A CONDENSER MICROPHONE FO[R

BY M. R. RATNAGAR

THE working principle of the condenser microphone is at least as old as the science of electronics, and one well-known manufacturer claims to possess more than 30 years of experience in this field. But it was not until comparatively recently, with the advent of greatly improved techniques and standards in the allied fields of sound reproduction, recording and broadcasting, that the inherently high qualities of the condenser microphone have been exploited. Today, those who are connected with these professions have come to recognise its supremacy over other more conventional microphones. The needs of the professional are catered for adequately by a few specialist firms, who in the process of meeting the near-perfection standards demanded by their customers, have earned for themselves a high reputation and for which they are entitled to charge prices in the region of £150 and upwards—prices quite out of the reach of the average amateur's pocket.

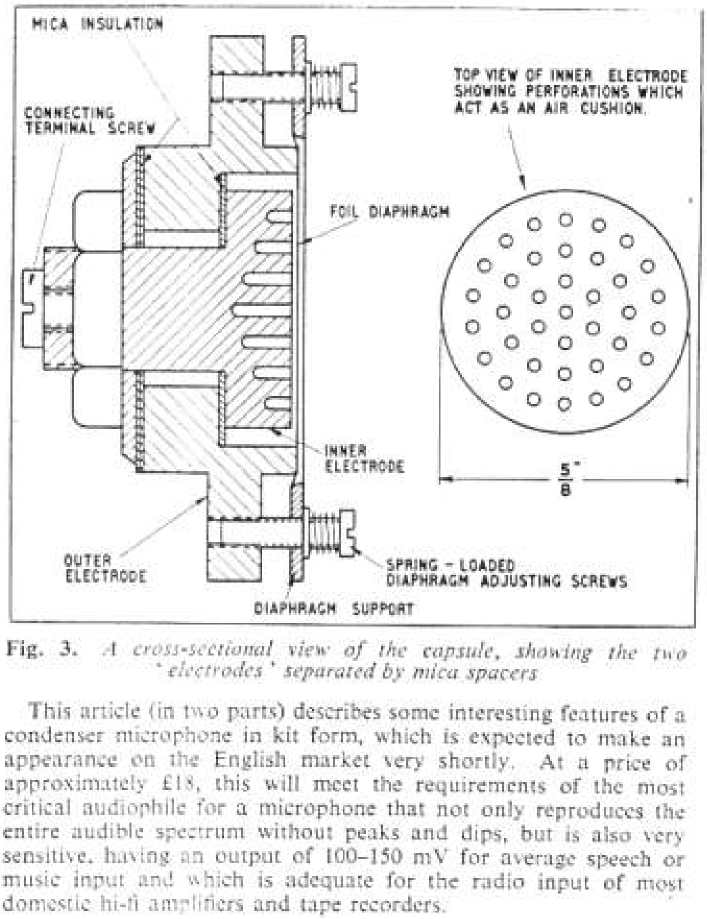


Fig. 3. *A cross-sectional view of the capsule, showing the two 'electrodes' separated by mica spacers*

This article (in two parts) describes some interesting features of a condenser microphone in kit form, which is expected to make an appearance on the English market very shortly. At a price of approximately £18, this will meet the requirements of the most critical audiophile for a microphone that not only reproduces the entire audible spectrum without peaks and dips, but is also very sensitive, having an output of 100–150 mV for average speech or music input and which is adequate for the radio input of most domestic hi-fi amplifiers and tape recorders.

Some Basic Theory

Some basic theoretical considerations that have a direct bearing on the practical aspects of condenser microphone design will first be outlined and it will be shown how these considerations have been taken into account in the 'Microkit' condenser microphone.

The unit of capacitance, the Farad, is defined as follows:—

$$C = Q/V \text{ or } Q = CV$$

where: C is the capacitance in Farads,
Q is the charge in ampere-seconds, and
V is the polarising potential in volts.

Assume that we have a capacitor (**fig. 1**) made up of two flat plates, rectangular in shape, equal in size and of side dimensions a and b respectively, and that they are separated by a distance d (the units of all measurement should, of course, be the same throughout, i.e., inches or centimetres, as the case may be). The capacitance (C) of such a capacitor is then:—

$$C = \frac{k \times 8{\cdot}84 \times A}{100d} \text{pF}$$

where: k is the dielectric constant of the material between the plates (for vacuum, $k = 1$, and for all practical purposes may be taken to be the same value in air).
A is the area of the plates ($a \times b$ in fig. 1).
d is the distance between the plates.

