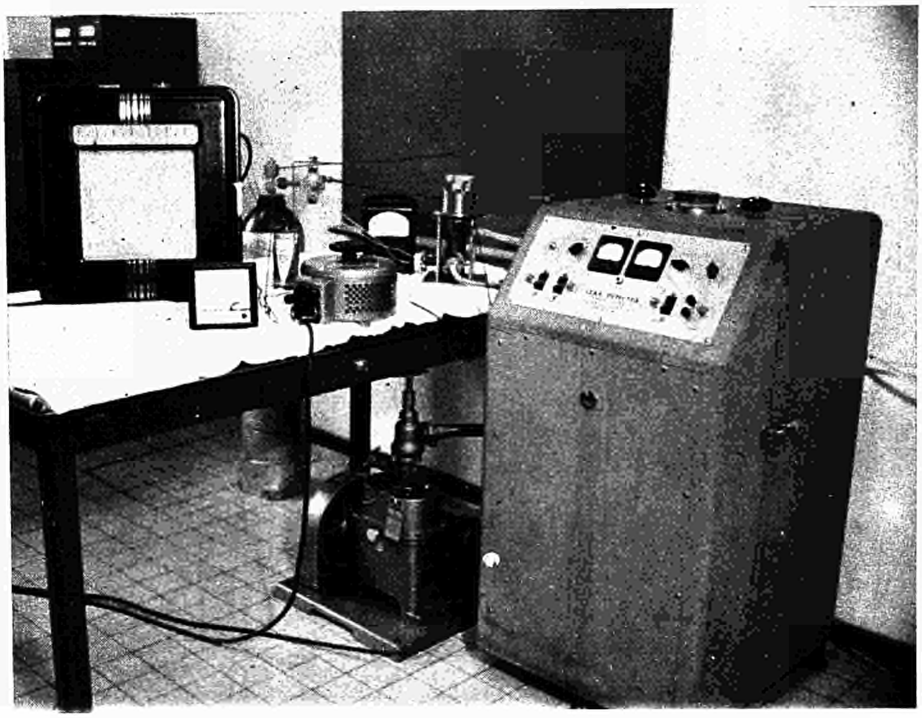


Fig. 7 - Equipment used at the C.E.N. laboratory for testing the tube.

