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THE DUOPLASMATRON ION SOURCE FOR THE NEW CERN LINAC PREINJECTOR

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1. INTRODUCTION

The purpose of this report is to bring up to date the information available on the design and construction of the new CERN Linac preinjector ion source. The source is closely based on the "old" Linac (Von Ardenne) duoplasmatron[1,2] which has operated successfully for more than 13 years.

2. DESIGN AND CONSTRUCTION

When the decision was made to construct a new 50 MeV Linac for the CERN PS, and consequently a new preinjector, it was decided to retain the duoplasmatron type of ion source. However, since the new preinjector was to operate at 750 kV, as opposed to the 500 kV of the "old" one, certain changes in the source design became necessary. The changes were essentially dictated by the new accelerating column design. Since the 500 kV column[3,4] had also proved very satisfactory in service, it was decided to simply make a longer version[5] for 750 kV operation. As the potential difference between the column anode and the walls was therefore to be increased, it was clearly advisable to reduce the diameter of the re-entrant anode to arrive at approximately the same voltage gradients as in the "old" column. Thus a smaller duoplasmatron was called for, to fit within the smaller titanium anode. Upon examining the design of the "old" source it became clear that by adopting a re-entrant type of body and supporting flange it would be possible to reduce the size considerably, whilst at the same time keeping the dimensions of the plasma/beam forming components identical with the original proven design. Besides reducing the over-all diameter of the column anode the re-entrant source body shape allowed a longer frontal cone on the anode enabling the front face to be the same diameter as the column median and cathode electrodes. The result being a "cleaner", more symmetrical electrode configuration in the most critical part of the accelerating tube. Figures 1 and 2 show the new and "old" sources, respectively, within their column anode envelopes. Figure 3 indicates the position of the source in the column electrode assembly.

Figure 4 shows the basic schematic of the inner parts of the source in cross-section and these components were not changed. The actual cross-section of the new duoplasmatron is seen in Fig. 5, and the complete device is seen in side and front views in Figs. 6 and 7, respectively. Figure 8 is the rear view with the oxide cathode$^{1,6)}$ removed, thus showing the small ($\emptyset$ = 0.6 mm) central anode hole.

3. MAGNET DESIGN

Before finalizing the new source design a check was made, using the X6TRS code$^{7)}$, to see if the pure iron body (Armco) of the smaller version would magnetically saturate anywhere at full coil current. The highest values of field computed were around 21 kG in the iron which is below saturation for correctly annealed Armco$^{8)}$.

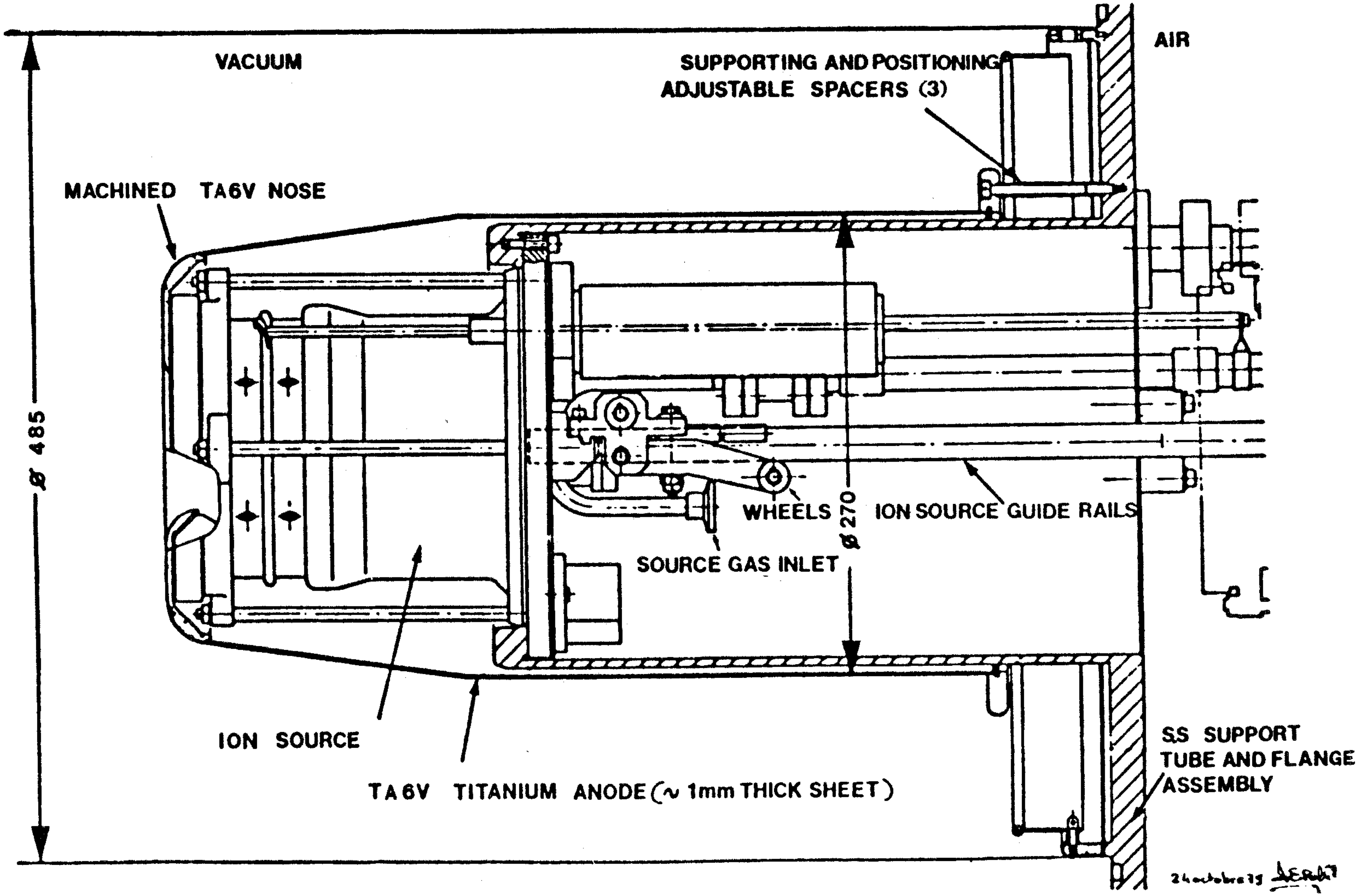
3.1 The magnet

Figure 9 is the computer plot of the magnetic flux lines in the body and Armco arc chamber (or snout) and Fig. 10 is an enlarged scale plot of the critical source anode/snout "compressor" region showing the focusing effect of the field lines in the pole face gap. The electromagnet is the cylindrical "C" type, symmetrical about the axis, common to duoplasmatrons. The molybdenum disc is indicated with the small diameter hole through which the compressed plasma passes into the expansion cup.

The magnitude and shape of the axial field in the region of Fig. 10 is shown in Fig. 11 $^{1)}$. The peak axial field in the gap is about 6 kG in normal operation. Also shown in Fig. 11 is the smaller axial field peak produced by the expansion magnet$^{1)}$ (see later section on the expansion cup).

Another advantage (especially in the handling) of trimming the iron source body to a minimum is the reduction in weight. The new source weighs 32 kg compared to the 43 kg of the old version. The main magnet

FIG 1 CROSS SECTION THROUGH COLUMN ANODE ASSEMBLY·



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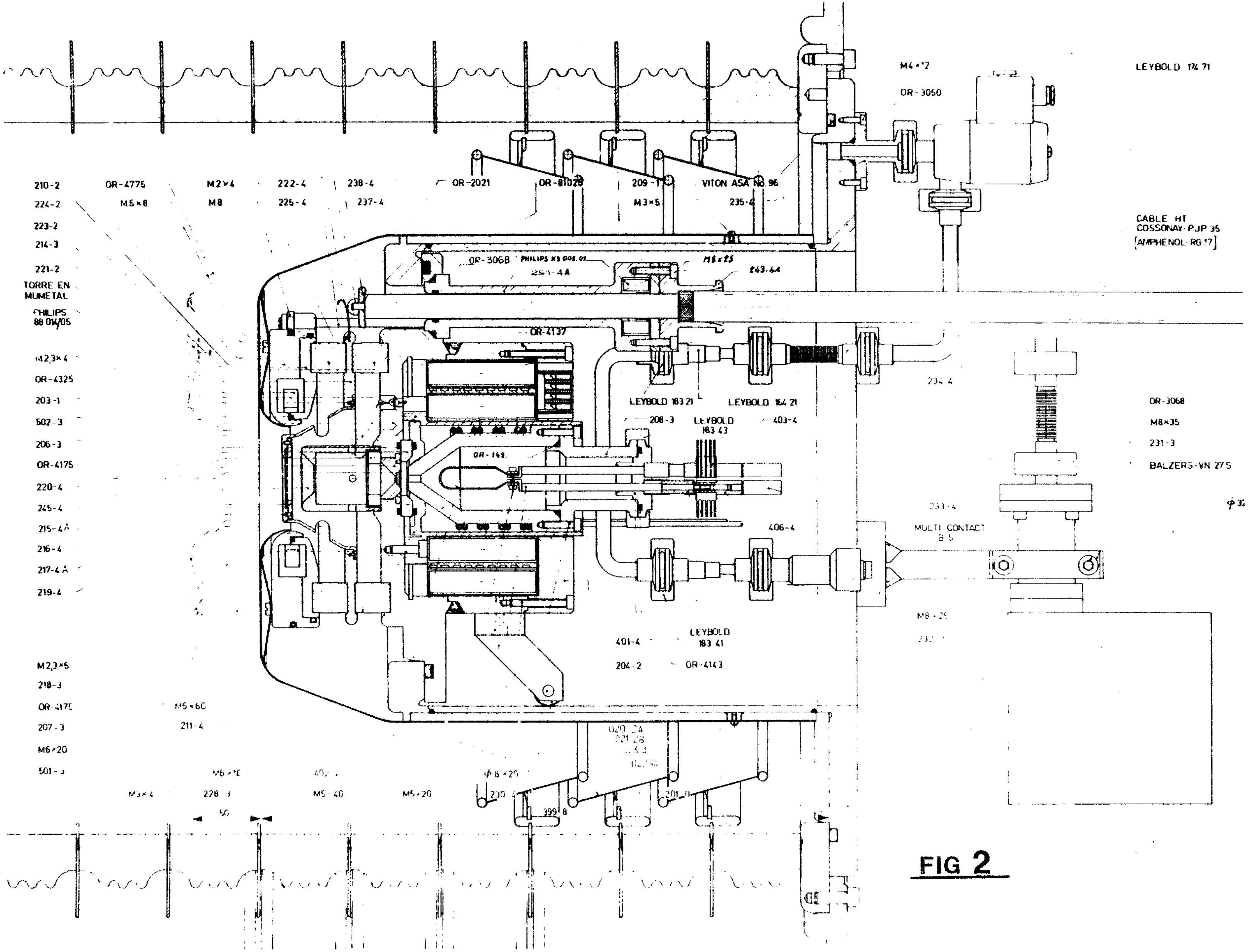

210-2
224-2
223-2
214-3
221-2
TORRE EN MUMETAL
PHILIPS 88 014/05
M2,3×4
OR-4325
203-1
502-3
206-3
OR-4175
220-4
245-4
215-4A
216-4
217-4 A
219-4
M2,3×5
218-3
OR-4175
207-3
M6×20
501-3
OR-4775
M5×8
M2×4
M8
222-4
225-4
238-4
237-4
OR-2021
OR-81028
209-1
M3×5
VITON ASA No. 96
235-4
OR-3068
PHILIPS K3 005.01
251-4A
M5×25
243-4A
OR-4137
OR-149.
LEYBOLD 183 21
LEYBOLD 164 21
208-3
LEYBOLD 183 43
403-4
406-4
LEYBOLD 183 41
401-4
204-2
OR-4143
M5×60
211-4
M4×2
OR-3050
LEYBOLD 174 71
CABLE HT
COSSONAY-PJP 35
[AMPHENOL-RG 17]
234-4
OR-3068
M8×35
231-3
BALZERS-VN 27S
233-4
φ 3
MULTI CONTACT B 5
M8×25
232
020 2A
021 2B
3 4
02
φ 8×25
230
399 8
201 0
M3×4
228 3
50
M5×40
M5×20
M6×10

FIG 2

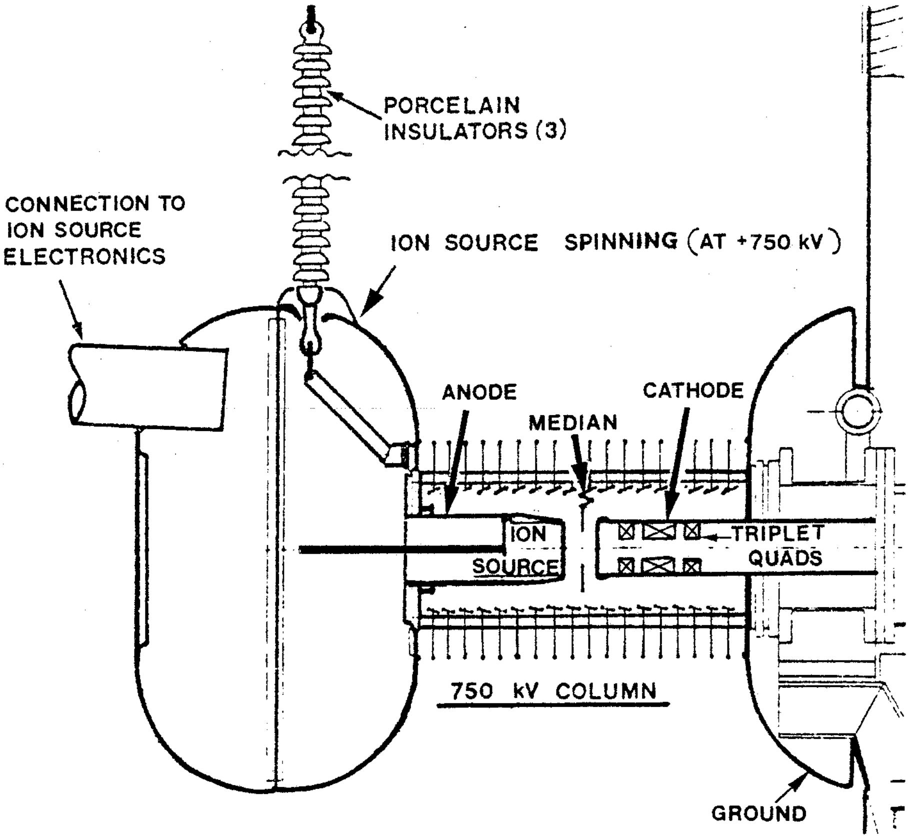
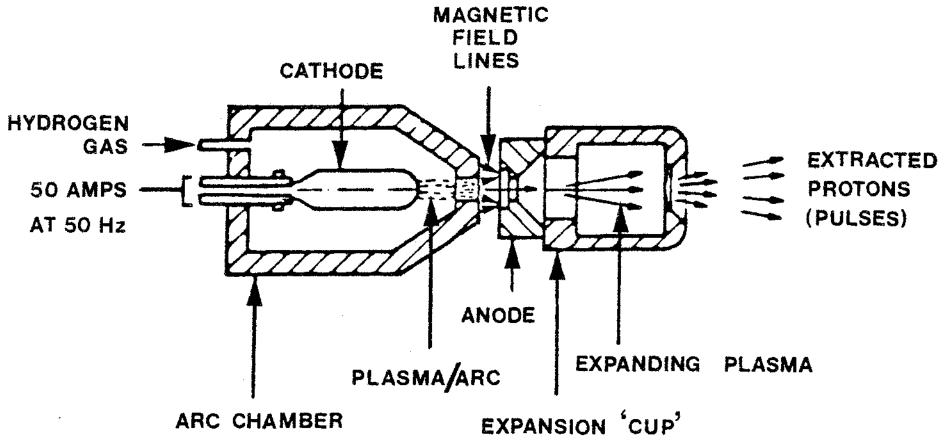


FIG 3 PRINCIPAL COMPONENTS IN AND ON THE NEW LINAC PRE-INJECTOR ACCELERATING COLUMN·

coils are made as before, from 1 × 2 mm rectangular section insulated copper wire potted in an araldite. The central water cooling channel and back plate sub-assembly are cast in the araldite at the same time. The magnet coil, together with the rear Armco back plate, is thus removable (as previously) in one unit (the two coils are connected in series externally).

