In Other Fields

Valves and Gas-filled Relays in Science and Industry

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ALTHOUGH in the eyes of the man in the street the thermionic valve is probably associated almost entirely with the science of radio communication—hence the common term "wireless valve"—it is appreciated in technical circles that the limitations of its application by no means end with this field. In spite of this, few except specialists, realise how many types of valves have appeared during the past few years, incorporating designs aimed principally at the industrial or laboratory application.

The versatility of the modern thermionic valve, and the improvements in cathode technique, methods of obtaining high vacua and high insulation, and experiments in gasfilling, offer an ever-expanding scope for the ingenuity of electrical engineers and scientists.

A great deal more attention has been paid in America to the applications of valves in industry and science than in this country, and surveys have been issued for a large number of practical applications, many of which are in actual daily use.[1]

A brief review of some of the types of British-made valves which have recently been introduced for such purposes may therefore prove of interest.

Although not coming within the category of a thermionic valve, the photoelectric cell as an electron-operated device is rapidly becoming recognised as an invaluable tool, not only to science, but to industry of all kinds. This article is not, however, intended to deal with the applications of photoelectric cells, but to describe some types of thermionic valves in the proper sense. These may be roughly divided into two groups: the hard vacuum group, and the gasfilled group.

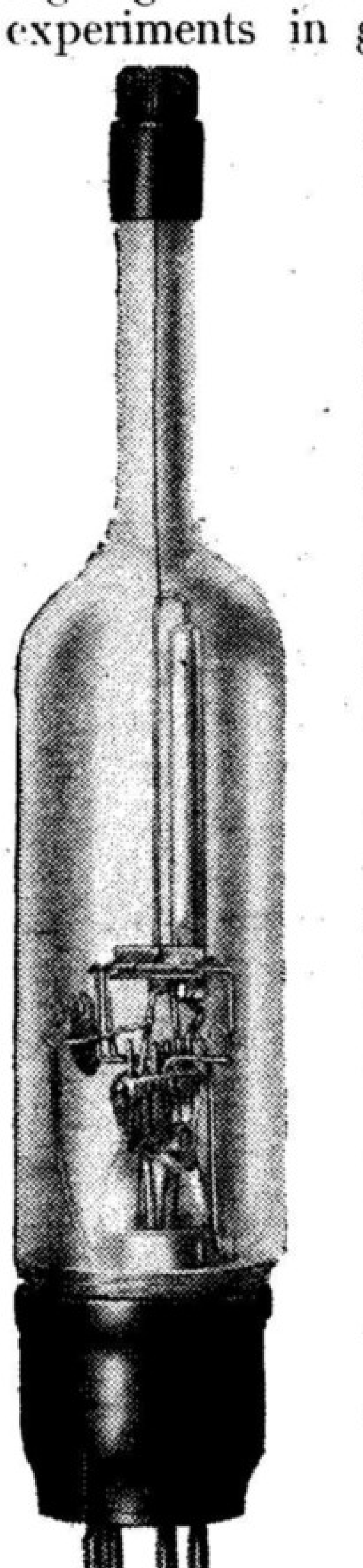

Fig. 1.—The electrometer triode has an extremely high input impedance, and is designed for use as a substitute for electrostatic measuring instruments.

Hard valves are necessarily limited in their power-handling capacity by the electron emission of their cathodes, and in their efficiency by their internal impedance, and their use would therefore be expected to be restricted to scientific instruments for measurement or detection of electrical energy well within the capacity of the electron emission, or for use as rectifiers or in amplifiers for operating either visual or sound reproducing mechanism.

Apart from valves developed for use in amplifying equipment, some examples of hard valves developed for scientific instrument use are: electrometer triode, valve voltmeter triode, peak voltmeter diode, and the ultra-short wave oscillator of the split-anode Magnetron type.