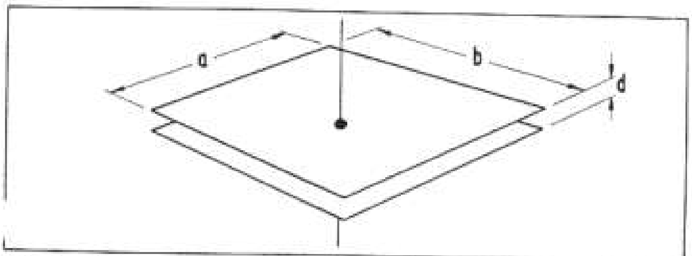


Fig. 1. *Diagrammatic representation of a simple capacitor. The capacity varies as ($a \times b$) and inversely as (d)*

We shall see how the two formulae above are in fact inter-related and how some practical conclusions may be drawn from this relationship:—

1. From the expression, $Q = CV$ we can conclude that given a constant polarising voltage (V), the charge (Q) is directly proportional to the capacitance (C).

2. From the second formula we can conclude that the capacitance (C) measured in pico-Farads (pF) is directly proportional to the dielectric constant (k) and to the area of the plates (A), but that it is inversely proportional to the distance (d) between the plates.

It would seem from the above two conclusions that, in order to obtain the maximum charge (Q) out of a given capacitor, it should have very large plates (A), across which is connected a very high polarising voltage (V) and the plates themselves should be very closely spaced (d).

However, the last two conditions are conflicting because there is a practical limit as to how closely the plates may be spaced for a given voltage across them. Theoretically, this value is 3,000 V/mm. In other words, two plates spaced 1 mm apart can 'stand' 3,000 V across them; if the voltage is higher, or the distance is less, there

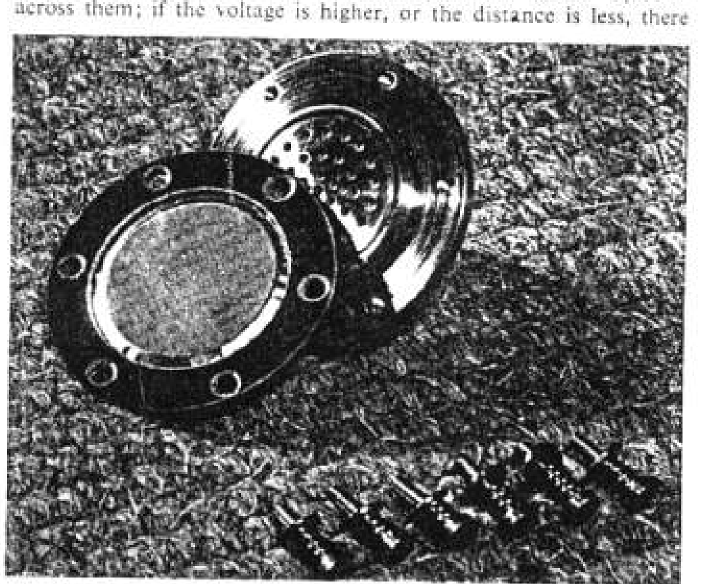


Fig. 2. *The two main sections of the capsule, together with the six fixing screws. The perforations are clearly visible*

'HE AMATEUR

PART ONE — THE CAPSULE

would be an arc-over resulting in a breakdown of the air space between them. It is well to remember that in practice, owing to the fact that air is seldom free from impurities and perfectly dry, the stated theoretical figure of 3,000 V/mm is modified on the safe side to, say, 2,000 V/mm.

The heart of the condenser microphone is the capsule (fig. 2), and all the theoretical rules stated so far apply equally well to the working of the capsule in practice, because, after all, it is basically a capacitor.