For the new source, higher temperature rated wire, insulated with Kapton and Teflon, is used for the magnet. The new wire is rated at 220°C compared to the previous 120°C varnish insulated type. The maximum permissible d.c. current for the assembly is fixed at 10 A, with a cooling flow of about 0.5 $\ell \cdot \text{min}^{-1}$. Water, with about 30% ethanol as corrosion inhibiter, is now preferred instead of the oil originally used, to avoid

FIG 4 SCHEMATIC OF PROTON ION SOURCE (DUOPLASMATRON)



hydrocarbon contamination of the vacuum side of the source when dismantling. Since the source cooling system is now a closed loop entirely up at the 750 kV level, no continuous high voltage gradients have to be traversed, so water cooling is possible. (The water is cooled by passing it through a standard R.4 air-cooled radiator on the source electronics platform.) The slight reduction in the over-all width of the magnet coils, necessitated by the reduced diameter Armco body, was compensated by an increase in their length; the final number of turns per coil being ∿ 500 as on the "old" source. A possible alternative to the lengthy araldite potted construction would be to use wide, anodized aluminium foil (e.g. ANO-FOL)[9] as the conductor for the coils. The insulating Anodic film on the aluminium being only a few microns thick allows a much better packing factor, compensating for the × 1.61 increase in resistivity of aluminium compared to copper. The resulting coil could be lighter and in one piece, with no water cooling required as the material will operate at up to 500°C. The main problem is in making the electrical connections reliable on such a coil and it would probably be best to have the whole assembly made at the manufacturers.

4. THE ARC CHAMBER

The only change made was to nickel plate the inside surfaces to eliminate the formation of rust that can occur when the arc chamber is

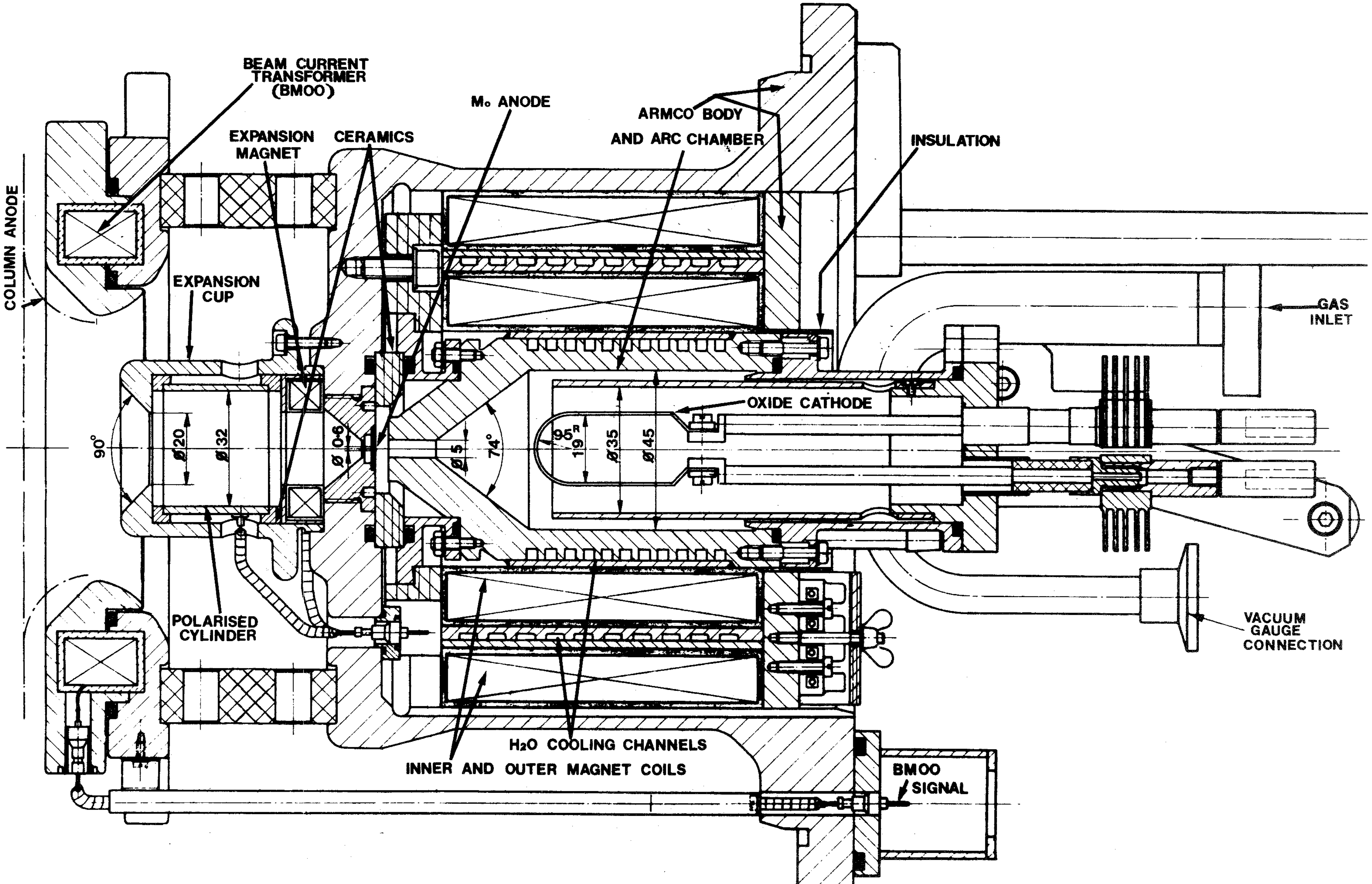


FIG 5 CROSS SECTION OF DUOPLASMATRON 1

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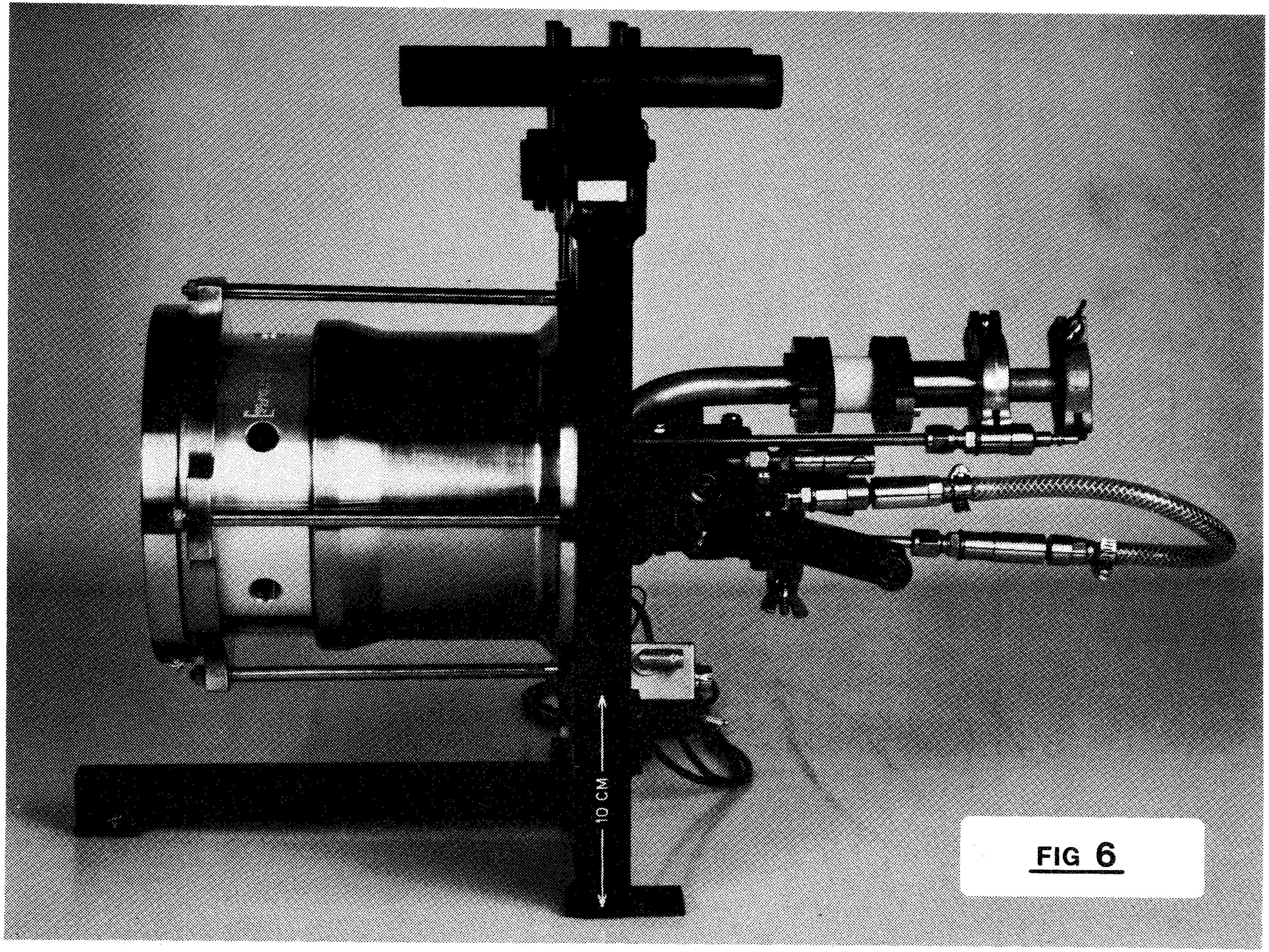