The electrometer triode, illustrated in Fig. 1, was first developed towards the end of 1930, and has proved of value to many workers in laboratories and factories for the accurate measurement of electrostatic potentials and very small electric currents. The chief characteristics of the electrometer triode is its extremely high value of grid-cathode impedance. In standard types of triode, as used in radio receivers, the grid-cathode impedance may reach a value of 10^9 ohms, but seldom exceeds this value, so that such valves could not be employed to replace electrostatic instruments. The electrometer triode was designed with a view to removing this limitation, and in the type illustrated, the insulation resistance between grid and other electrodes is greater than 10^{17} ohms. It has also been found possible in this valve to reduce the total residual grid current to less than 10^{-15} ampere, while retaining reasonable sensitivity. At 1,200 kc/s the input impedance exceeds 100 megohms.

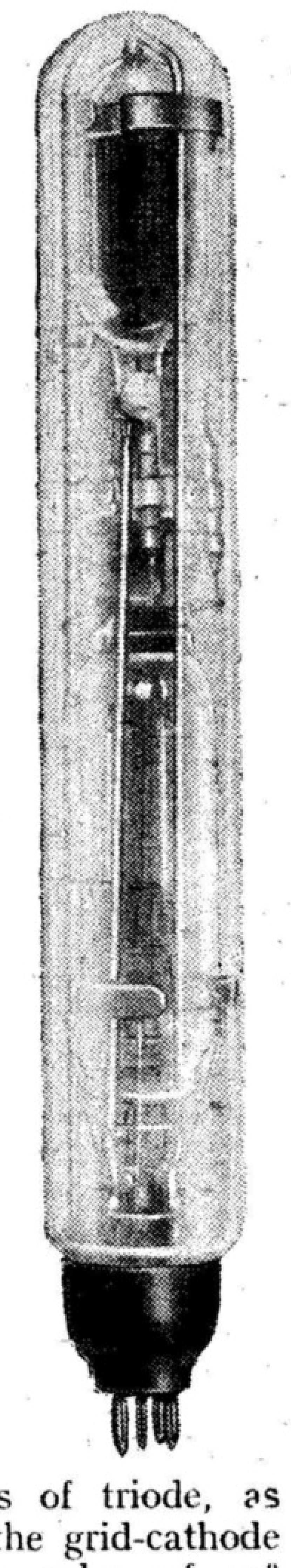

Fig. 2.—For photometry of lamps: an electrometer triode combined with a standard photo-cell.

These features are achieved by mounting the control electrode, or grid, in the form of a flat plate supported from two pillars of special high-resistance glass, the grid lead being taken to a terminal through the end of a stem also of high resistance glass, and sealed to the top of the bulb. The anode and filament are mounted on a glass pinch which supports the two pillars. In the glass used for the bulb and stem in the electrometer triode care is taken to ensure low surface leakage, unaffected by exposure to the atmosphere over long periods.

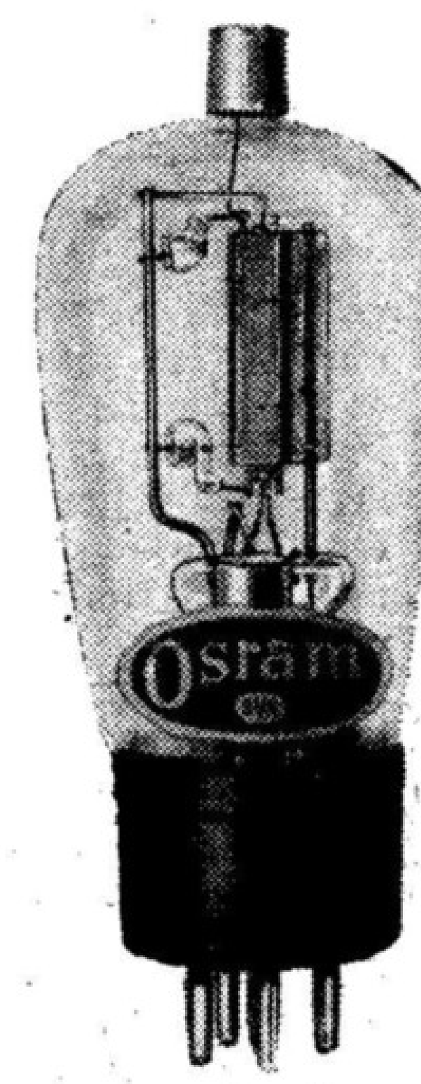

Fig. 3.—A valve voltmeter triode, with high input impedance at radio frequencies.