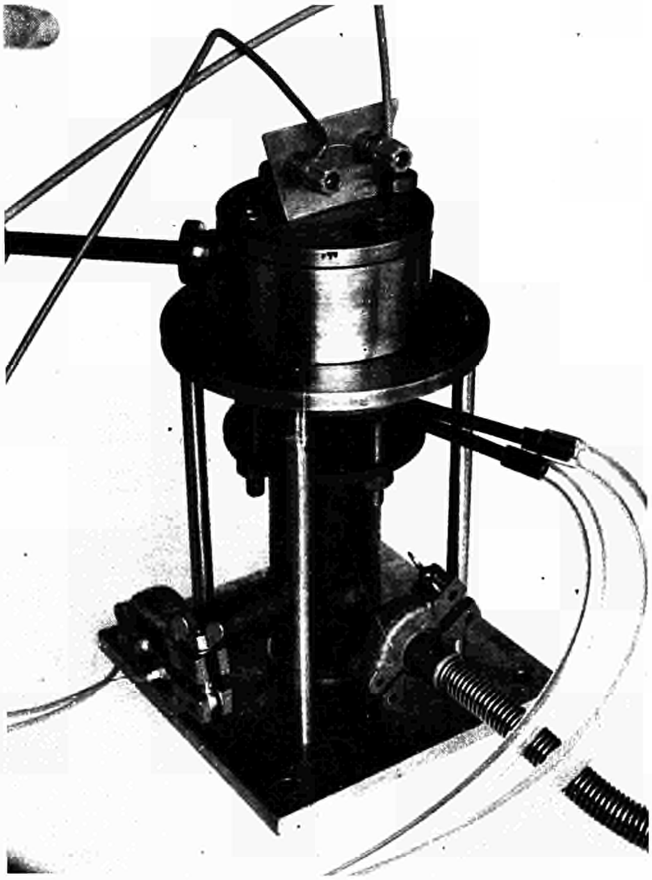
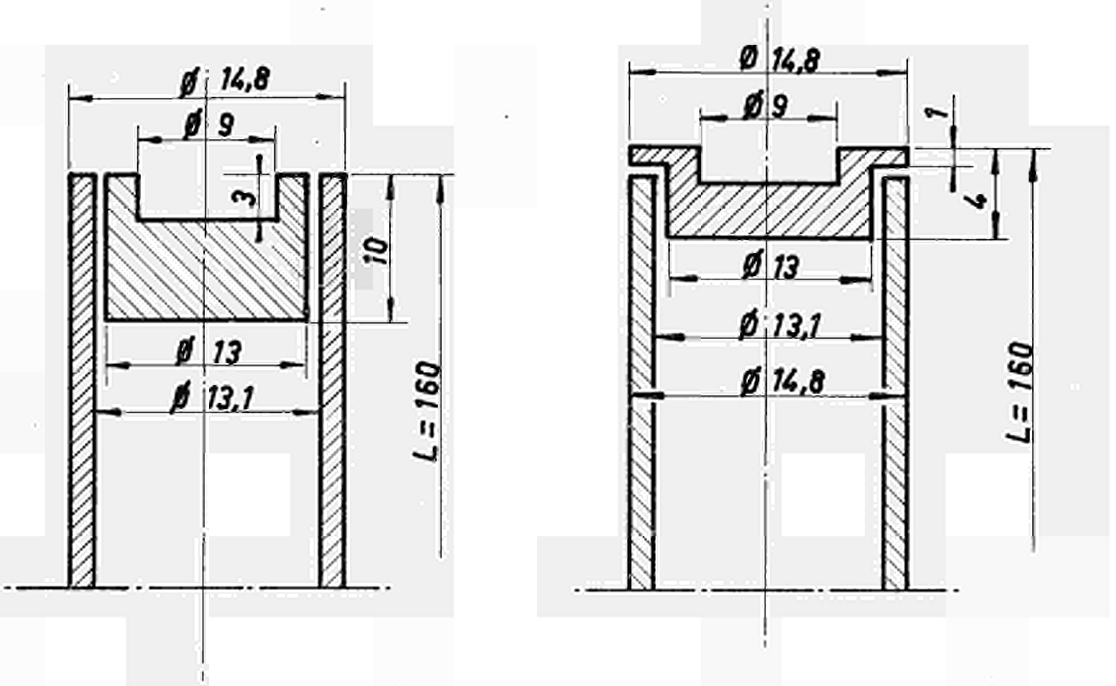


Fig. 8 - Testing equipment close-up.


TYPE a

TYPE b

Fig: 9 SKETCH OF THE END-PLUG TYPE“a„ AND TYPE “b„

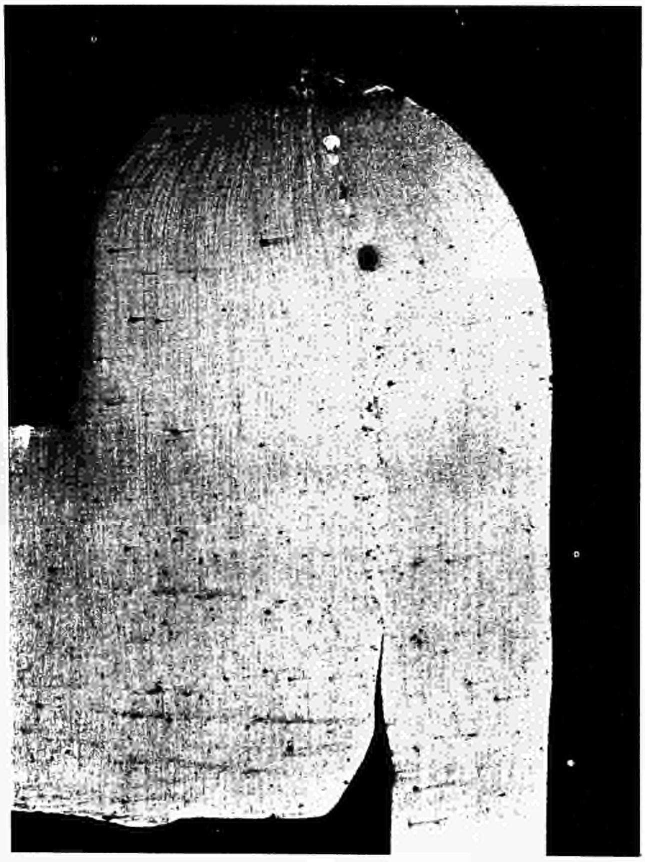


Fig. 10 – End-plug type a – welding of S.A.P.
Montecatini 960 undegassed. (× 25)