FIG 6

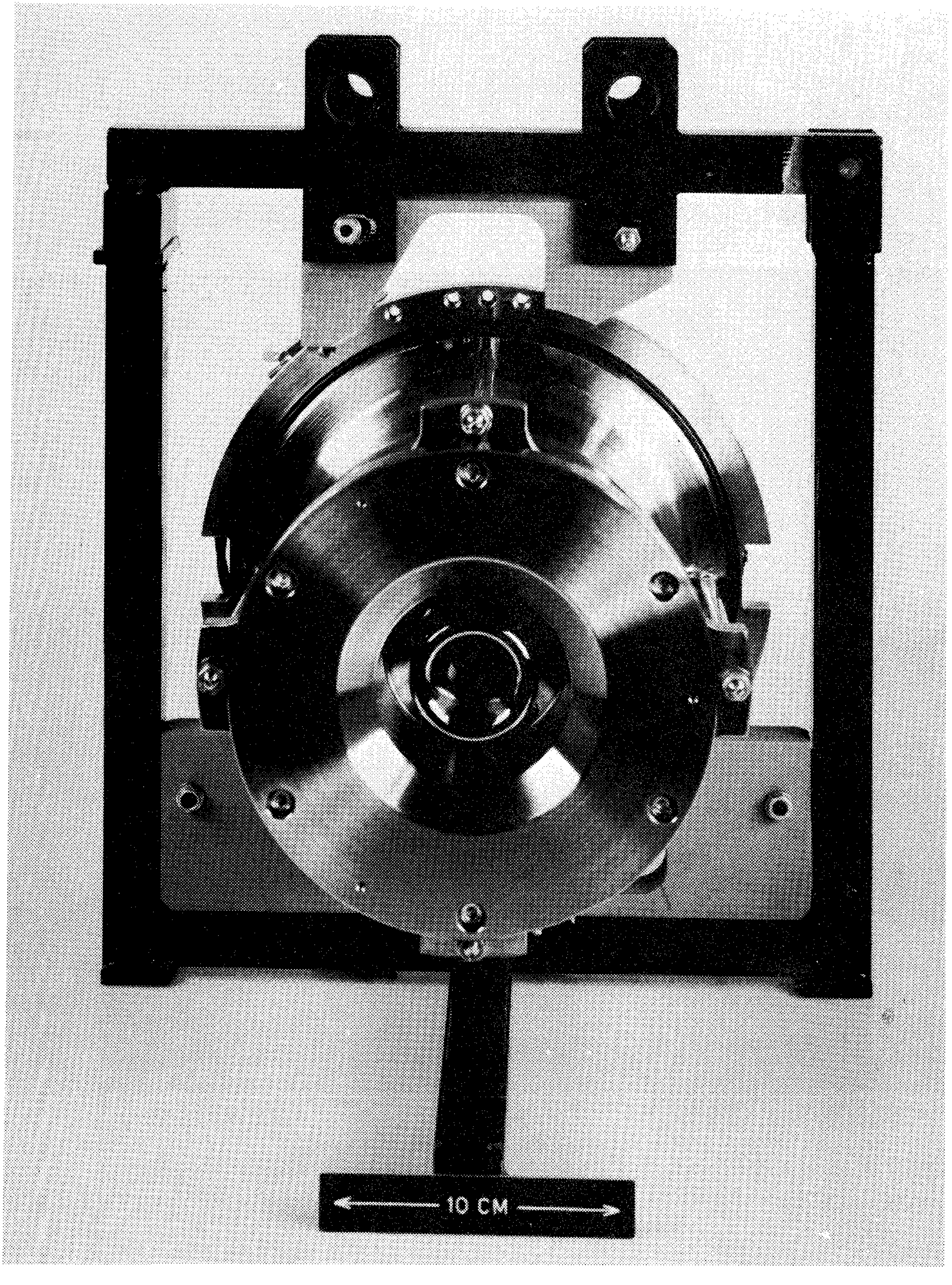


FIG 7

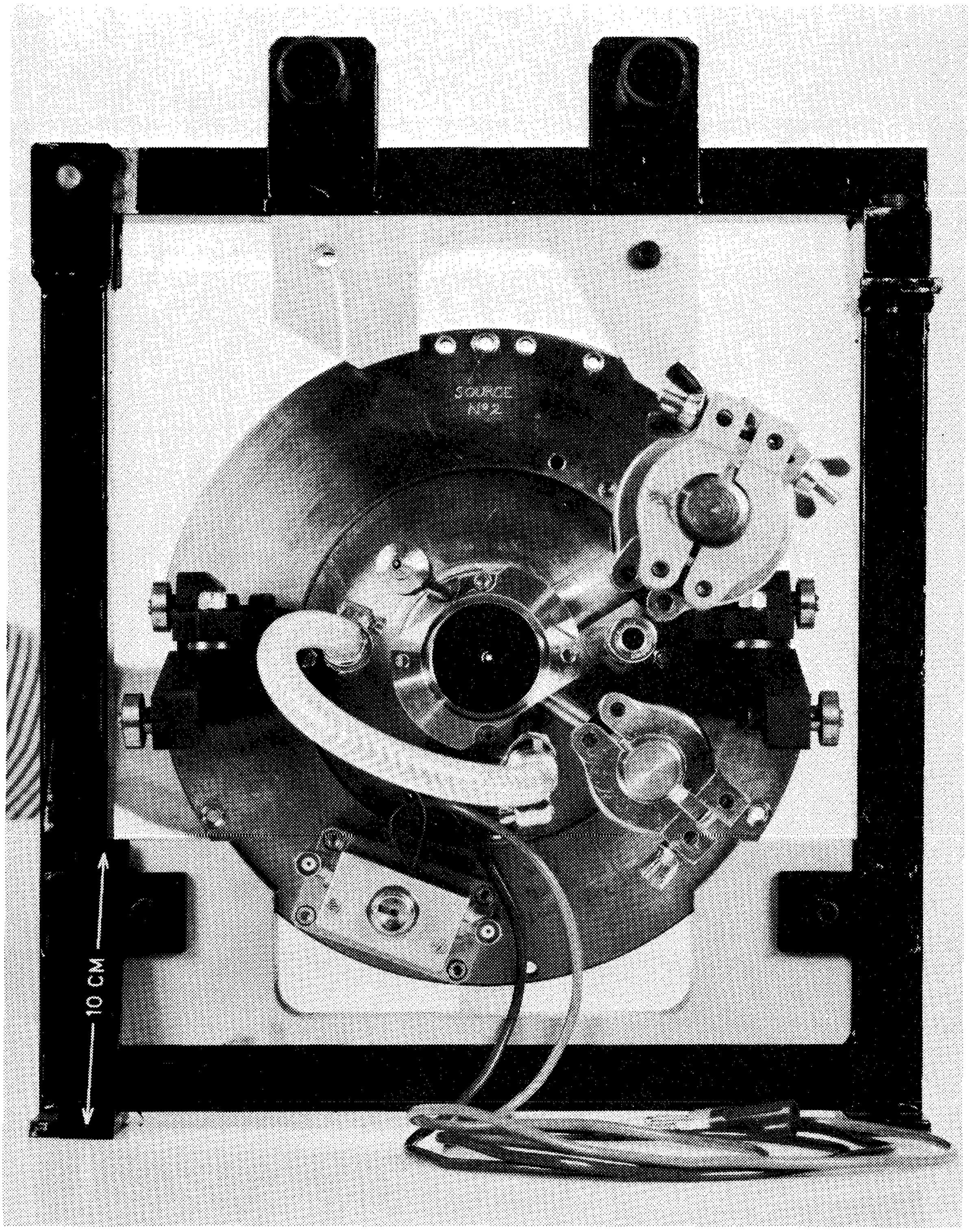


FIG 8

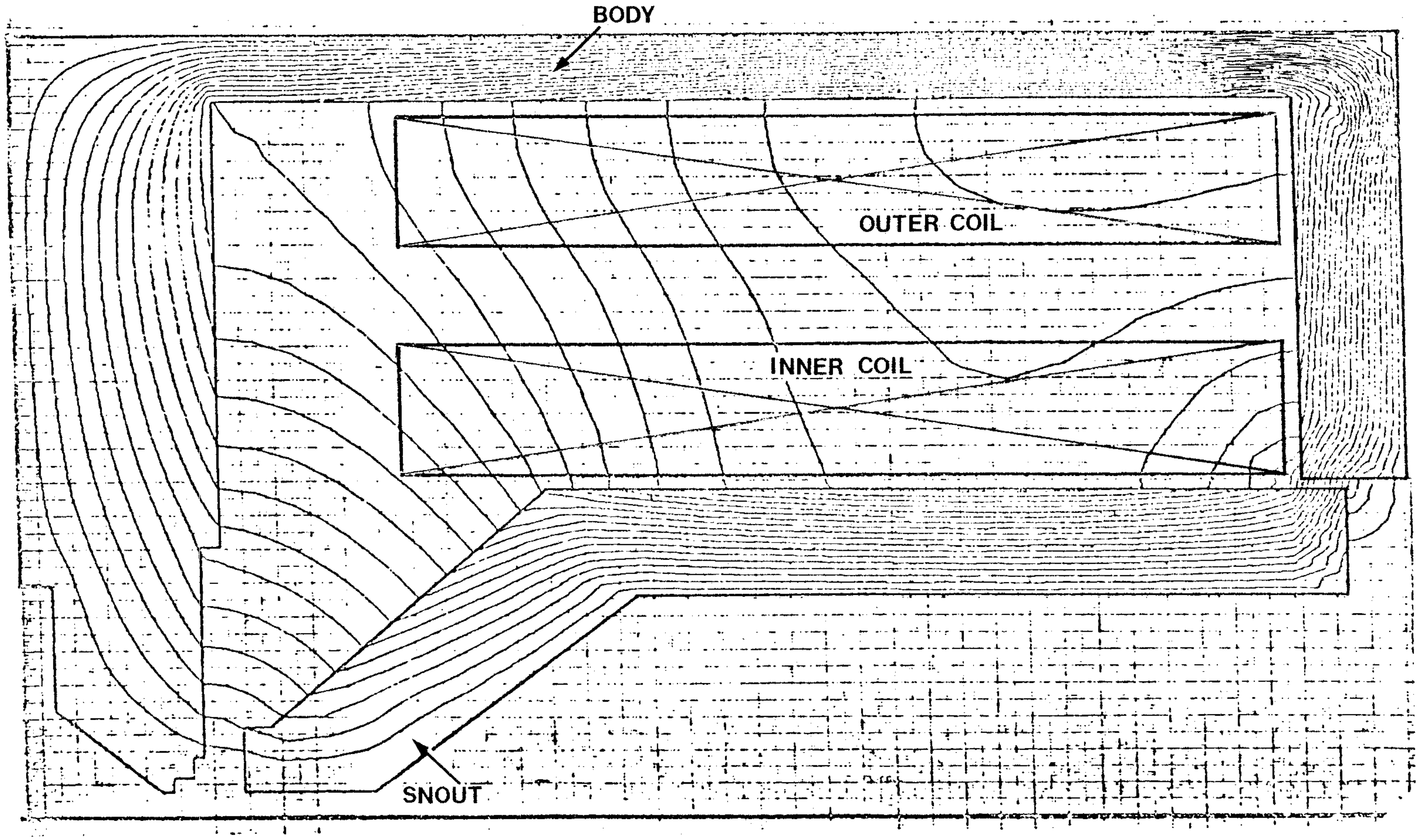


FIG 9 MAGNETIC FLUX LINES DISTRIBUTION IN BODY AND SNOUT(ARC CHAMBER) OF DUOPLASMATRON 1

FIG 10 MAGNETIC FLUX LINES AT ANODE OF DUOPLASMATRON 1

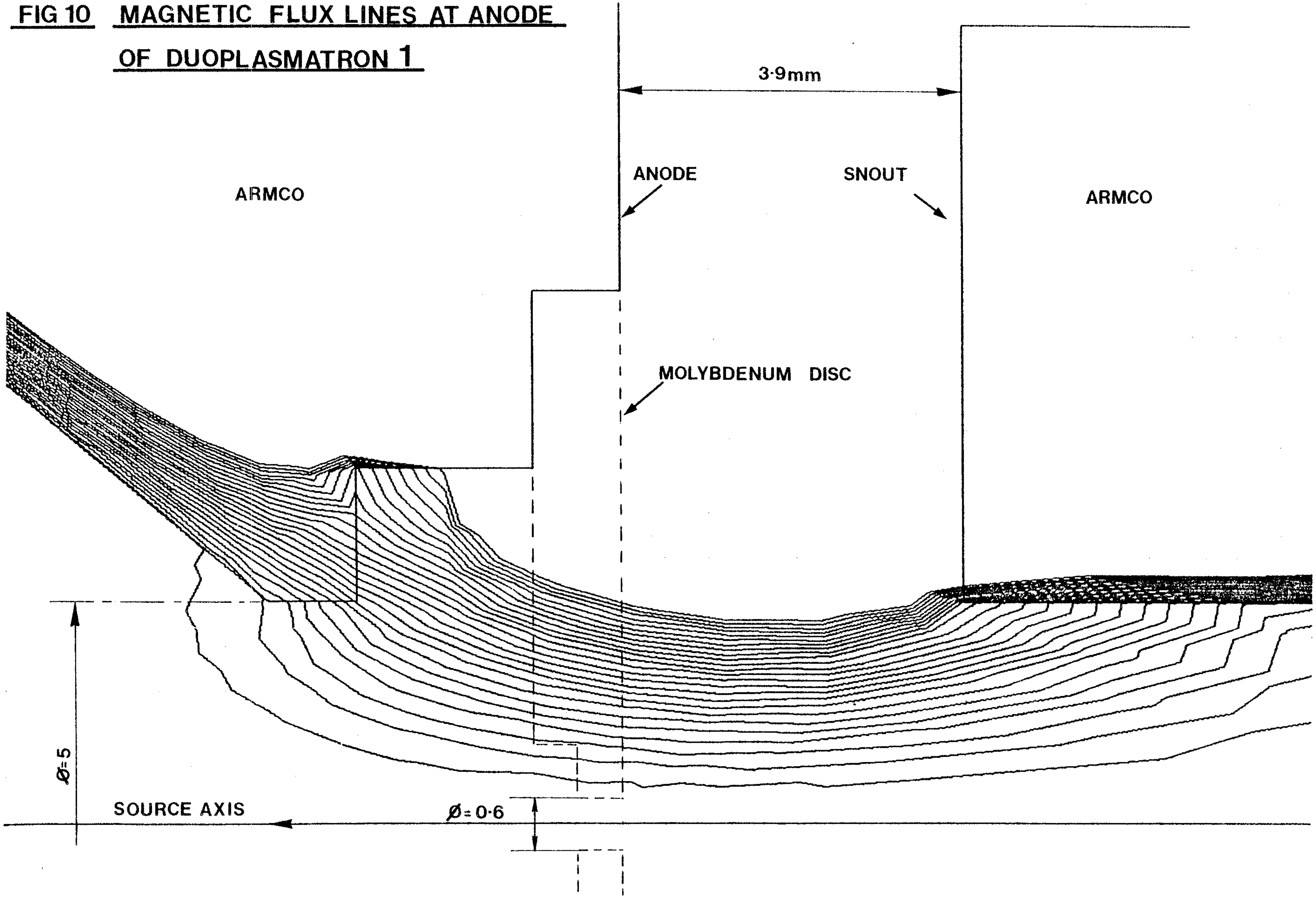
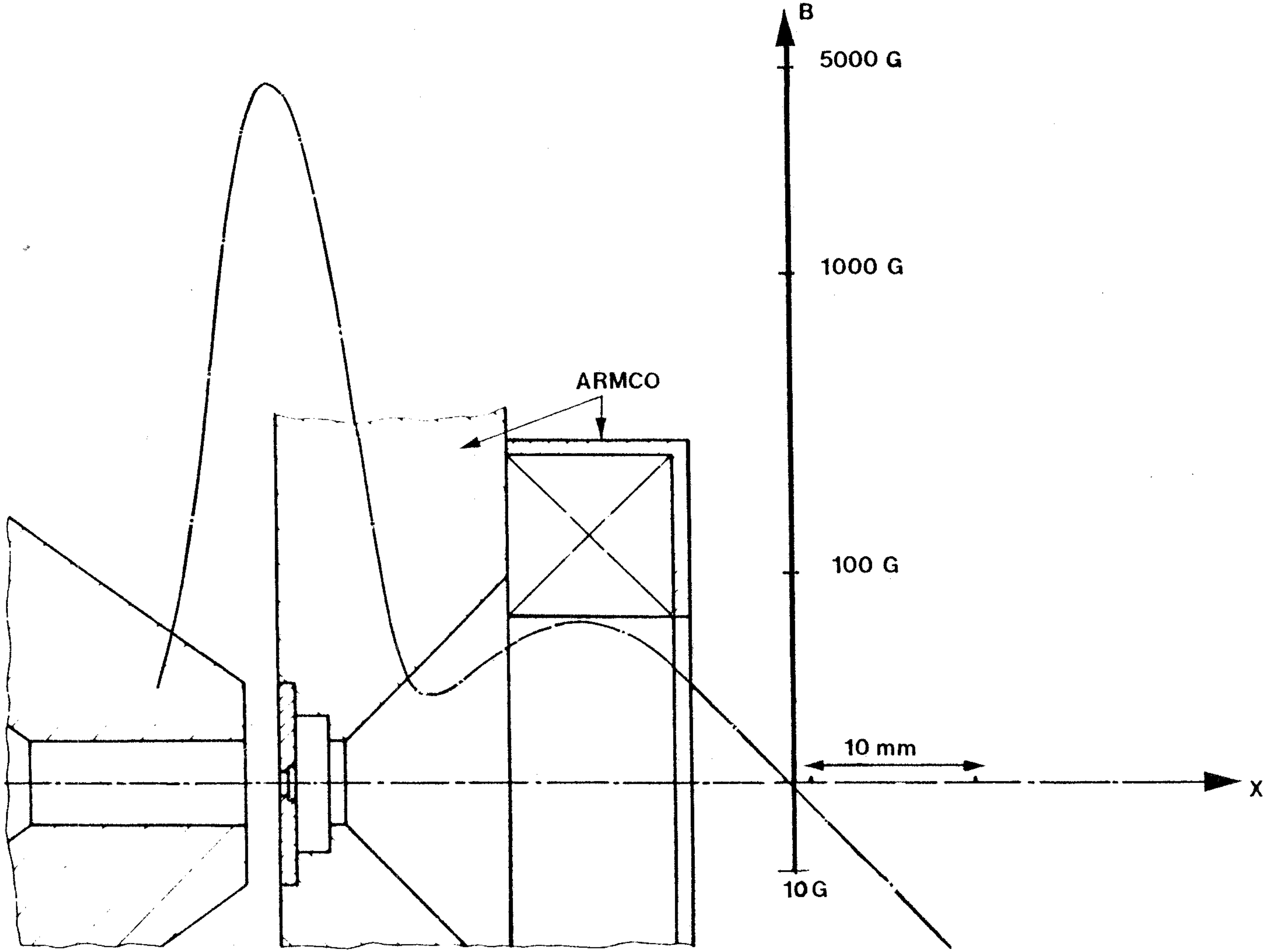