Ensuring Stability

A further precaution is taken to ensure that the getter surface does not spread over the upper portion of the bulb and the grid insulating pillars. Internal and external guard rings are provided, connected to a pin in the base of the valve. The guard rings and getter surface are arranged to be maintained at earth potential, thus obviating the risk of stray charges accumulating on the glass, and ensuring stability of characteristics. The advantages of this valve over the more usual form of electrometer are comparative robustness, low input capacity and greater sensitivity and stability.

The electrometer triode may be used in several ways[2] for the measurement of every small charges and currents, such as photoelectric or ionisation currents, or high resistances. Thus electrostatic potentials of from 0.1 millivolt to 6 volts may be directly determined. A practical application is in conjunction with a photoelectric cell for accurate photometry of lamps. To meet such a case a special tube has been developed, combining the

[1] See *Electronics*, January, 1935.

[2] Warren, *G.E.C. Journal*, 6-2 (1935).

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electrometer triode and a standard photo-cell with a grid coupling resistance, mounted together in an evacuated glass bulb (Fig. 2).

Another important application is the

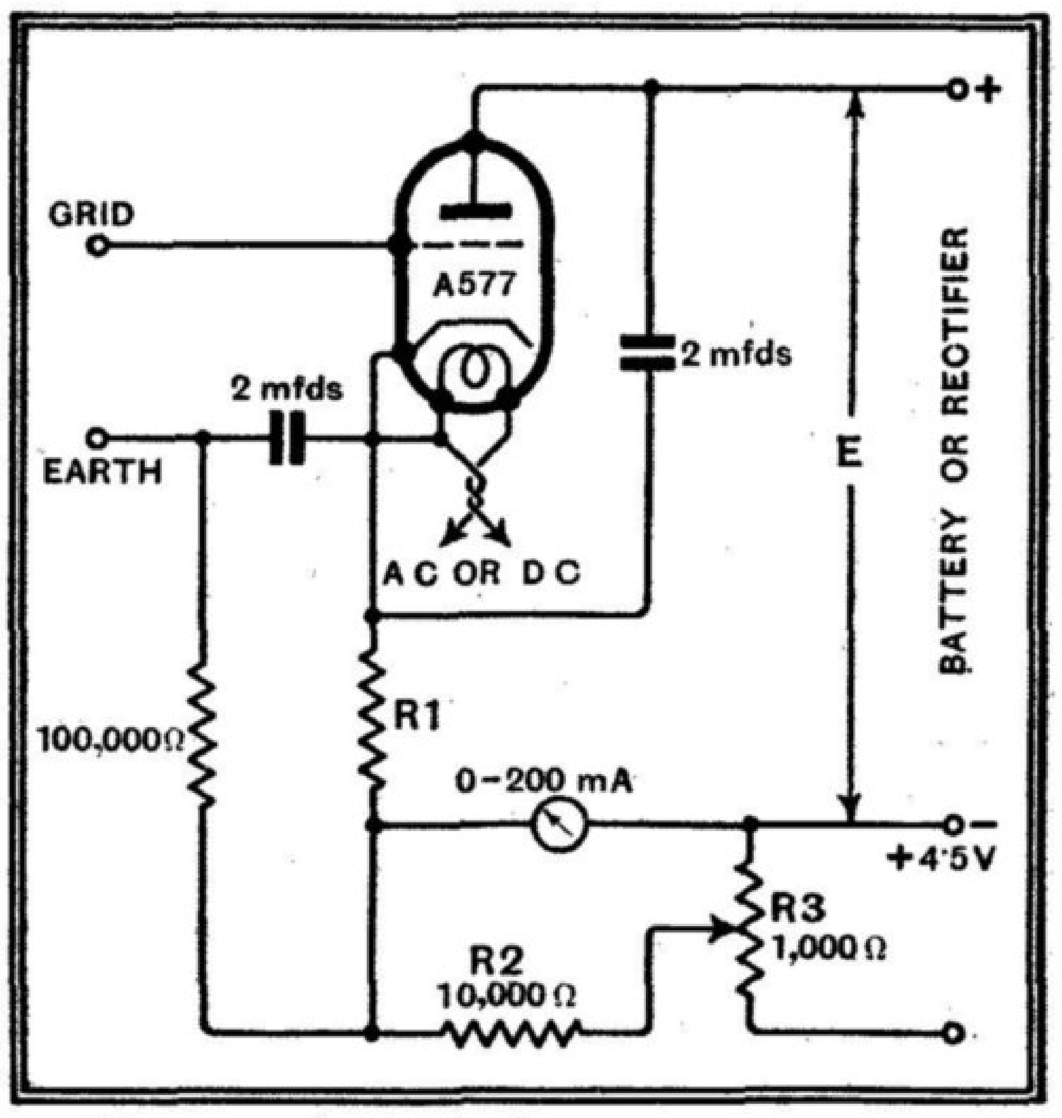

