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Editorial

The Magnetron

THE technical journals of the last few months bear witness to the great amount of research work, both theoretical and experimental, which is being devoted to the magnetron. To the mathematical physicist the split-anode magnetron offers problems enough in the calculation of electron paths and of the mechanism of oscillation and energy conversion. The experimenter will find an ample field in the development of magnetrons capable of producing on a commercial scale several hundred watts at a wave-length of a few centimetres, that is, at frequencies of 1,000 to 2,000 megacycles per second.

In the earliest magnetron oscillators (Hull and Elder 1924) the magnetic field was used in lieu of a grid, a varying field producing a varying anode current. The first to produce oscillations with a constant magnetic field was probably Začek, but nearly all the subsequent development has followed the introduction by Habann in 1924 of the split-anode magnetron and its connection in a push-pull circuit by Manns in 1927. In a recent number of *Nature*[1], however, F. B. Pidduck gives a preliminary outline of a theoretical investigation of the single anode magnetron.

Much of the earlier lack of agreement as to the characteristics of the magnetron has now been cleared up by the discovery that it can function in at least two very different ways, one mode of operation occurring with longer waves and the other with shorter waves, with an intermediate region in which the action is probably a combination of both. The first type of oscillation is usually referred to as dynatron or circuit-frequency oscillations because the frequency depends on the constants of the oscillatory circuit, and the oscillation is maintained by the negative resistance characteristic of the magnetron. The second type, in which the frequency depends on the orbital periods of the electrons within the valve, is referred to as electron or transit-time oscillations.

A paper describing the general theory and the results of a number of experiments made at Oxford University was recently published by E. W. B. Gill and K. G. Britton[2]. An interesting account of the development of water-cooled split-anode magnetrons at the University of Jena has just been published by Pfetscher and Puhlmann[3]. Attempts to obtain greater outputs are generally limited by the temperature rise of the anode. The heating is often very local and the edges of the slits suffer severely, sometimes being melted although the anodes are made of

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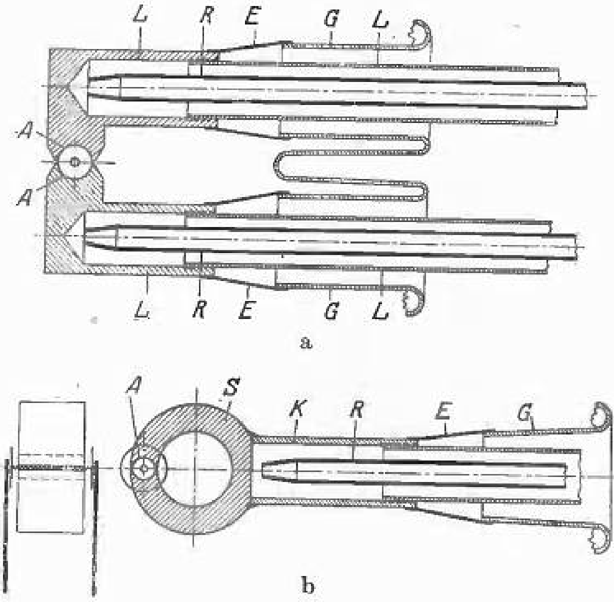
[1] *Nature*, June 6th, 1936, p. 945.

[2] *Jour. I.E.E.*, Vol. 78, p. 461, April, 1936.

[3] *Hochfrequenztechnik und Elektroakustic* 47, p. 105, April, 1936.