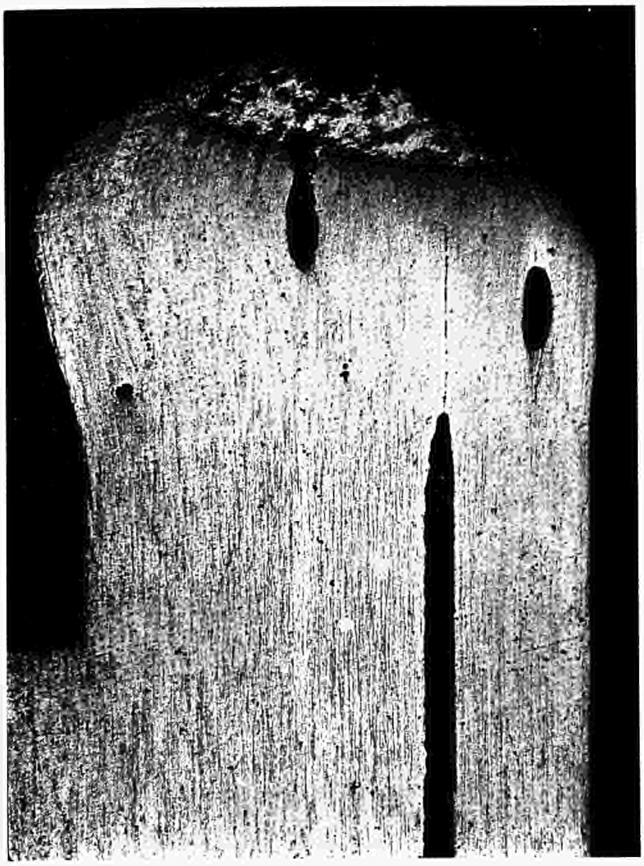


Fig. 11 - End-plug type a - welding of S.A.P. Montecatini 930 undegassed. (× 25)

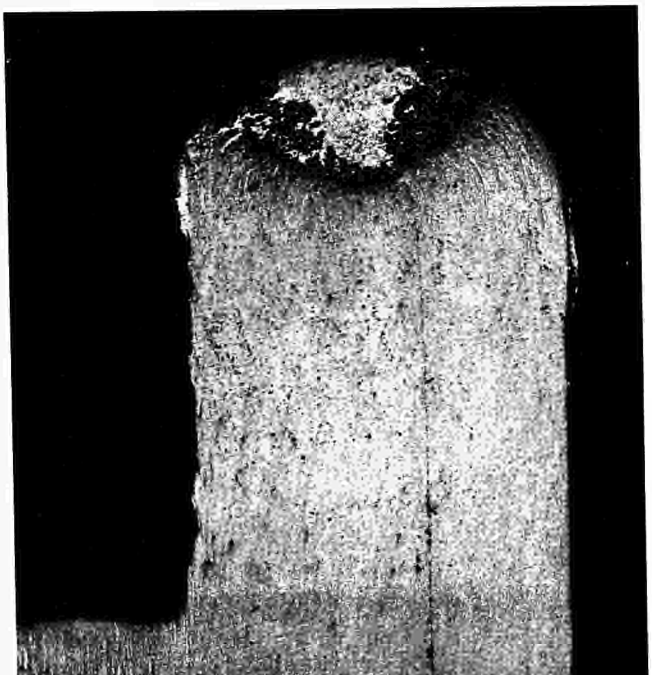


Fig. 12 - End-plug type a - welding of S.A.P. Montecatini 930 degassed 24 hrs at 625°C. (× 25)