FIG 11 TYPICAL MAGNETIC FIELD IN THE DUOPLASMATRON ANODE REGION (FROM REF.1)



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exposed to the air for some time. The plating was found to have no observable effect on the working of the source and the "old" source has also been so treated. (For the same reasons the whole of the ion source iron body was always previously nickel plated.) As before the arc chamber is centred on the small anode plasma exit hole to high precision, the specifications[10] including a concentricity of ±0.05 mm. This is to ensure that the hole is centred on the coinciding magnetic and mechanical axis of the snout channel, ensuring maximum flow of the compressed plasma, falling on the molybdenum anode disc (Fig. 5), through the 0.6 mm diameter anode hole. The geometric compression[11] produced by the 5 mm diameter snout channel is retained. The physics of the plasma in this region has been investigated by many people and described in detail, such as in Ref. 11.

4.1 Possible improvements

The weak point in the mechanical design of the arc chamber is the fixation of the chamber at the snout (front) end with "ceramics and vacuum seals under heavy mechanical loads"[12]. To avoid this by supporting the arc chamber from the rear would mean redesign of the source magnet assembly and arc chamber insulation/vacuum sealing. The insulation, capable of withstanding the 2 kV peak initial arc voltage, would become more complicated in detail design, but an advantage could be the elimination of the ceramic ring and "O" rings near the snout/anode. In general, the present design works well, provided care is taken in initial assembly and that no undue forces are applied to the arc chamber via the oxide cathode supports during handling.

Another possibility would be to make the snout and source rear Armco plate from one piece and to insulate the arc chamber from the plasma with a ceramic sleeve covering the whole of the inside surfaces. The chamber would thus be at anode potential and the arc would strike from the cathode to the anode (molybdenum disc) via the snout channel (as at present), but the whole arc chamber would remain at ground (anode) potential all the time. In the normal design of the duoplasmatron the insulated arc chamber is connected either directly to the cathode or, as in our case, between anode and cathode using resistors. Figure 12 shows the present electrical arrangement. Normally it is considered best to avoid large

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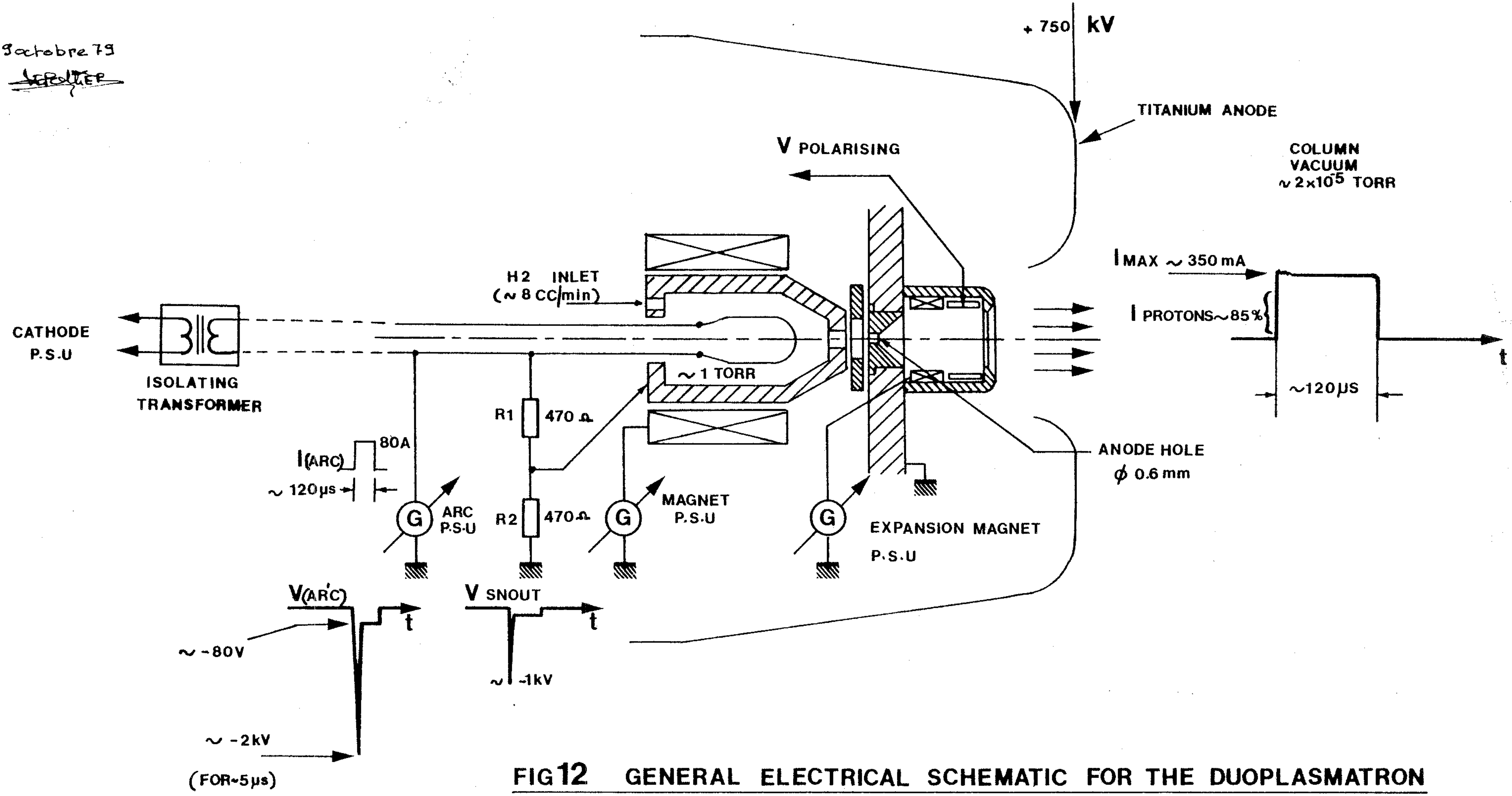
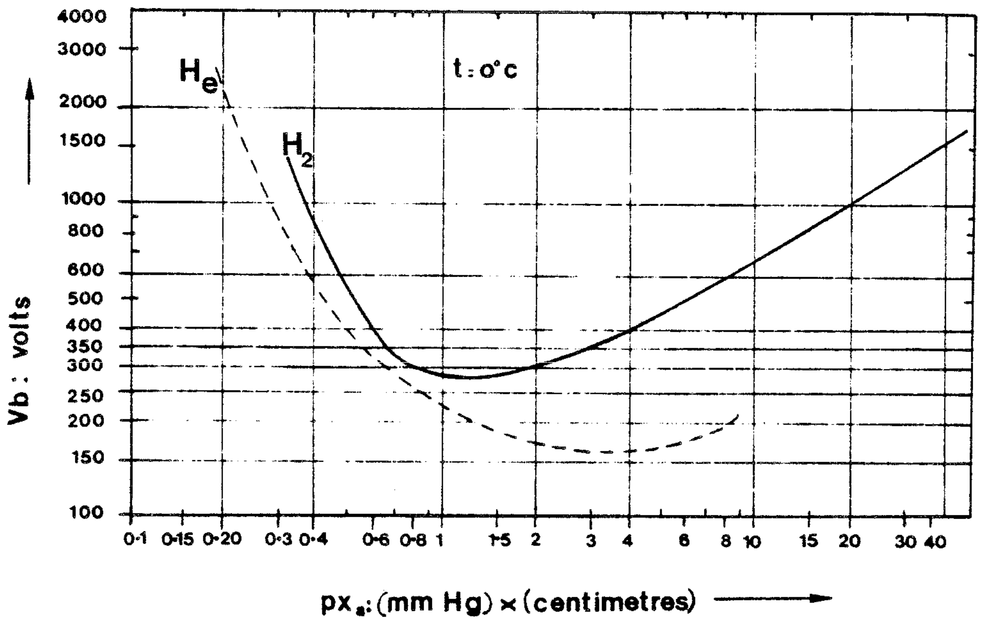


FIG 12 GENERAL ELECTRICAL SCHEMATIC FOR THE DUOPLASMATRON

areas of ill-defined potential, such as on the surface of a ceramic, within an arc chamber and in contact with the plasma. However, in view of the considerable mechanical and cooling advantages possible, such an arrangement was in fact tested by the author and B. Piosczyk*).

Once the criteria for Paschen breakdown (Fig. 13) had been met in the design of the insulating sleeves, the source arc worked normally. The source was not tested in an accelerating column but a "beam" (from H_2 gas) was obtained using ∿ 20 kV extractor electrodes in a test rig. The noise (or "hash") on the beam pulse appeared to be slightly higher in amplitude when running with the insulation and grounded snout, but this was not verified during the brief time available. There appeared to be a considerable number of backstreaming electrons passing through the BMOO source beam current measuring transformer, originating from the simple extractor electrode and so the differences between the standard source and this special one were not accurately measured. The main influence on the noise amplitude seemed to come from the change in diameter of the snout channel when using the ceramic sleeve, rather than the material itself. This was verified by using different sizes of stainless steel

FIG 13 BREAKDOWN POTENTIALS, AS FUNCTIONS OF PRESSURE AND SPACING (PASCHEN CURVES)



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*) Visitor fron Kernforschungszentrum, Karlsruhe, Germany (1977).

sleeves to reduce the channel diameter. With the snout iron channel opened out to 6 mm diameter and the ceramic sleeve inside diameter at 4 mm, the source output as seen on the BM00 was virtually identical with the standard situation (5 mm I.D. in snout). If the snout channel was reduced to 3 mm I.D. (either by the ceramic sleeve or a stainless steel one), the extracted beam, I_{ext}, fell by ∿ 20% compared to the standard ∅ 5 mm snout case. Conversely, if the snout channel was opened out to 7 mm I.D., the I_{ext} fell off again and the oscillations on the beam definitely increased.

During these tests with different sleeves the length of the snout channel was varied from 7.5 mm to ∿ 13.5 mm with no observable effect. (In the past, "normal" arc chambers have been used with these different values.) In each test the other source parameters were adjusted for an optimum beam. The main changes were made in the main magnet and expansion cup magnet currents. The conclusion reached was that the snout channel diameter must lie between 4 and 6 mm for no change in source output and that a ceramic sleeve with an I.D. of 4 mm fitted into a snout channel of 6 mm I.D. produced an ion beam output virtually the same as the standard snout. The disadvantage of using such a sleeve (assuming accelerator column tests would be satisfactory) is the fragility of the ceramic in the snout channel. For the tests the sleeve was machined from one piece of machineable ceramic (Macor), but, in case of breakage, it would be more practicable and cheaper to use a separate replaceable snout channel piece, mated to the main arc chamber sleeve. Figure 14 is a cross-section of the arc chamber equipped with the complete ceramic insulation over all of the inside surfaces including the cathode supports at the rear. If such a layout were adopted the advantages could be as follows: the "O"-ring seals at the front of the arc chamber plus the ceramic ring could be eliminated and the vacuum seals replaced with a metal type more easily. This might eliminate the heavy ions observed previously in the beam[13,14]. Batalin et al.[15] and Abroyan[16] have found that "O"-ring seals in the arc chamber were a major source of heavy ions in the beam. For this reason the KEK-PS ion source[17,18] uses special metal seals which could provide the answer for our source. Normally metal seals require high compression forces of ∿ 150 kp•cm^{-1} obtained usually by many more bolts than those required for "O"-rings.