Fig. 4.—A typical valve voltmeter circuit. R1 and R2 constitute the backing-off circuit, with zero adjustment on R3. Suitable operating conditions for various voltage ranges are given in the accompanying table.

RMS Voltage Range	0—5	0—15	0—50	0—100	0—150
Supply Voltage E (anode + bias)	35	75	270	270	270
Bias Resistance R_1 ...	13,000 ohms	60,000 ohms	250,000 ohms	550,000 ohms	800,000 ohms

measurement of glass electrode potentials in the determination of hydrogen-ion concentration values; also the determination of high resistances and for the study of the piezo-electric effect in crystals.

The valve voltmeter triode, as typified in Fig 3, which shows Type A577, is a valve having more or less standard amplifier triode characteristics, but designed to exhibit an extremely high input AC resistance at high frequencies.

The A577 valve consists of an indirectly heated triode system showing a mutual conductance of approximately 2 mA/volt, but with the grid support wires held by means of two separate glass beads so disposed as to afford a much higher insulation resistance than if the grid were mounted on a pinch in the ordinary way. This construction would render the valve unsuitable for use in amplifiers owing to microphony, but is essential for its particular application for purposes of measurement.

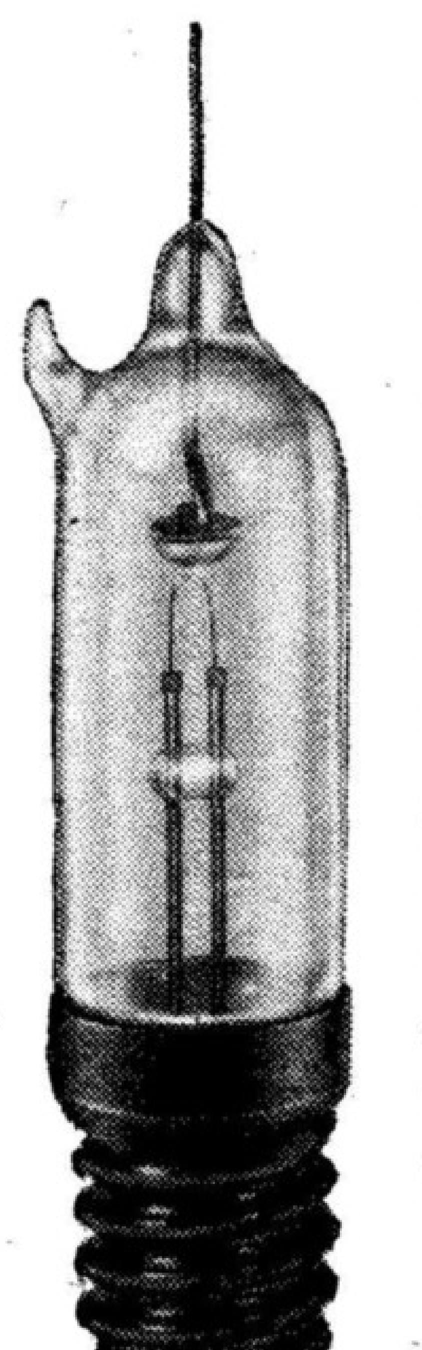

Fig. 5.—A peak voltmeter diode. Type A373.