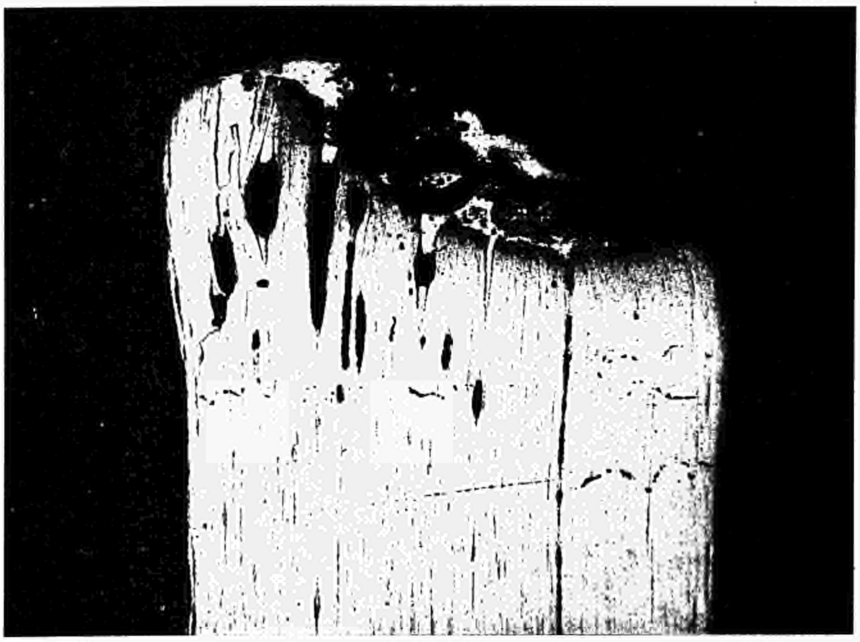


Fig. 13 – End-plug type a – welding of S.A.P. Montecatini 895 undegassed. (× 25)

Fig. 14 – End-plug type a – welding of S.A.P. Montecatini 895 degassed 24 hrs at 625°C. (× 25)

Note presence of blisters even after degassing.

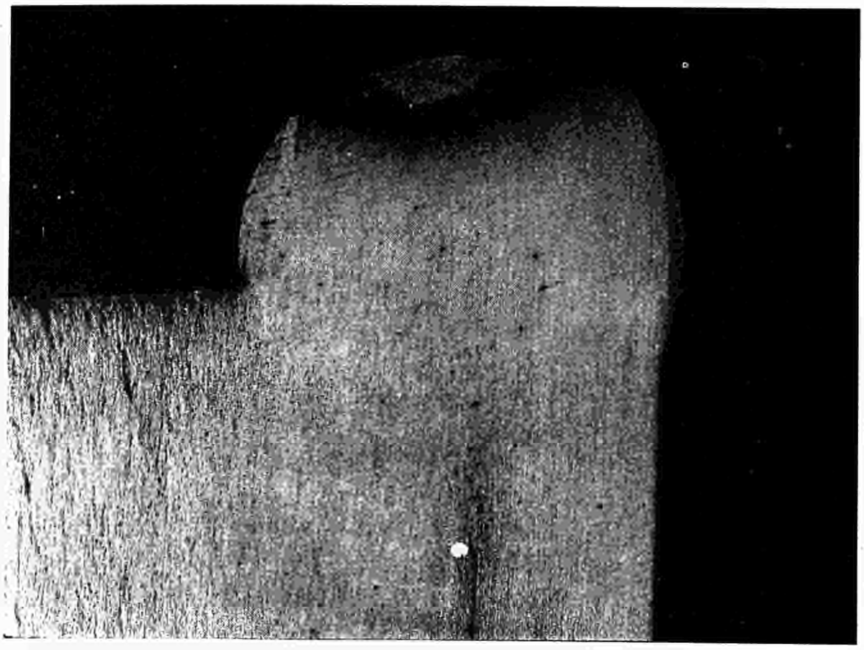


Fig. 15 – End-plug type b – welding of S.A.P. Montecatini 930 undegassed. (× 25)