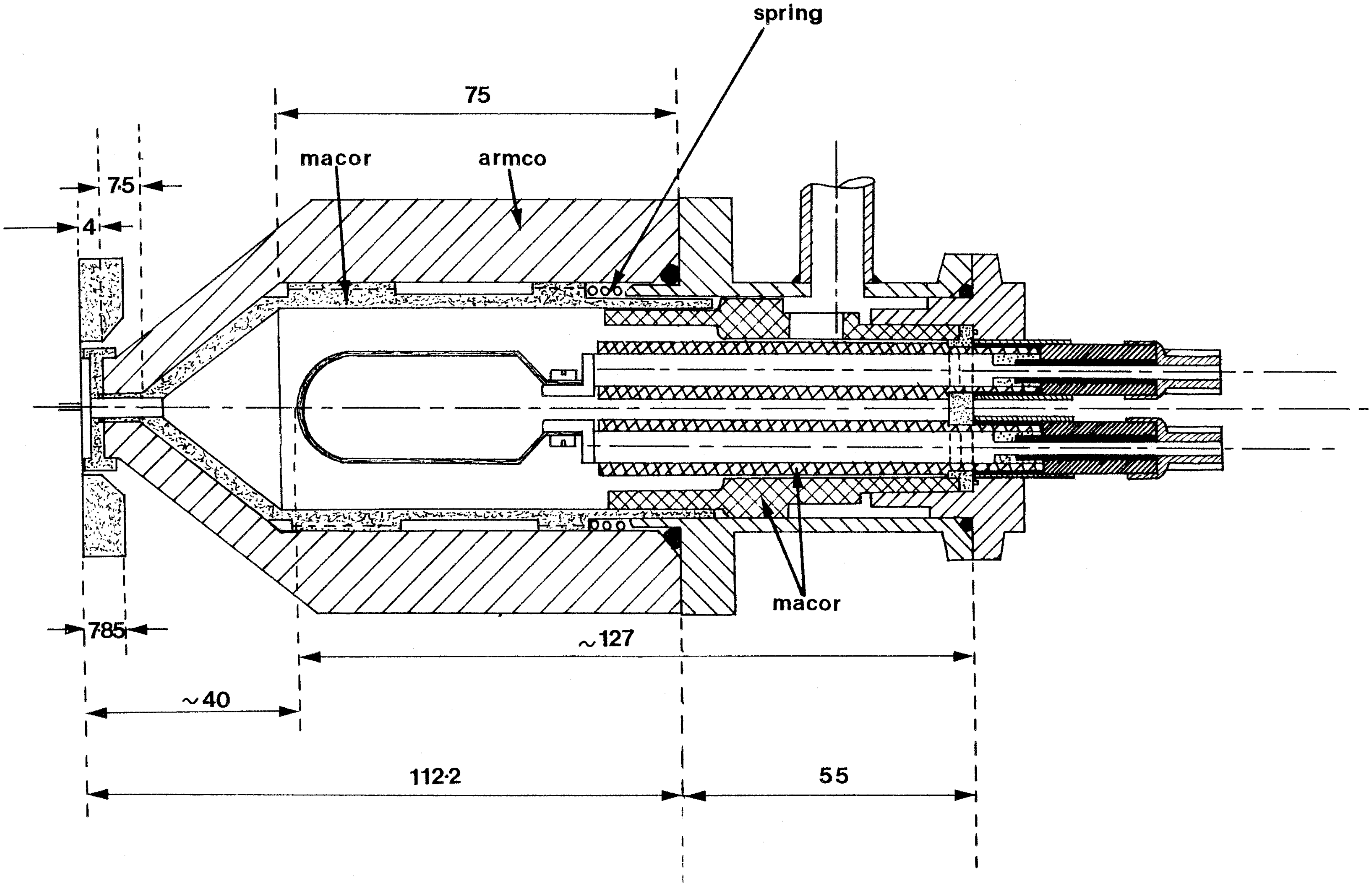

FIG 14 SPECIAL INTERNALLY INSULATED ARC CHAMBER

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The seals used on the KEK source are claimed to be much lower in required sealing force, meaning less bolts in the limited space available. If the internally insulated arc chamber were used, there would be no ceramics under compression in the source.

It was found, after several hours of operation, that the insulating arc chamber sleeve became coated with a thin film of evaporated material, presumably from the oxide cathode. This appeared to have no effect on the source operation and probably is beneficial in providing a semi-conducting surface over the inside of the arc chamber and thus approximating more to the surface "seen" by the plasma in the normal iron chamber. The deposits did not appear at the insulating disc on the front of the snout, outside the line-of-sight to the cathode. The source was run for several days with no deterioration in output.

Besides making it easier to convert the source vacuum sealing to metal seals in the arc chamber, the suggested design could also eliminate the water cooling of that part of the source. With the arc chamber and back plate made in one piece of Armco, the 150 watts received from the oxide cathode could be dissipated by direct conduction to the main source body and thence to the surrounding support structure and air. In tests to simulate this arrangement, it was found that without any forced-air cooling of the rear of the source, the front of the arc chamber stabilized at 96°C. With forced-air cooling the snout temperature dropped to 60°C. If this design plus the previously discussed aluminium foil main magnet were used, the water cooling of the source could be eliminated completely. To improve the air cooling heat pipes could easily be incorporated in the design.

Before undertaking such a redesign, the present source with internally insulated arc chamber would have to be proven in the 500 kV accelerating column over a lengthy period.

4.2 Operating characteristics of the source

Returning to the conventional arc chamber design, Fig. 15 shows the arc impedance characteristics, with hydrogen, for the new source. The effect of the main magnet current and gas flow on the arc impedance "Z" is given over the normal operating values. Essentially the new source behaves the same as the "old" one when both are fitted with the 0.6 mm

THE ARC IMPEDANCE IN THE DUOPLASMATRON

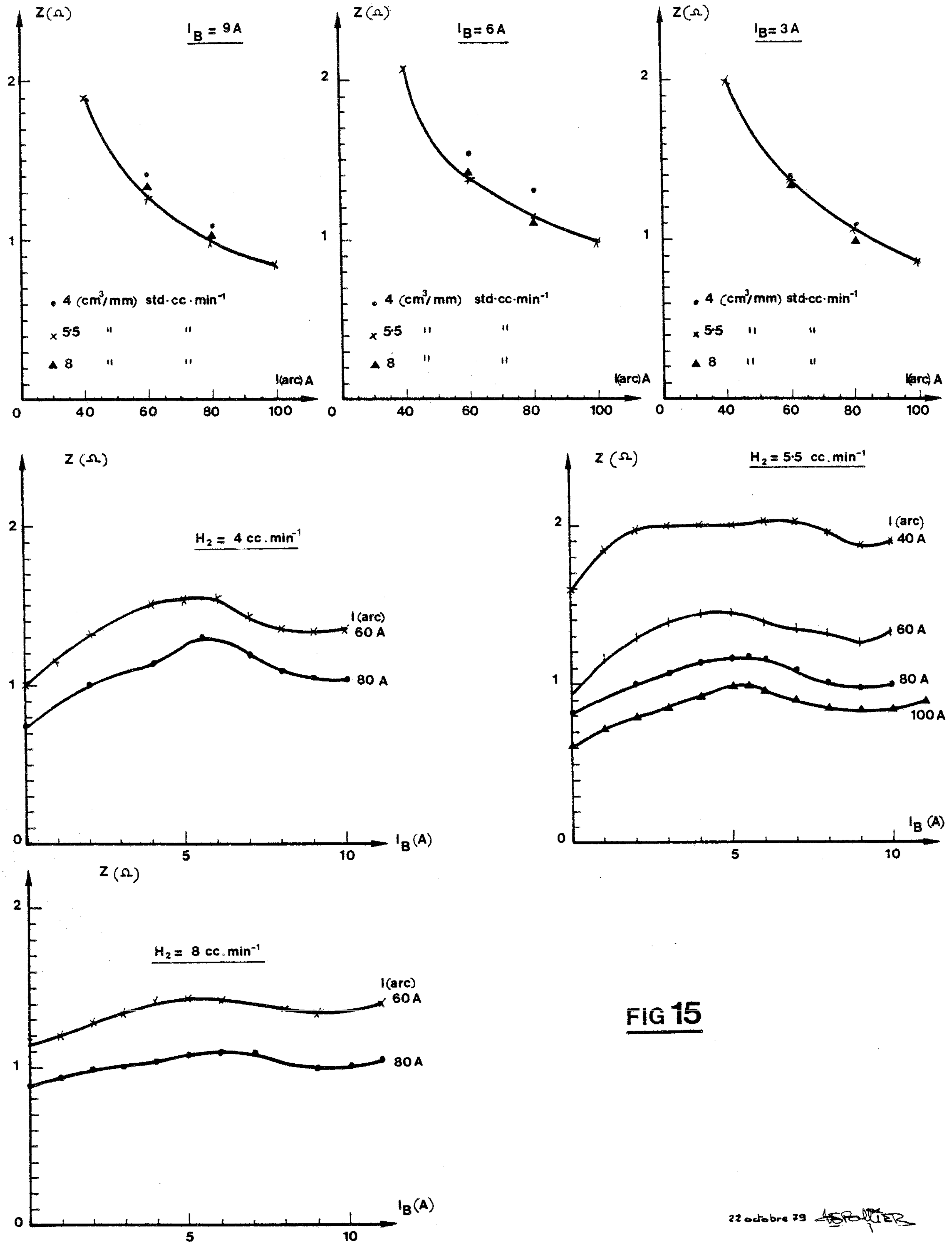

FIG 15

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diameter anode aperture. The original source described in Ref. 1 was built with a 1 mm diameter or greater anode aperture and consequently used gas flows of more than 30 std. cc. min^{-1} in order to obtain sufficient pressure in the arc chamber. In 1973 it was found that adequate proton current (∿ 350 mA) was still obtainable when the anode aperture was reduced to 0.6 mm diameter. This was achieved by different tuning of the source, low-energy transport line and linac parameters and thus meant lower hydrogen consumption. This was first tested on the "old" source in the old linac and subsequently incorporated in the design of the "new" source. The lower hydrogen flow is of particular importance to the pumping system of the new preinjector[19].

Finally, Fig. 16 gives the arc power supply schematic for the present duoplasmatrons. A delay line[20], suitably charged, discharges into the arc chamber, the arc pulse length being determined by the pulse forming network length (PFN). This system is in use on both old and new linac preinjector ion sources.

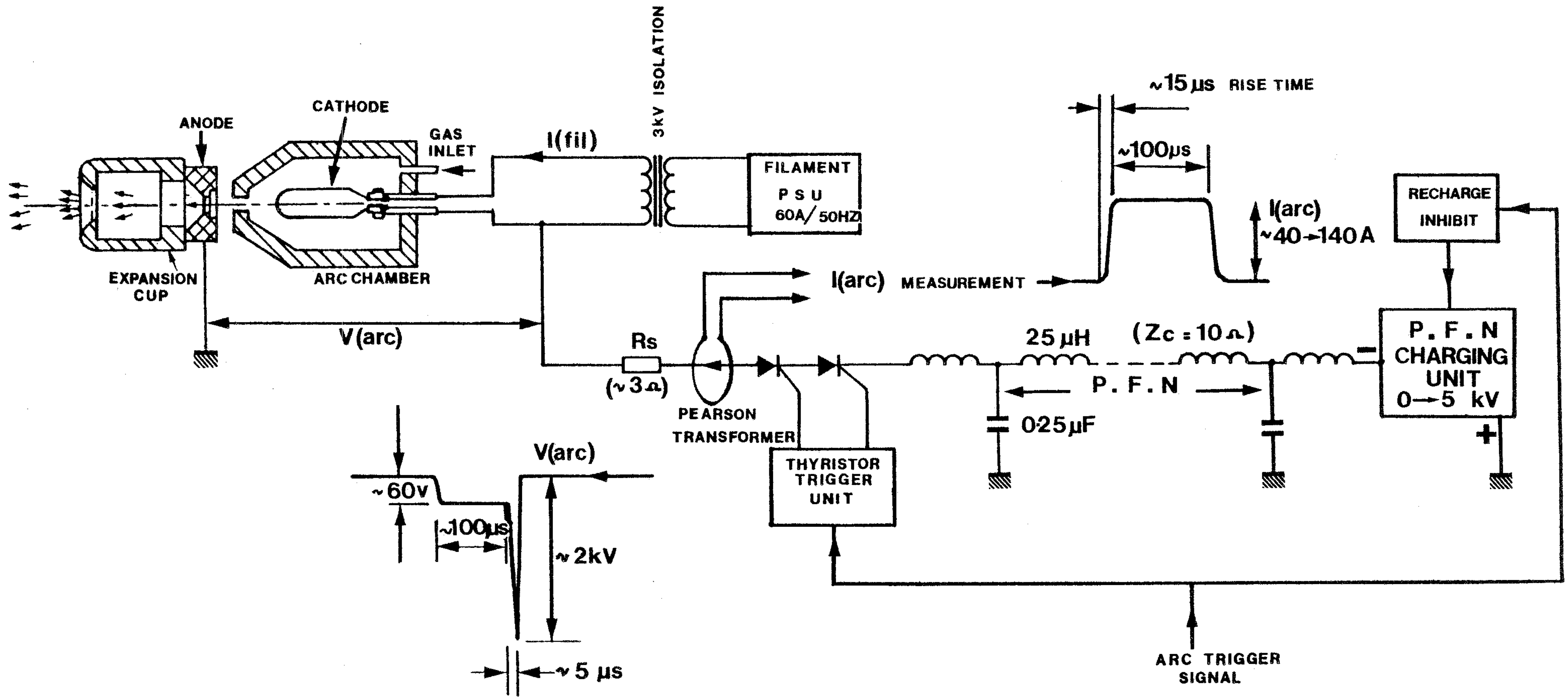
Basic source operating parameters are:

Output current	∿ 350 mA (protons, max.)
Repetition rate	∿ 1 to 2 Hz
Beam pulse length	∿ 250 μs max.
Gas flow (hydrogen)	∿ 6 std. cc. min^{-1}
Arc chamber pressure	∿ 0.5 to 1.5 Torr
Arc current	∿ 70 to 100 A
Cathode heating current	∿ 50 A
Main magnet current	∿ 7 A
Expansion magnet	∿ 1.1 A
Particles available, to date:	protons (∿ 350 mA), deuterons (∿ 150 mA), alphas (∿ 20 mA).

5. THE EXPANSION CUP AND MAGNET

The reasons behind the original design of the expansion cup are discussed in Ref. 1. Since it works well enough, and its operating parameters have been well documented over a long period, it was incorporated unchanged in the new source. The fixation however was changed from the threaded system to a four screws one with a precision shoulder location. The material is titanium TA6V chosen, as before, for its superior high voltage holding properties[21].

FIG 16 DUOPLASMATRON ARC P.S.U AND CONNECTIONS



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In 1974 it was found possible to operate the "old" source in the "old" linac preinjector column without the original extraction molybdenum grid in front of the expansion cup. Since then, the ions are extracted from the plasma surface, formed at the exit of the cup, by the electrostatic field of the column at the anode electrode surrounding the ion source. This simplifies the source and its electronics (no extraction power supply is now needed), and the same arrangement was adopted for the new source. In case future developments require the reinstallation of the grid, provision was made for a HV vacuum feedthrough on the source body and the necessary hardware constructed. This development, by removing the grid support piece, exposes the expansion cup face directly to the high gradient of the column accelerating gap and so the titanium alloy cup has to be polished and cleaned to the same standard as the column electrodes5). Another difference between the present expansion cup and the one described in Ref. 1 is the installation of an insulated stainless steel cylinder in the main body of the cup. This was done several years ago and increases the beam output when biased to at least -30 V d.c. The noise on the beam is also reduced and the emittance improved for a given set of other source parameters. The negative wall created in the cup by the cylinder repels electrons, increasing their containment time and assisting presumably in post ionization of the remaining gas passing through. The effect saturates out at > -30 V and normally the cylinder (designated PEC) is polarized at -50 V for all operating conditions.

