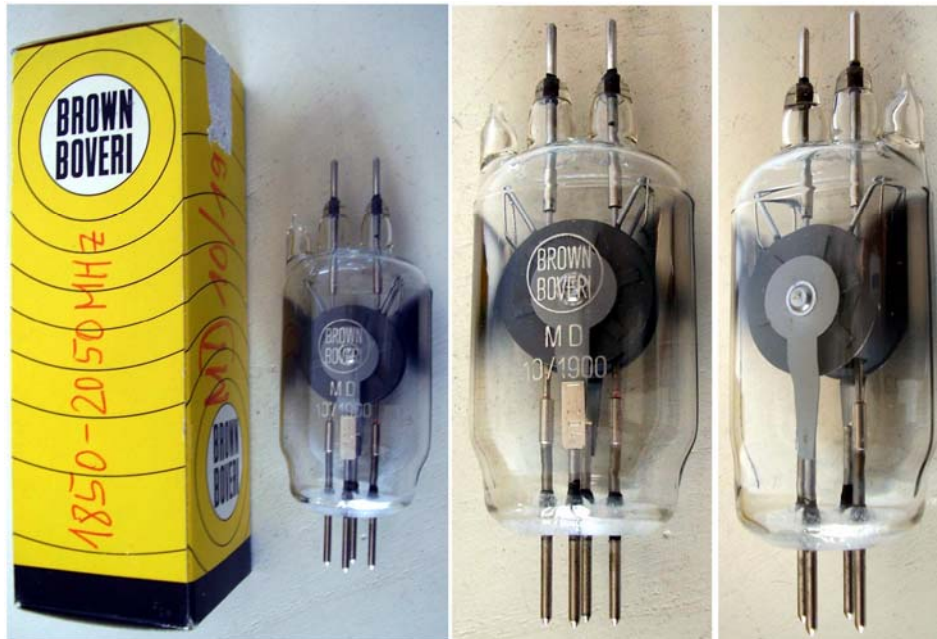
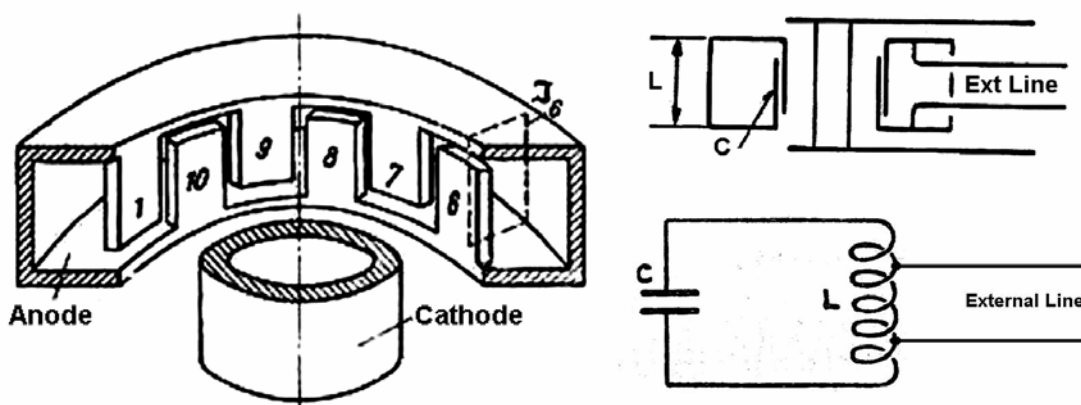


MD10/1900 - 'Turbator' CW Magnetron



The family of 'Turbator' single-cavity magnetrons was introduced in 1948 by Brown Boveri for its line of microwave communication sets. The designer, Dr. Lüdi, had started experimenting microwave tubes including magnetrons years before. In the design of his 'Turbator' he integrated an interdigital structure and the resonating cavity. This solution was innovative, quite similar to that of coaxial magnetrons. The single cavity, integrated with the twelve interdigital segments, granted the very high spectral purity required for the intended application. Yet the whole anode assembly was simple to manufacture, no need for tight tolerances, as in the multi-cavity magnetrons.