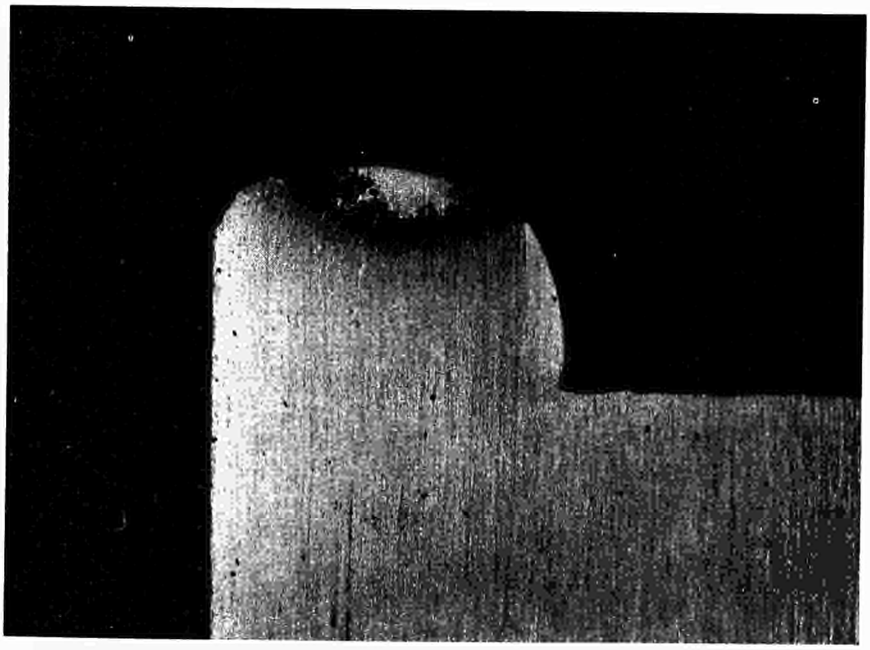


Fig. 16 – End-plug type b – welding of S.A.P. Montecatini 930 undegassed. (× 25)

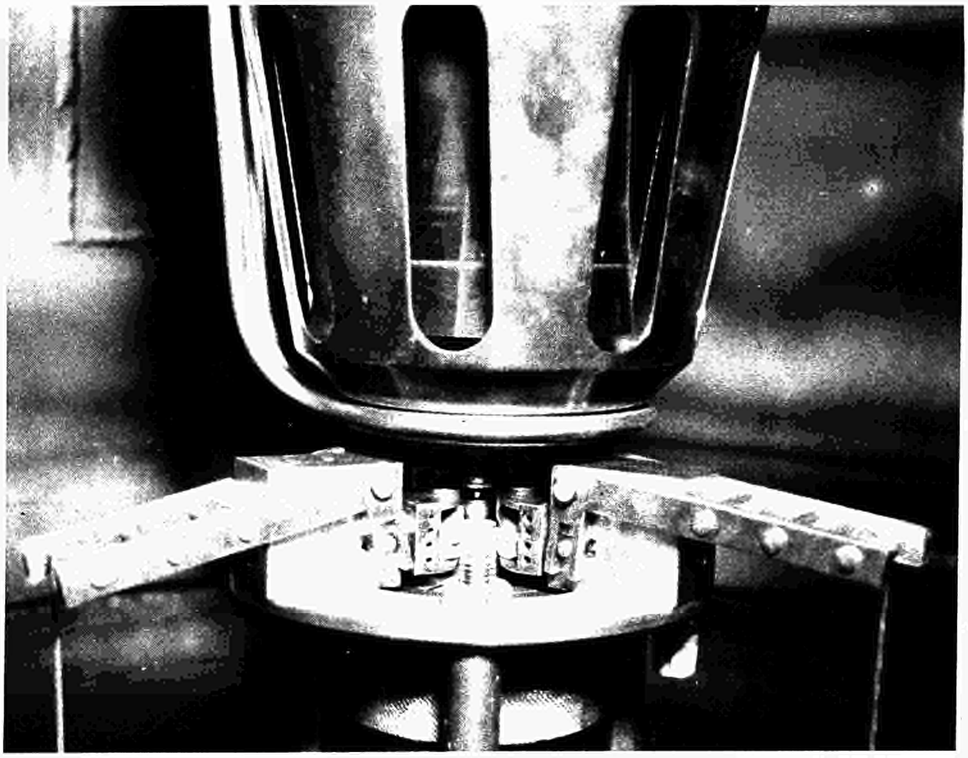


Fig. 17 - View of the equipment used to weld end-plug type b.