The cross-sectional view of the capsule (fig. 3), shows that it consists of two accurately machined and aligned plates which are more conveniently referred to as electrodes—an inner and outer electrode, which are electrically insulated from each other. The insulating material used is mica. The assembly is solidly bolted together to ensure the maximum rigidity and stability. The inner

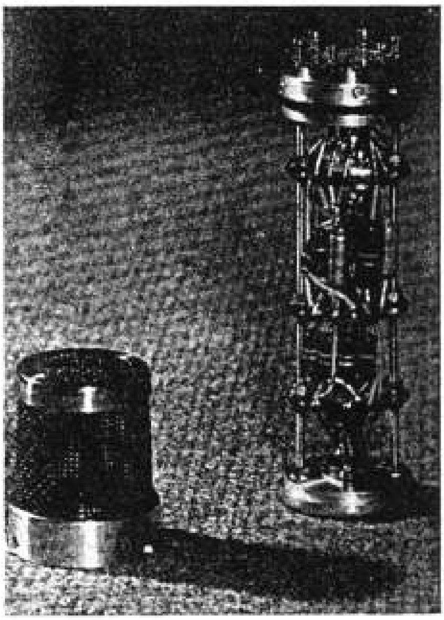


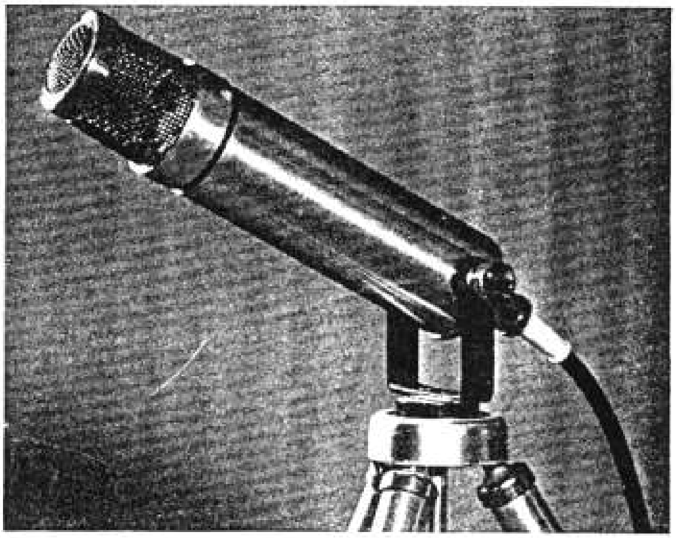
Fig. 4. *This shows the complete microphone housing, with pre-amplifier immediately beneath the capsule*

electrode is perforated with 0·8 mm diameter holes to varying depths in order to form a sort of air cushion, which helps towards obtaining a smooth frequency response. The entire assembly is so adjusted that the surface of the inner electrode is below the level of the surrounding flange on the outer electrode by 50 microns (0·002 in.). The object of this is to ensure that the foil diaphragm, when in place and adjusted by means of six spring-loaded screws, will be in good electrical contact with the flange of the outer electrode, but spaced from the inner electrode by 0·002 in. Thus the capsule with its diaphragm is in fact a capacitor, consisting of the inner electrode as one plate and the outer electrode plus diaphragm as the other.

Most Fascinating Part

Although the diaphragm in the completed condenser microphone is an integral part of the capsule, especial mention is made of it here because it provides perhaps the most fascinating part of the do-it-yourself operations in the proposed kit.

The foil material, which is an aluminium–magnesium–silicon alloy, is 15 microns (0·0006 in.) thick and is manufactured specially for this sort of application. Considering its thickness, the material is many times stronger than ordinary wrapping foil (so-called 'silver paper') and, most important, it has great dimensional stability. However, it is essential that a certain amount of care be exercised in the way in which it is handled and it is essential to follow carefully the detailed step-by-step instructions in the manual for the kit.



The completed microphone mounted on a stand

Briefly, the procedure is to cement the foil to a pertinax support, wait for the glue to set and trim away the excess foil with a razor blade. It is necessary to take care that the working surface of the foil is kept dust-free during these operations and that it is not scratched in any way. It will be apparent that with a clearance of the order of 0·002 in. between the underside of the foil and the inner electrode when the diaphragm is in position, even a slight scratch could result in a short circuit. Should there be an accident, however, a solvent is provided for dissolving away the old cement and there is sufficient spare foil to make a fresh start. Once the diaphragm is in place and the necessary adjustments carried out according to instructions, the protective metal screen can be attached around the capsule and it can safely be left in position and forgotten.

Why not use as it is?