tantalum or molybdenum. To avoid this, cooling wings may be fitted to the edges, and in this way an output of 130 watts at a wavelength of 80 cm. has been obtained. These wings can also serve as the plates of air condensers to provide capacitive coupling between the split anode and the external circuit. For still higher powers water cooling must be employed, and the difficulty of doing this without introducing large losses of the high frequency energy can be overcome by making the oscillatory circuit serve as the cooling system. Instead of using sheet metal for the anode, massive copper blocks are employed, the cylindrical space being drilled out as shown in the Figures. For wavelengths of 100 metres or more two entirely separate copper blocks are employed (Fig. 1*a*), each sealed to the glass *G* by the thin foil *E*. The water passes up the inner tubes and away through the surrounding outer tubes. These copper tubes constitute the circuit, the length of which can be adjusted by an external bridge piece (Fig. 2*a*). For shorter wave lengths the whole oscillatory circuit must be contained within the valve which must be constructed for a fixed wave length. Such a valve is shown in Fig. 1*b*. The copper piece *S* constitutes the oscillatory circuit fed at its centre point by means of the outer water cooling pipe *K*. Fig. 2*b* shows two such valves for wavelengths of 19 and 46 cm. respectively.



a

b

Fig. 1.—*Electrodes of water-cooled magnetrons.*

The coupling with the external load is made capacitively by means of plates near the split-anode ; these plates can be plainly seen in the photographs, and the connections to the load are those at the top of the photographs. The filaments are arranged as cylindrical spirals in order to get the necessary emission. The following table gives the data of these three valves.

A troublesome phenomenon referred to by several authors is the heating of the filament due to electronic bombardment which may be sufficient to enable the valve to continue to function without any other supply of power to the filament. Megaw (see later) protects the filament from bombardment by means of a grid. The effect of filament bombardment may act cumulatively and produce an unstable rise of filament temperature to a destructive value. It necessitates not only careful design but careful operation.

In the same number of *Hochfrequenztechnik*[4] H. G. Möller, the author of one of the leading German text books on electron valves, has a mathematical paper on the calculation of the electron paths in magnetrons. As he rightly remarks, one cannot obtain a clear idea of the mechanism of the magnetron until one knows the paths followed by the electrons under the varying conditions.

The same subject was recently investigated

Valve.	Anode		Filament watts.	λ cm.	V_a volts.	I_a mA.	H	Output. watts.	Efficiency	
	diam. mm.	length mm.							η_1	η_2
A	10	17	140	100	3,600	430	1,400	850	55	50
B	6	20	100	46	3,700	300	2,050	450	40	37
C	4	15	50	19	2,200	180	3,200	80	20	18

Note.—η_1 is excluding and η_2 including filament watts. The field excitation losses are not included.

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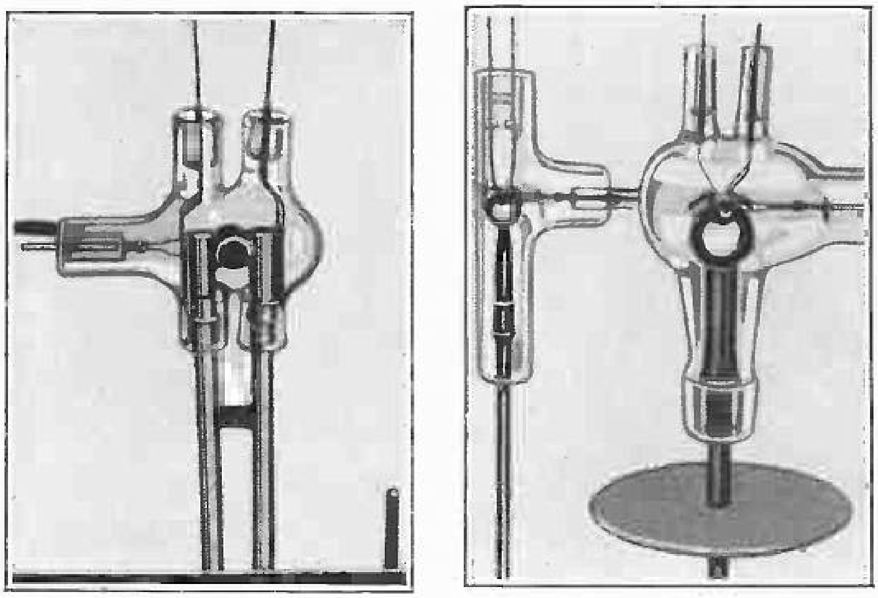
[4] Vol. 47, p. 115, April, 1936.

very thoroughly by F. Müller of Leningrad[5], in two papers, the first dealing with the longer-wave or circuit oscillations, i.e., those whose frequency is dependent upon the circuit constants, and the second with the short-wave or electron oscillations. In both these papers the author seeks to calculate the paths of the electrons under various conditions, including the inclination of the magnetic field to the axis of the magnetron.