Other suggestions such as feeding RF power into the cup via the PEC electrode, in order to improve further the ionization in the cup and perhaps raise the proton yield, have not yet been seriously tried. The new source cup is seen in Fig. 17.

When the new source was tested in the new 750 kV preinjector, it was found, in the position selected for the source within the column anode, that a higher current and hence magnetic field in the expansion cup magnet was desirable. A higher ion beam output was realized at expansion magnet currents about 2 or 3 times higher than normally used in the "old" source at 500 kV. This higher current and hence power dissipation in the small indirectly cooled magnet coil meant changing the design to a higher temperature rated one. The previous coil design used a 0.3 mm diameter

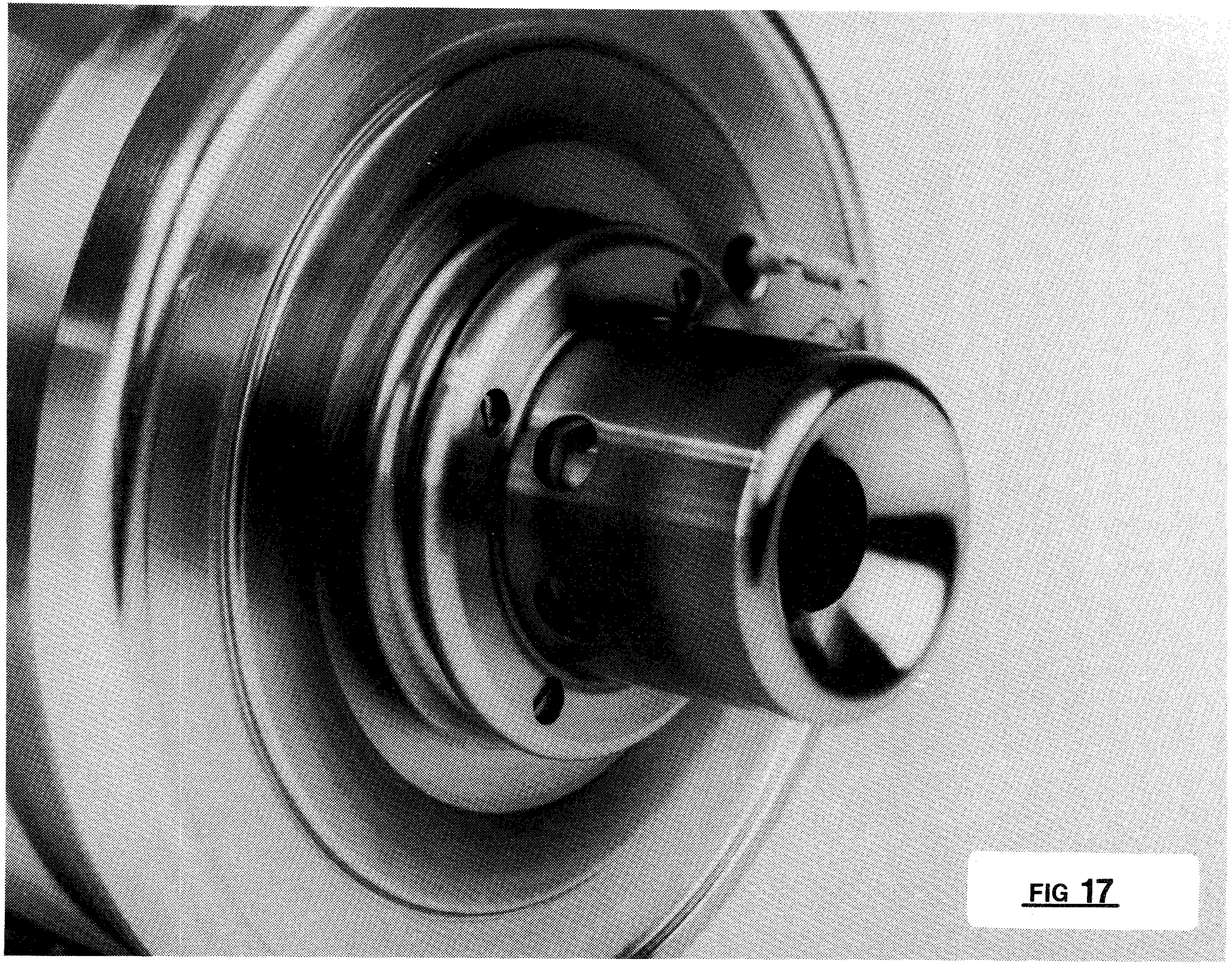
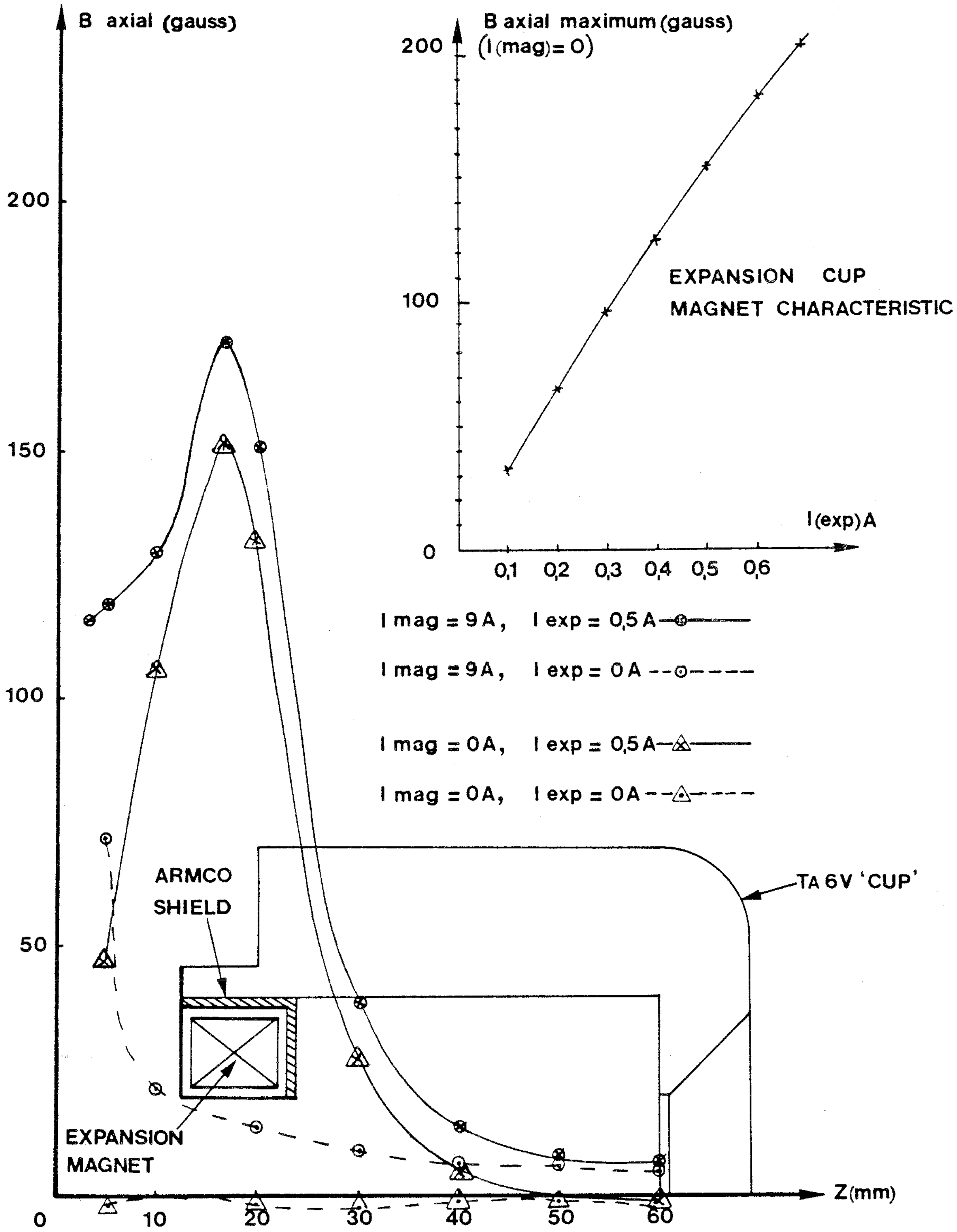


FIG 17

varnish insulated copper wire of about 380 turns, potted in ordinary araldite and sealed in a soldered beryllium bronze containing ring chamber. The heat generated within was conducted away at the contact points in the expansion cup (Fig. 5). Since it is difficult, owing to the restricted space, to use some form of forced cooling (e.g. water), it was decided to change the materials inside the containing ring chamber. Kapton and Teflon insulated 0.3 mm diameter wire capable of running at 220°C was selected and, after some tests[22)], potted in araldite charged with boron nitride powders of two grades. The best proportions giving proper filling between windings and also greatly improved thermal conductivity were found to be 120 parts by weight of HPC 40 (grain size = 0.105 to 0.420 mm) + 60 parts by weight of HPF 325 (grain size 0.044 mm). Araldite "F" (Ciba-Geigy) charged thus had a measured thermal conductivity of 4.6×10^{-3} $W \cdot cm^{-1} \cdot {}^{\circ}K^{-1}$ at 30°C and 13×10^{-3} $W \cdot cm^{-1} \cdot {}^{\circ}K^{-1}$ at 100°.

The pre-wound potted coil was cured at 70°C for 30 h (1.0 part by weight accelerator added). By comparison, the uncharged araldite "F" gave a value of 1.0×10^{-3} $W \cdot cm^{-1} \cdot {}^{\circ}K^{-1}$ at 30°C under the same test conditions. The small coil after being set in the araldite mix is now housed in a stainless steel electron beam welded chamber. Stainless steel, although a poor thermal conductor (~ 0.15 $W\ cm^{-1} \cdot {}^{\circ}K^{-1}$) was chosen for its low outgassing (when cleaned and baked out correctly). It was suspected that the previously measured heavy ions in the proton beam[13,14)] could be originating from porous solder or beryllium bronze in the original expansion magnet housing. Since running the new source in the 750 kV column with the new expansion magnet, there have been occasions when the emittance plots have indicated the presence of heavier masses. To clarify the situation, the source output will have to be examined again with a mass separating magnet in the beam line. At least the new expansion magnet can be eliminated as a possible source of contamination. The 750 kV ion source operates continuously with > 1 A expansion cup magnet current compared to the previous "old" source values of ~ 0.4 A in the 500 kV column. Figure 18 is the plot of the magnetic field values in the expansion cup with and without the contribution from the source main magnet fringe field. The values shown were taken with the "old" type of expansion magnet. At ≥ 1 A in the new type it is not yet saturating. Figure 19 displays the individual components of the new expansion magnet, with the

FIG18 AXIAL FIELD IN EXPANSION CUP WITH AND WITHOUT MAIN MAGNET



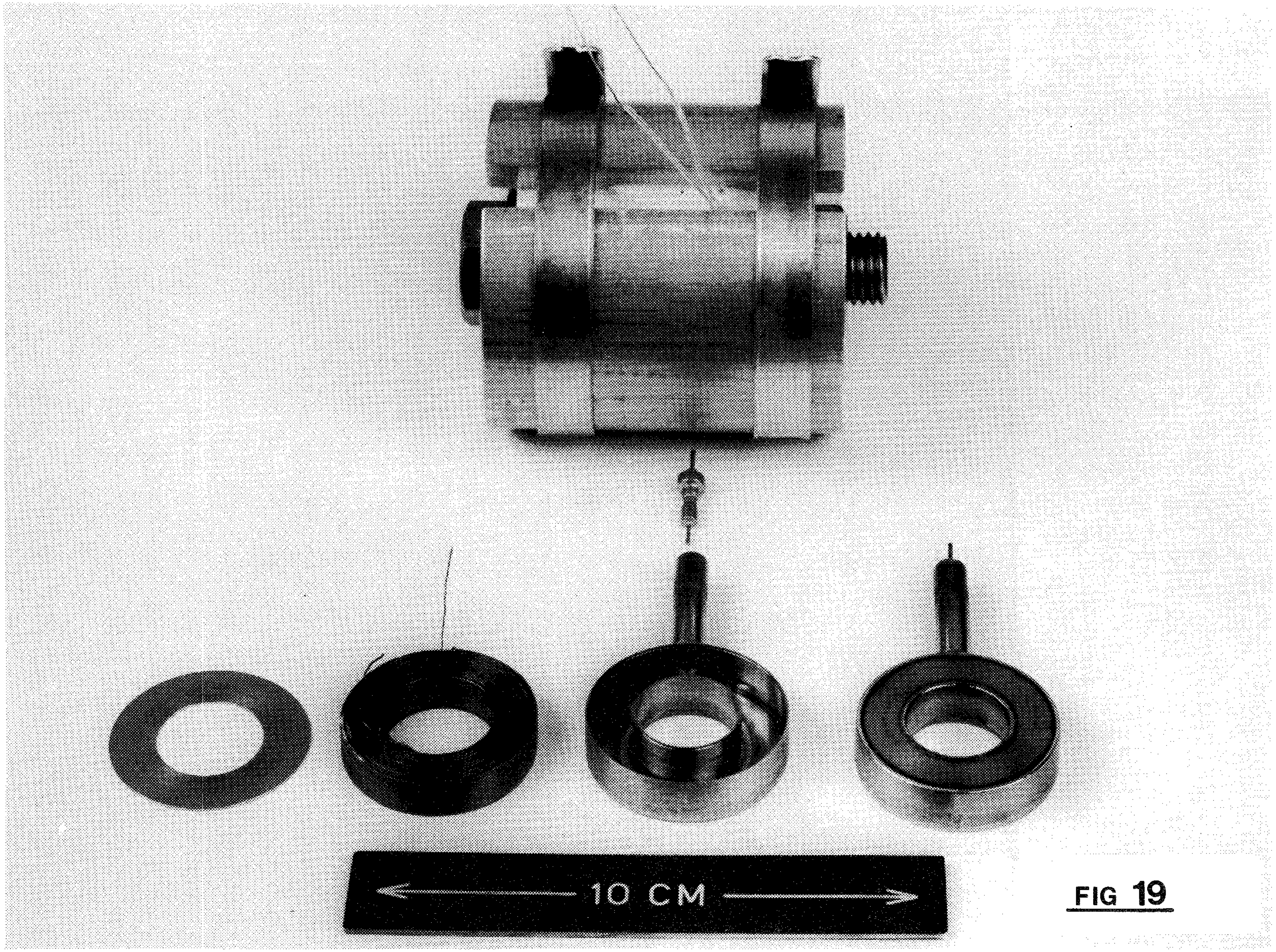


FIG 19

potting mould in the background. The thin (0.5 mm) walled chamber is made from 316L vacuum grade stainless steel. In tests it was found that the charged araldite retained its integrity after tests at 300°C. Although there is air left in the magnet chamber when finally closed, to improve the thermal contact between the pre-potted coil and the chamber walls, more charged araldite is injected into the air space before final welding. With 1 A flowing in the 0.3 mm diameter copper coil wire, the current density is very high at $14.15\ \mathrm{A{\cdot}mm^{-2}}$. No failure has occurred yet in many months of operation but it would seem unwise to go much higher in current with the present design. An estimate of the wire temperature using the usual formula for change in resistance with temperature, i.e.

$$R_2 = R_1(1 + \alpha\Delta t)$$

to the first order, or

$$\Delta t = \frac{\frac{R_2}{R_1} - 1}{\alpha} ,$$

where

Δt is temperature change,
R_2 = resistance when hot,
R_1 = resistance when cold, and
$\alpha = 4.3 \times 10^{-3}$ for Cu gave 329°C for the original type of coil running at 0.4 A.