Having obtained a capsule and a diaphragm which comply with the requirements outlined earlier, the uninitiated might well ask why it should not be possible simply to enclose the capsule in a protective housing and connect it by means of a screened lead to the normal microphone input of an amplifier—assuming, of course, that a suitable polarising voltage is applied across the two electrodes. Unfortunately, this is not a practical solution, for the following reasons:—

1. The self-capacitance of the screened lead used for making the connection may easily be greater than the capsule capacitance if the latter is, say, 150 pF. Therefore, the relatively small changes in capsule capacitance resulting from movement of the diaphragm due to sound pressure can be swamped out by the high capacitance of the screened lead shunting the capsule capacitance.

2. Even the slightest movement of the screened lead would cause capacitance changes in it, resulting in objectionable noises being added to the signal.

3. More serious is the question of impedance. Assuming that the 'static' capsule capacitance is of the order of 150 pF, it will have a reactance of 33 megohms at a frequency of 32 c/s. So far as the amplifier input is concerned, this amounts for all practical purposes to an open circuit at the end of a screened lead connected to one of its inputs and would probably also give rise to objectionable noise. Furthermore, from the point of view of the capsule the output, especially at the low frequency end of the audio spectrum, would be seriously attenuated, since it would be shunted severely by the relatively low input impedance of the amplifier.

To obviate these difficulties, the standard practice with condenser microphones is to incorporate a pre-amplifier as near as possible to the capsule, i.e., in the microphone housing itself (fig. 4). The Microkit pre-amplifier is in fact a two-stage circuit using one half of a double-triode (ECC83) as an amplifier and the other half as a cathode-follower impedance transformer. Details of this and of the associated power supply will be given in the concluding article next month.

A CONDENSER MICROPHONE FOR THE AMATEUR

By M. R. RATNAGAR — Part Two: PRE-AMP AND SUPPLY

LAST month we explained that there are good reasons for connecting the microphone capsule straight to a pre-amplifier unit in the same housing. The input of such a circuit is shown in fig. 1 in simplified form. The capsule is represented by *Cm*, the polarising voltage is shown as a battery, *Vp*. *Ck* is a coupling capacitor, *Ri* is the input resistor and *Rg* is the grid leak resistor.

Cm is charged via *Ri* by the battery *Vp*. Sound pressure on the diaphragm of the capsule *Cm* results in capacitance changes in it, causing current flow in the circuit and corresponding voltage variations to appear across *Ri*. These voltage variations across *Ri* are fed to the grid of the first triode section via a coupling capacitor *Ck* and amplified in the usual way. The amplified signal at the anode is fed via a coupling capacitor to the grid of the second triode section and the final output is taken off at low impedance (600 ohms) at the cathode. The advantage of this arrangement is that the microphone can be connected to the amplifier or tape recorder, which might be a considerable distance away, without loss of high frequency response and without resorting to the use of a step-down transformer.

The input resistor *Ri* should be of a value that will not shunt the equivalent capsule reactance at the lowest frequency it is desired to reproduce. The Microkit circuit employs two 22 Megohm resistors in series, i.e., a total of 44 Megohms and some professional circuits use an even higher value, viz., 60 Megohms. It has been found in practical tests that a too extended low frequency response can be undesirable, because then the microphone begins to

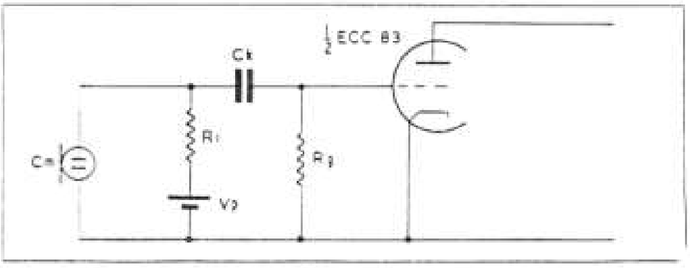


Fig. 1. *Representation of the basic input circuit, with Ri as the DC supply feed and Rg as the grid leak*

respond to pressure changes that are not necessarily audible—such as those caused by the opening and closing of doors—and to vibrations via the foundations of the building, etc. Besides this, there is the more serious consideration of resistor noise, which is directly proportional to the number of resistor elements in *Ri* and to the bandwidth of the audio spectrum it is desired to reproduce. Consideration was given to these two factors and the choice of *Ri* was governed by a compromise between an adequate low frequency response and an acceptable noise figure.