In the current number of the *Telefunken Zeitung*[6], K. Fritz discusses the results obtained by Müller and gives a general explanation of the way in which the electrons are enabled to abstract energy from the field and give it out in the form of oscillations.

A paper by Groszkowski and Ryzko[7] describes a type of magnetron in which an ordinary spiral grid surrounds the filament. This is used for modulating the oscillator in the manner commonly employed with triode oscillators, and experiments show a linear relationship between the grid voltage and the oscillatory current, thus permitting a deep and distortionless modulation. Attempts to modulate the magnetron by varying the anode voltage whilst keeping the magnetic field constant, or vice versa, have not proved very satisfactory on account of the critical relation between the two and the anode diameter upon which the oscillation of the magnetron depends. The authors even tried a conical anode in the hope that the oscillation would occur at the optimum value of the diameter for the momentary values of the anode voltage and magnetic field, but it was a vain hope. It would appear from their experiments that good linear modulation would be possible by simultaneously varying both anode voltage and magnetic field so that their ratio was always of the optimum value for the given valve, but this would be a very complicated method if indeed it could be accomplished. The authors therefore tried the grid magnetron and found that it gave excellent results. The grid voltages were varied between 0 and −100, and gave a linear decrease of the oscillatory current over a wide range, due, of course, to the decreased emission. The grid currents varied between 0 and 1.5 milliamperes. The experiments were made at a wavelength of 1.8 metres ($f = 167 \times 10^6$).


(a)

(b)

Fig. 2.—*Water-cooled magnetrons.* (*a*) $\lambda = 1$ *to* 4 *metres;* (*b*) *left,* $\lambda = 19$ *cm,* *right,* $\lambda = 46$ *cm.*

The modulating problem is also discussed by E. C. S. Megaw[8], in a very interesting review of the development of the magnetron.

He also advocates the use of a grid, but the type of grid employed consists of two wires running parallel with the filament, one on each side of it. When not employed for modulating, this grid is connected to the filament and serves to protect it from electronic bombardment.

Megaw discusses a matter on which the Russian authors admit they have not made any observations, viz., the effect of the modulation on the frequency. Megaw says that the variation may be as much as 2 per cent., but that it can be reduced by using an oscillatory circuit of high capacitance, or by simultaneous modulation of the

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[5] *Elek. Nachrichten Technik*, pp. 131, 183, May, June, 1935.

[6] *Telefunken Zeitung*. March, 1936, p. 31.

[7] *Proc. I.R.E.*, May, 1936, p. 771.

[8] *G.E.C. Journal, VII*, p. 94, May, 1936.

Valve.	Anode diam.	Filament.	λ metres.	V_a	H	Output watts.
E465	2 cm.	5.5 V, 6.5 A	2—8	2,000	400—1000	150
CW11	1 cm.	3.7 V, 3.8 A	1—5	1,200	500—1,500	50
E639	1 cm.	3.7 V, 3.8 A	0.5—5	1,000—1,500	500—1,500	20—50

grid and anode voltages as already mentioned. This refers to wavelengths between 1 and 3 metres; for shorter waves employing electronic oscillations, Megaw says that good linearity up to 50 per cent. can be obtained by anode voltage modulation with 0.5 per cent. frequency variation; he also suggests employing frequency modulation with a constant amplitude as the possible best solution.

The General Electric Co. now produces commercially several types of magnetron valves suitable for different frequencies and outputs. They also have standardised suitable electromagnetic and permanent magnet systems for use with the valves.

The table above gives particulars of three types of magnetron manufactured by the General Electric Co. and described by Megaw.