The new coil has not been measured yet, but must be hotter at 1 A despite its improved "cooling". If future source development calls for even more expansion cup magnetic field, a possible magnet construction capable of running very hot (to $\sim$ 500°C) could be to use the anodized aluminium foil type of coil (as previously discussed for the main magnet). An experimental expansion magnet of this type was tested successfully in the ion source (Fig. 20), but in the form shown was too fragile to be practicable. Such a construction could be open to the vacuum since there are no organic materials present. Finally, Fig. 21 shows the view looking into the expansion cup. The small 0.6 mm diameter anode hole can be seen and the electrical connections to the expansion magnet and PEC cylinder.

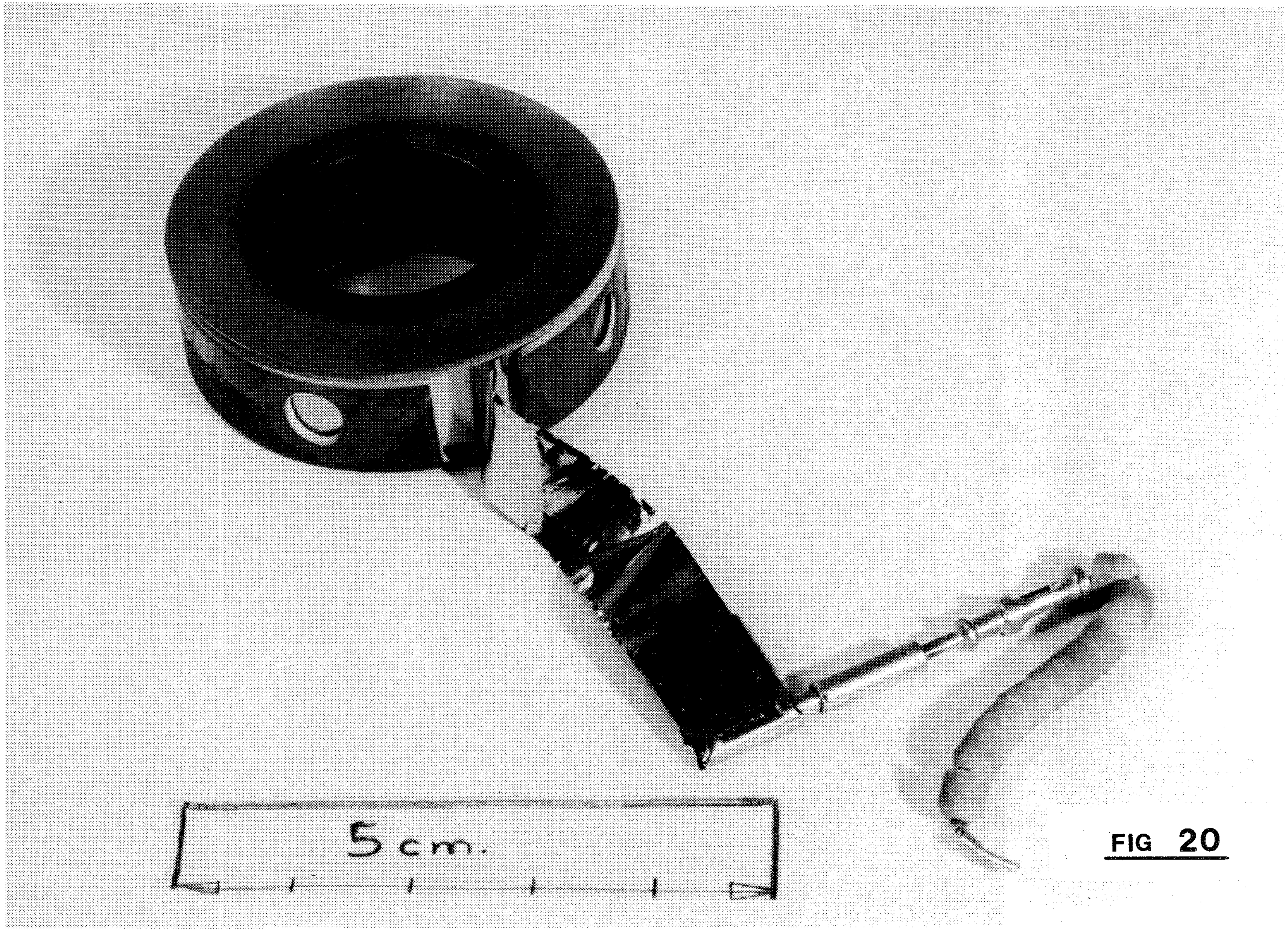


FIG 20

FIG 21

6. OXIDE CATHODE[1,6)]

The source cathode construction has remained unchanged since the original report[1)]. Its operating lifetime has steadily increased on average, probably due to increasing handling and construction experience. The longest running time yet recorded was 6541 h in 1975. This was in the "old" source, without the extraction grid, and corresponded to $\sim 20 \times 10^6$ arc pulses spread over about 1 year of operation. The cathode seems to be most reliable when it is left running under fixed conditions, undisturbed. Figure 22 shows the cathode and its supports as used in the new source. The various reports on the construction procedure[1,6,23,24)] all mention the importance of further grinding down of the commercial carbonate powder used, without really specifying the final size to be attained. This has now been measured[25)] with an electron microscope looking at the powder after the recommended 6 h grinding in a ball-mill. Figure 23 shows the $BaCO_3$, $SrCO_3$ and nickel powder mix, as used to make the oxide layer, at a magnification of × 2500. The marker scale = 1 μm per division, and most of the mix appears to be particles of ∿ 1 μm adhering to each other to form larger conglomorates. If commercially available $BaCO_3$, $SrCO_3$ and Ni of ∿ 1 μm grain size is now available, the extra grinding should not be necessary. The ratio of the BaO to the SrO in the final sintered layer is important regarding the emission, as shown in Fig. 24 [26)]. The CERN cathode has a ratio of 42.86% BaO to 57.14% SrO. Since the barium oxide evaporates faster than the strontium oxide, so the proportions change and the emissivity eventually falls[26)].

7. SOURCE PERFORMANCE

Since there is more than enough proton current available from the new duoplasmatron for the new linac, no effort has been put into increasing the output. This is not the case with alphas however, and efforts are being made at present to increase the alpha particle yield. The quality of the proton beam is considered adequate and good emittances have been measured in the 750 keV transport line to the new linac. Figure 25 shows an emittance as measured in the horizontal plane before the beam buncher[27)], the r.m.s. value[28)] being 9.89 mm mrad with a "medium beam". Figure 26 gives an emittance in the horizontal plane after the buncher, with $\varepsilon_{rms} = 9.38$ mm mrad. These results are given just as examples; more complete information can be found in Ref. 27.