The choice of the grid leak resistor *Rg* was governed by similar considerations, and for convenience its value was fixed as the same as that for *Ri*, viz., 44 Megohms.

The input coupling capacitor, *Ck*, should be of high quality, i.e., one that has a low loss resistance and stability over a long-term period. A ceramic disc type fulfils this requirement, besides which it is extremely compact for its capacitance value (1,000 pF) and voltage rating (500 V). The complete pre-amplifier circuit is shown in fig. 3.

The function of the power unit is to supply the HT and LT for the pre-amplifier valve and a polarising voltage for the capsule. At first sight this might seem like a fairly simple requirement, and perhaps the reader would believe that these supplies can surely be

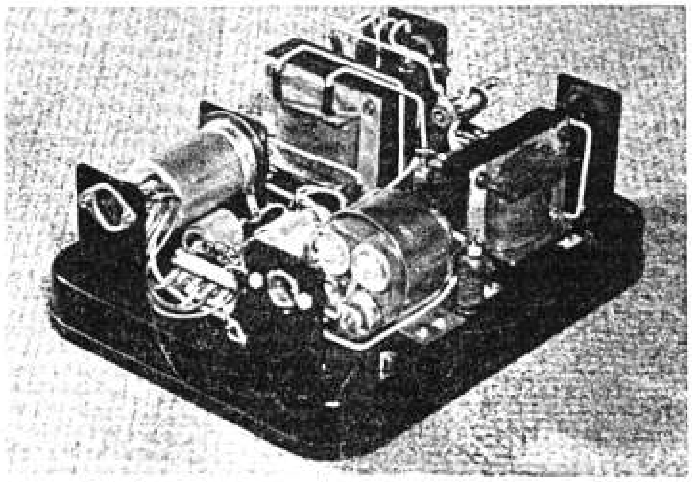


Fig. 2. *The power supply unit with its cover removed*

'tapped off' his existing equipment. It is not quite as simple as that, however, because all three supplies, including the LT, must be DC voltages—in fact, virtually ripple-free. Ideally, batteries could be used, but apart from the question of size, the expense of periodic replacement would be quite considerable.

For these reasons, the power supply circuit chosen (which is more or less of 'classic' design) has rather a large number of elements and high values of capacitance (fig. 6). Nevertheless, with the aid of modern components and the use of selenium contact-cooled rectifiers, a compact design has been achieved with practically no heat generation (fig. 2).

In the interests of running the pre-amplifier valve as cool as possible and ensuring at the same time that it will have an extended life, the LT voltage for the heaters is adjusted to about 10% lower than its rated value.

Connection to the microphone pre-amplifier is made via a flexible multi-core cable, which apart from carrying the various power supplies to the pre-amplifier, also carries the audio output *from* the pre-amplifier. The power supply box serves as a sort of junction bridge to tap the audio signal out via a conventional co-axial socket. The connection from this point to the main amplifier or tape recorder

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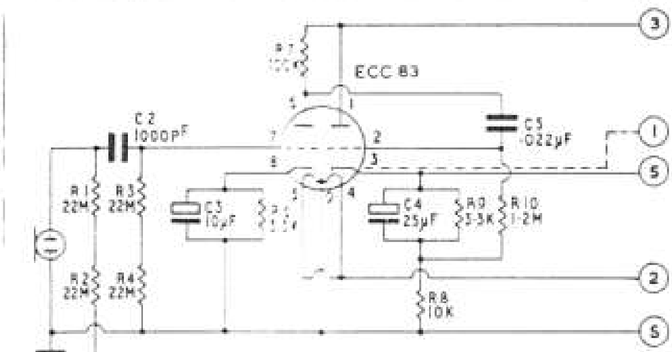

Fig. 3. *Complete pre-amp circuit with all the component values. The terminal numbers correspond to those on the power pack* (fig. 6)

CONDENSER MICROPHONE—(*continued*)

can then be extended to 100 yds. or more, using normal single-core screened microphone cable.

The wiring and components of the pre-amplifier are supported on a framework consisting of three pertinax spacers, which are drilled and fitted with tinned eyelets which act as solder points, and also some plain holes to lead wires through (**fig. 4**). The valve is positioned as high as possible in an inverted position, so that the shortest possible connections may be made to the capsule. The framework is built-up on the microphone baseplate, which also carries a 5-pin 'Preh' plug. Two threaded rods are used as supports.