In addition, the grid connection is taken to the end of the bulb remote from the other electrodes. In this type of valve the input AC resistance as measured on a cold valve at one megacycle is approximately 20 megohms.

The principal application of this valve is in a mains-operated or portable valve voltmeter in which the valve operates as an anode bend rectifier and may cover a wide range of voltages when operating at high frequency. A typical circuit diagram illustrates its use as shown in Fig. 4, and such an instrument can be arranged to include the measurement of voltages at all frequencies within the normal radio and audio range.

To meet the laboratory need for a direct reading peak voltmeter to operate on frequencies up to about 100 megacycles/sec., the small directly heated diode illustrated in Fig. 5 (Type A373), has been developed. This valve is of small dimensions and operates from a 2-volt filament supply, being capable of use with a peak anode voltage of 2,000 at frequencies up to 50 megacycles, or 1,500 volts at frequencies up to 100 megacycles.

The valve employs a short filament system with an anode supported at the remote end of the bulb, the anode connecting wire projecting to carefully defined length beyond the end of the bulb. This valve is so designed that the input capacity is very low (about 0.5 m-mfd.)

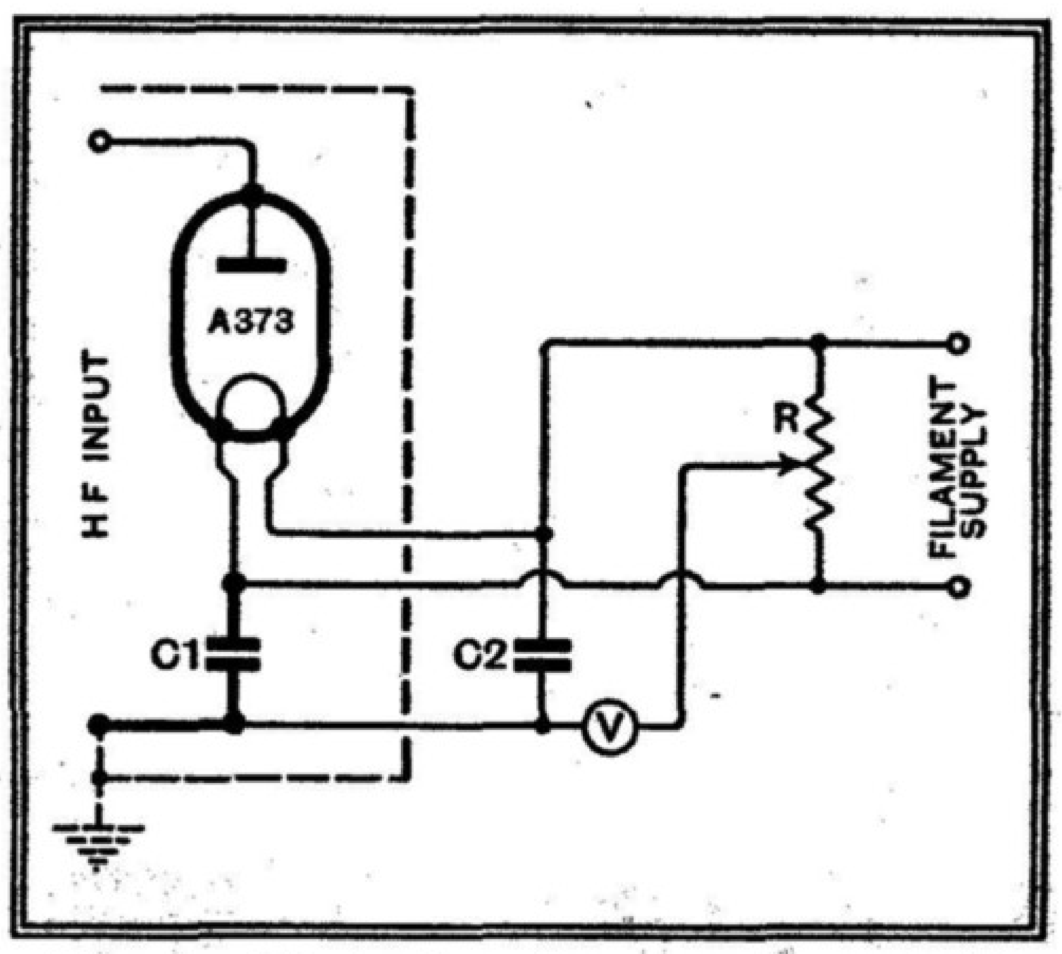

Fig. 6.—Illustrating the use of a special diode for measuring peak voltages. The filament supply must be insulated from earth by at least 500 megohms. C1, C2, 0.001 mfd. for any radio frequency; R, 100 ohms, centre tapped; V, electrostatic voltmeter or equivalent.

in spite of a very small anode-filament clearance.

Fig. 6 illustrates a suitable circuit with Type A373 arranged for high-frequency voltage measurement. For such purposes it is normal to employ an earthed screening case around the RF part of the instrument and an insulation resistance of not less than 500 megohms between the filament and earth.

Another important application is the measurement of modulation characteristics, for which the diode is used in conjunction with a cathode-ray oscillograph.

With the increasing technical interest in oscillations of ultra-short wavelength, the limitations of the more common triode circuits in producing, amplifying and detecting such oscillations has led to the development of other methods. The principal limitations arise from the inter-electrode capacities and the electrode lead inductances, and also from the transit time of the electrons in their path.

The type of valve which has been developed to reduce the effect of these limitations is known as the split anode Magnetron and a full description of the construction and operation of such valves has been given elsewhere.[3]

The split anode Magnetron is of increasing interest to investigators employing ultra-high frequency circuits. This range may be taken as representing wavelengths lying between 10 metres and 1 centimetre, it being estimated that the practical wavelength limit of conventional