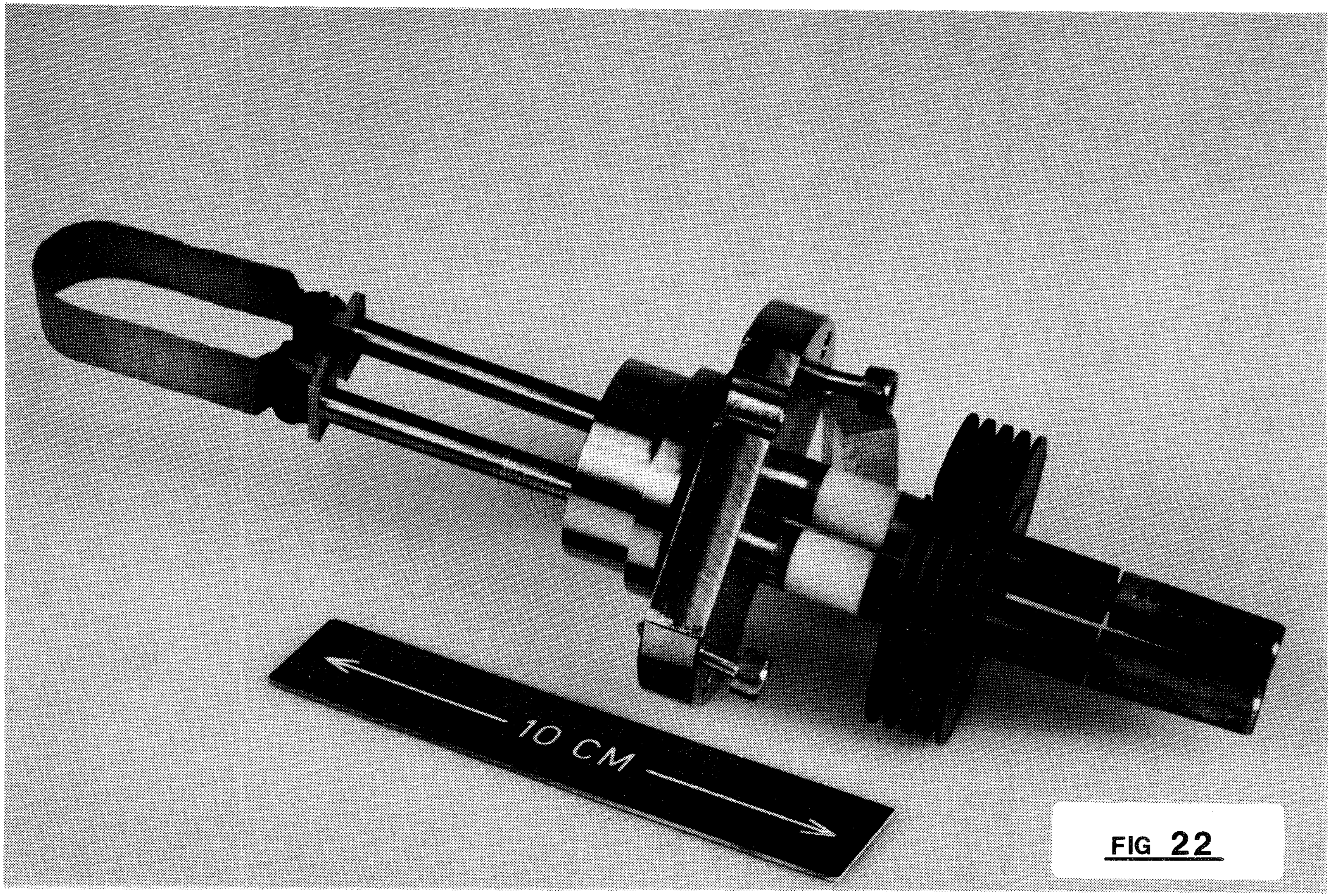


FIG 22

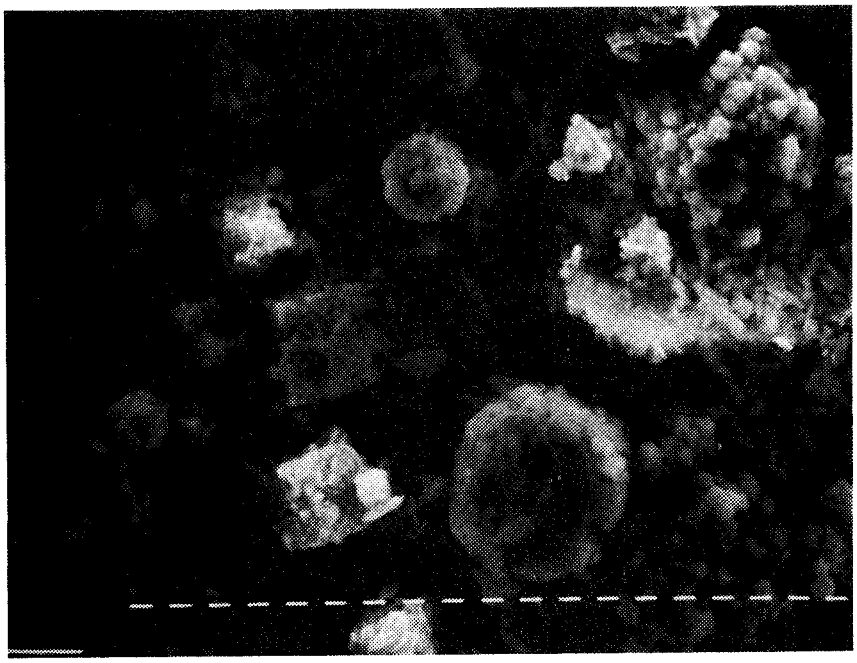


FIG 23

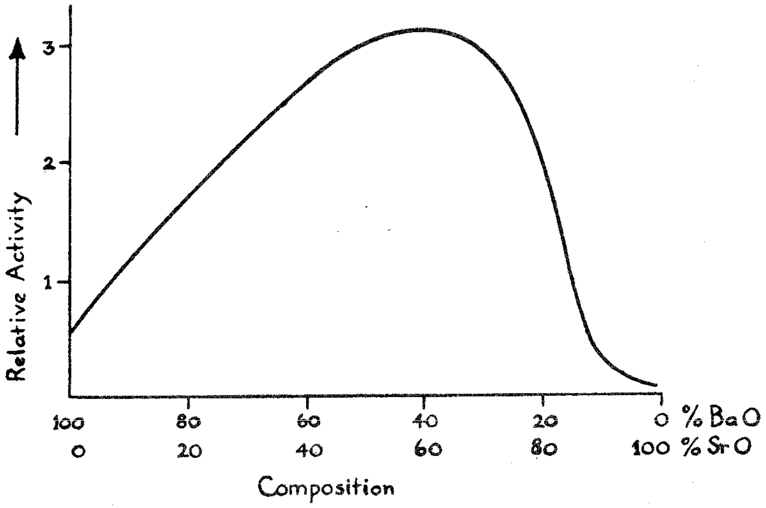
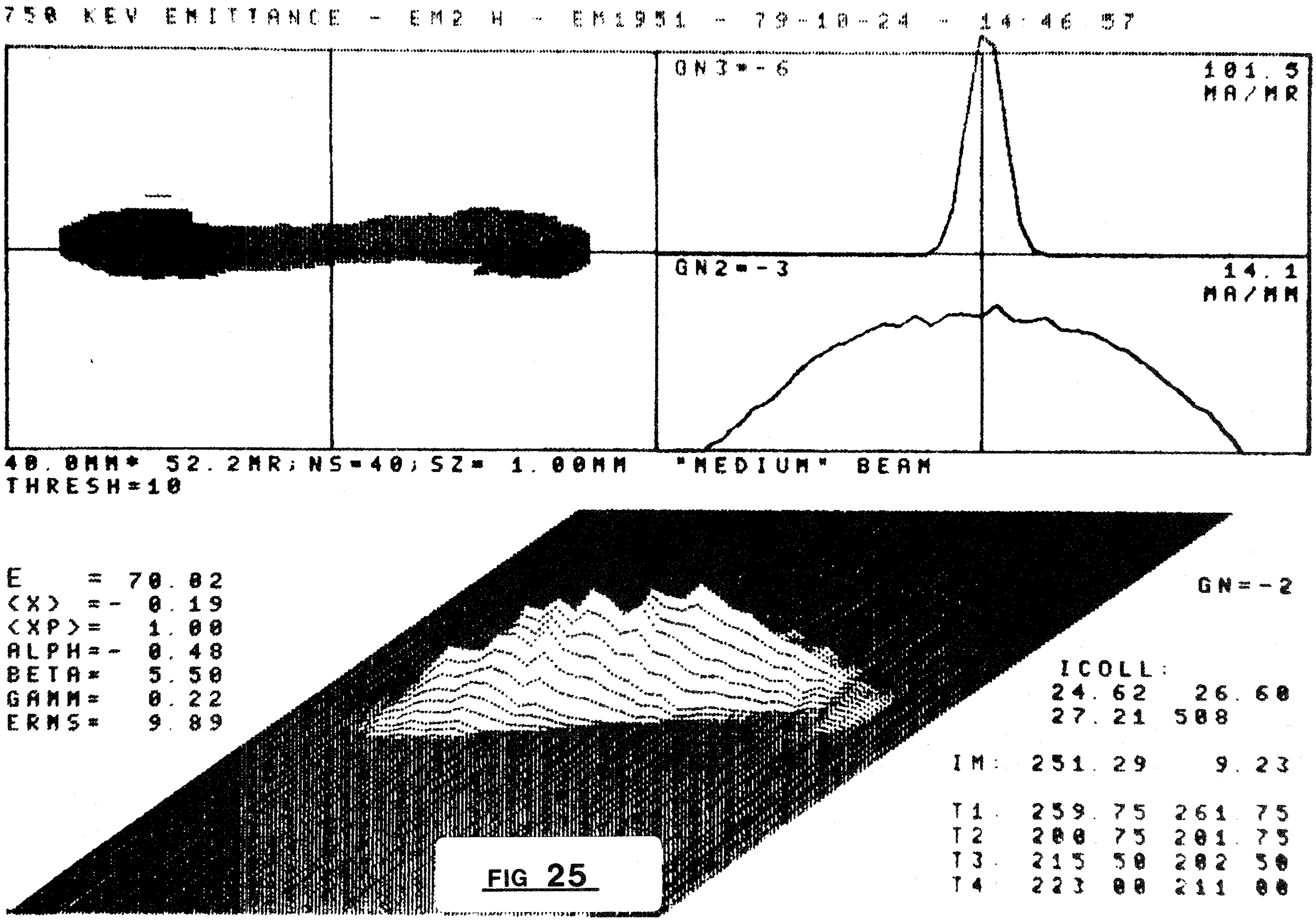


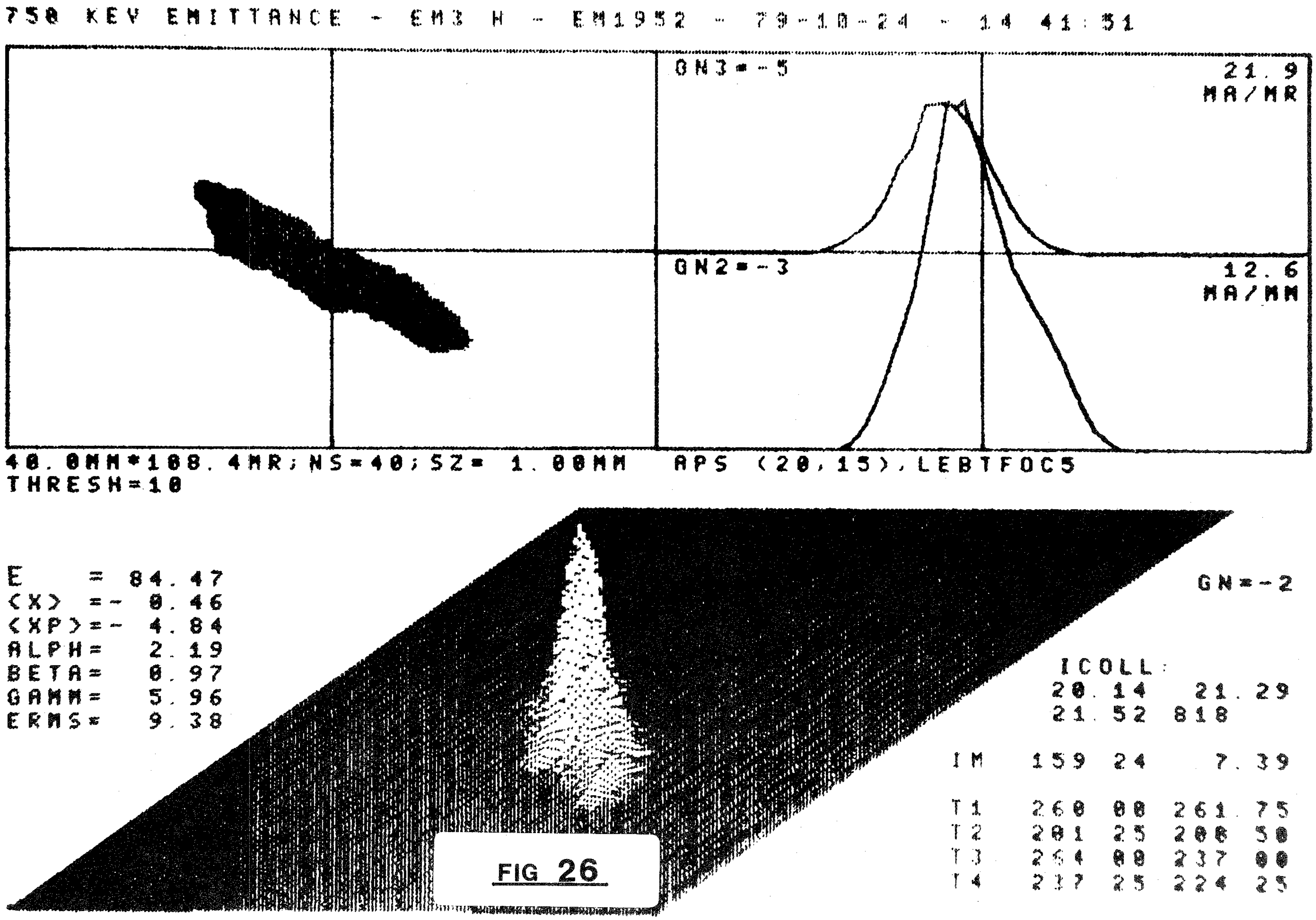
FIG 24 SHOWING HOW THE EMISSION FROM AN OXIDE CATHODE DEPENDS ON ITS COMPOSITION



```
750 KEV EMITTANCE - EM2 H - EM1951 - 79-10-24 - 14:46:57
```

```
40.0MM* 52.2MR;NS=40;SZ= 1.00MM  "MEDIUM" BEAM
THRESH=10

E    = 70.02
<X>  =- 0.19
<XP>=   1.00
ALPH=-  0.48
BETA=   5.50
GAMM=   0.22
ERMS=   9.89

ICOLL:
24.62  26.60
27.21 508

IM: 251.29    9.23

T1. 259.75 261.75
T2  200.75 201.75
T3. 215.50 202.50
T4  223.00 211.00
```

FIG 25



```
750 KEV EMITTANCE - EM3 H - EM1952 - 79-10-24 - 14 41:51

40.0MM*108.4MR;NS=40;SZ= 1.00MM   APS (20,15),LEBTFOC5
THRESH=10

E     = 84.47
<X>  =- 0.46
<XP>=- 4.84
ALPH=   2.19
BETA=   0.97
GAMM=   5.96
ERMS=   9.38

                ICOLL:
                20.14   21.29
                21.52 818

          IM    159 24      7.39

          T1    260 00  261.75
          T2    201 25  200 50
          T3    264 00  237 00
          T4    237 25  224 25
```

FIG 26

Recently, J. Grando investigated[29)] some of the properties of the plasma in the expansion cup of the "old" duoplasmatron, using Langmuir probe techniques. The extraction field at the expansion cup exit aperture was simulated by means of a grid and it is hoped to repeat and continue the measurements to determine the position and shape of the plasma boundary in the "3 MeV" experimental 500 kV preinjector column. Although the CERN duoplasmatron performs well in general, some beam users would like to see a reduction in the noise (or "grass") on the beam pulse. This noise is considered to originate in the expansion cup and can also be varied by displacing the source relative to the column anode and hence extraction field. Unfortunately, the position for minimum noise gives an inferior emittance. Since such plasma noise is inherent in this type of source, it is not known yet by how much it can be reduced. It may even prove easier in the long run to change to an inherently quiet type of source such as a multidipole, also being investigated[30)] in this laboratory and elsewhere.

8. CONCLUSION

The program started in 1974, of producing an ion source for the CERN new linac preinjector, based on the long-standing CERN duoplasmatron, has been completed satisfactorily. Most of the effort has gone into producing a reliable source, compatible with the new preinjector demands rather than in basic duoplasmatron development. Now that the ion source described here is working routinely, perhaps some more investigations into its physics will be possible as there is always room for improvement.

Acknowledgements

Many people have contributed to the work reported here, from the PS design office through the CERN Workshops to the source operators. The author wishes to thank in particular H. Haseroth and C. Hill for critically checking this report and his colleagues H. Charmot, J.-P. Romero and J.L. Vallet for all their work and assistance in the program.

REFERENCES

1) B. Vošicki, M. Buzič and A. Cheretakis, The duoplasmatron source for the CERN PS linac, MPS/Int. LIN 66-11 (1966).

2) M. Von Ardenne, Tabellen für Elektronenphysik, Ionenphysik und Ubermikroskopie, Berlin, Springer, 1956.

3) J. Huguenin and R. Dubois, Measurements on a high-gradient accelerating tube model, etc., CERN 65-23 (1965).

4) J. Huguenin, R. Dubois, G. Visconti, R. El-Bez, The new 500 keV single-gap pre-injector tube for the CERN Proton Synchrotron linac, MPS/Int. LIN 66-13 (1966).

5) M. Hone, The accelerating column for the preinjector of the new CERN linac, CERN/PS/LR 79-38 (1979).

6) H. Charmot, M.A. Hone, J.L. Vallet, Procedure for making the oxide coated cathode for the linac duoplasmatron ion source, MPS/LIN/ Note 74-7 (1974).

7) T.R. Sherwood, PS Division, CERN.

8) Data from Armco S.A., Courbevoie, France.

9) Metalloxyd GMBH., Cologne, W. Germany.

10) M.A. Hone, H. Haseroth, Internal memo to E. Boltezar, MPS/LIN/ M.H./H.H./ab. (13.6.74).

11) H. Krupp and H. Winter, A C.W. operated duoplasmatron multiply-charged ion source, Nucl. Instrum. & Methods 127 (1975) 459.

12) E. Boltezar, Duoplasmatron I, MPS/ML/Note 74-20 (1974).

13) J. Knott, P. Têtu and M. Weiss, Measurements on the unbunched 500 keV beam in the 3 MeV experimental area, MPS/LIN/Note 75-1 (1975).

14) H. Haseroth, M. Hone, J. Knott and M. Weiss, 750 keV beam measurements, stage 1, PS/LIN/Note 76-22 (1976).

15) V.A. Batalin et al., PTE 5 (1967) 60.

16) M.A. Abroyan et al., Soviet Conf. on Charged Particle Accelerators, 1968 (Jerusalem, 1972), p. 372.

17) M. Kobayashi and A. Takagi, Construction of duoplasmatron ion source for the KEK-PS, IEEE Trans. on Nucl. Sci., Vol. NS-24, No. 3, June 1977, p. 1587.

18) G. Horikoshi, KEK Annual Report, 1972, p. 34.

19) Système à vide du nouveau linac, PS/LR/Note 79-5 (1979).

20) H. Haseroth and P. Têtu, CERN/PS/LIN 76-6 (1976) and 1976 Proton Linear Accelerator Conf., Chalk River, Canada.

21) J. Huguenin and R. Dubois, CERN Yellow Report 65-23 (1965).

22) Note interne, ISR-BOM/MB/AP/afm (1977), M. Blin and A. Perrot.

23) F. Chiari, Procédé de formation de la cathode à oxyde de la source duoplasmatron du linac, MPS/LIN/Note 73-5 (1973).

24) Technology Note B18, Meetings on Technology, etc., CERN 74-9 (1974).

25) J. Adam, SB Division, CERN (1979).

26) P. Parker, Electronics, Edward Arnold Ltd. (1960), p. 160.

27) B. Bru and M. Weiss, Design of the low energy beam transport system for the new 50 MeV linac, CERN/MPS/LIN 74-1 (1974).

28) B. Bru and M. Weiss, Computational methods and computer programs for linearized analysis of periodic structures and beam transport systems under space charge conditions, CERN/MPS/LIN 72-4 (1972).

29) J. Grando, Caracteristiques du plasma emissif de la source duoplasmatron, CERN/PS/LR/79-21 (1979).

30) M.A. Hone, A pulsed multi-dipole ion source, CERN/PS/LR 79-36 (1979) and 1979 Linac Conf., Montauk, N.Y., USA.