Foolproof System

A step-by-step wiring schedule in the manual with the kit incorporates a practically foolproof system, which is tabulated and coded in a manner that eliminates a number of unnecessary words. Besides this tabulation, a point-to-point schematic is provided (which incidentally opens out on the same page as the schedule) and which identifies each one of the solder points and other holes in the spacers by a system of letters and numbers. The system is so devised that it is not essential for the constructor to consult the circuit diagram unless, of course, he wishes to cross-check a particular connection for his own satisfaction.

The schematic may also be used finally to check all the wiring, by checking against each numbered point, not only the number of connections, but what they are and where they come from.

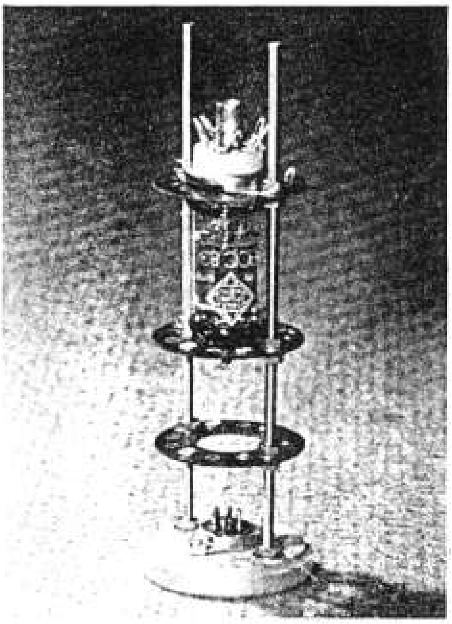

Fig. 4. *This picture shows the basic frame assembly, with spacers carrying eyelets which act as junction points for soldering*

When the pre-amplifier has been constructed and the wiring checked in the manner suggested, the main body of the microphone may be slipped over it, and the capsule holder attached and held in position by means of two special nuts that screw into the top ends of the two threaded rods. The connection to the capsule is made to its centre electrode by means of a solder tag and screw. The capsule itself is held firmly in its holder by means of a grub screw which also ensures that it is in good electrical contact with the microphone housing.

A swivel bracket is provided, the bottom of which is equipped with an adaptor to fit a standard (¼ in.) camera tripod. The photograph (fig. 5) shows the microphone mounted on a table-top camera tripod.

Readers interested in obtaining further information about the microphone should write to Microkit, Sweelinckplein, 65–A, The Hague, Holland. The manufacturers hope to arrange for U.K. distribution of the kit in the near future.

Fig. 5. *The swivel bracket permits easy fitting to a camera tripod*

Provided the condenser microphone is used with equipment capable of high quality reproduction, the first impression the user will have will be one of extreme realism. It has an excellent transient response and sounds such as the jangling of keys, the tinkling of glassware and cars with squeaky brakes are reproduced with almost frightening realism. Owing to the virtual absence of peaks and dips in its response curve, the condenser microphone is ideally suited for use in 'difficult' locations, where room acoustics are poor and where the conventional microphone generally makes matters even worse than they are in reality. No doubt the reader's particular field of audio interest will suggest its own uses for this microphone.

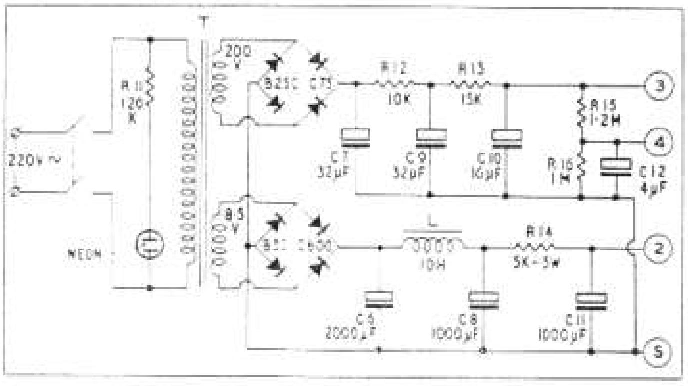

Fig. 6. *Complete circuit of the power supply, showing the very thorough smoothing employed. Heater supply comes from terminal 2, HT from 3 and polarising voltage from 4.*