Fig. 7.—Construction of a split anode Magnetron, as used at extremely high frequencies.

triodes is about 1½ metres as an oscillator or amplifier, and rather lower for detection. The split anode Magnetron, illustrated in Fig. 7, which shows type CW10, consists of an emitting cathode contained within an anode divided into two equal segments separated by narrow gaps, each segment being carefully insulated from the other. The valve operates in a magnetic field with the electrode axis approximately parallel to the lines of force. When under the influence of this field the electrons in their passage to the positive anode experience the deflecting force and, at a certain critical value of anode voltage and field strength, they will cease to reach the anode. This principle is applied in the Magnetron to impart a range of negative resistance to the valve similar in form to the dynatron characteristic arising from secondary emission in a tetrode. If a tuned circuit is connected between the anode segments and the high tension supply, oscillations can be produced and maintained at exceedingly high frequency.

Wavelength and Output

In the CW10 valve electronic oscillations may also be produced at wavelengths between 22 and 50 cms, and the type is designed to operate normally at an anode voltage up to 1,000 volts with a dissipation of 50 watts. The output ranges

[3] Megaw—*Journal I.E.E.*, Vol. 72, p. 326, 1933.

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from 10 watts at 1.2 metres' wavelength to 30 watts at 3 metres. The possible output increases with both anode voltage and filament emission, provided the magnetic field strength is increased with the anode voltage. For a given anode voltage the behaviour of the circuit can be entirely controlled, apart from wavelength adjustment, by means of the filament and field current rheostats. Using the electronic type of oscillation generator, an output of 2 watts is obtained at a wavelength of 25 cm.

Other types of split anode Magnetron are:

Type CW11, which is principally intended for dynatron oscillations at wavelengths of 1 to 5 metres.

Type E639, which is made with four anode segments allowing alternate wavelength ranges of from 0.5 to 1.5 metre with an output of 20 to 40 watts, and 1.5 to 5 metres with an output of 20 to 50 watts.

The field of micro-wave oscillations is one which is largely unexplored and hence the use of the split anode Magnetron is at present restricted to investigation by workers in the fields of both radio communication and medicine. This type of valve may ultimately be employed for point-to-point working on short-distance radio communication circuits or for radio beacons. The detection of moving objects ("wireless searchlight") is also an important possibility.

Workers in the medical field may discover new and promising possibilities in production of local heating, study of bacteria, etc.

(To be concluded.)