Left, sectional view of the 'Turbator' showing the doughnut-shaped anode system. The inner wall of the cavity is formed by twelve interdigital segments. The draft at right top shows where most of inductance and capacity are concentrated, indicated as L and C. Also showed the connections of the external transmission line to the internal walls of the cavity. The equivalent lumped-constants circuit is given at bottom right.

Few data found for this type, introduced in 1950 for use in the Brown Boveri 1M23 microwave link:

- **1.7 V @ 3.9 A filament**
- **1900 MHz center frequency \pm 7.5%**
- **5 to 15 W output**

Pinout and other information can be derived from the datasheet of the MD10-2000 and from the couple of pages from 'The Brown Boveri Review', Dec. 1941 on the early developments of the 'Turbator' magnetron.

The collection includes other 'Turbator' samples.

Turbator

Beschreibung

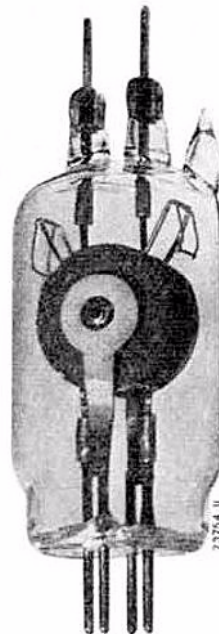
Der Turbator MD 10/2000 ist ein Mikrowellen-generator vom Magnetron-Typ, mit einer mittleren Frequenz von 2000 MHz und einem grossen Durchstimmbereich von ca. ± 200 MHz. Zur Schwingungserzeugung ist ein Magnetfeld erforderlich, wobei darauf zu achten ist, dass die Achse der Kathode mit der Achse des Magnetfeldes zusammenfällt. Die Röhre benötigt nur Heiz- und Anodenspannung. Gegenüber einem üblichen Magnetron hat der Turbator den Vorteil, die Durchstimmung ausserhalb der Röhre durchführen zu können und keine forcierte Kühlung zu benötigen. Er ist wie eine normale Empfängerröhre gebaut und kann dementsprechend leicht ausgewechselt werden. Ausser zum Betrieb mit Dauerstrich (mit max. 15 W Ausgangsleistung) ist der Generator auch für Impulstastung eingerichtet. Ferner besteht die Möglichkeit für den Anschluss äusserer Frequenzmodulationsmittel.

Description

The Turbator MD 10/2000 is a micro-wave generator of the magnetron type with a mean frequency of 2000 Mc/s and a wide tuning range of about ± 200 Mc/s. A magnetic field has to be applied for the production of oscillation; care is to be taken that the axis of heater-cathode is in the same direction as the axis of the magnetic field. The tube requires only heating and anode voltage. Considering a usual magnetron the turbator has the advantage of being tunable outside of the tube, and requires no forced air-cooling. It is designed like a usual receiving tube and may therefore easily be replaced. Besides continuous wave operation with max. 15 W output, provision is also made for the generator to be pulse modulated. Moreover, there is a possibility of connecting external frequency modulating means.

Description

Le turbator est un générateur micro-ondes du type magnétron, avec une fréquence moyenne de 2000 Mc/s et un grand domaine d'accord de ± 200 Mc/s. Pour la production des oscillations, un champ magnétique est nécessaire; le tube doit être monté de telle manière que l'axe du filament soit parallèle aux lignes de force du champ magnétique. Le tube ne nécessite que les tensions de chauffage et d'anode. Par rapport au magnétron usuel, le turbator a l'avantage de pouvoir être accordé de l'extérieur du tube et ne nécessite aucune ventilation forcée. Le turbator est construit comme un tube récepteur ordinaire, son remplacement est donc très facile. Le tube peut être utilisé aussi bien pour une puissance utile maximum à régime continu de 15 W que pour la modulation par impulsions. Il est également possible de connecter un dispositif supplémentaire pour réaliser une modulation de fréquence.





Allgemeine Daten
General Data
Caractéristiques générales

Elektrische Daten
 Electrical Data
 Caractéristiques électriques

Kathode } Oxyd, direkt geheizt
 Cathode } Oxide-coated, directly heated
 } à oxydes, chauffage direct

- $V_f (\Delta)$ 1,7 V $\begin{matrix} +0,05 \\ -0,1 \end{matrix}$
- $I_f (\Delta)$ 3,9 A $\pm 0,2$
- R_f 0,44 Ω
- P_a max. 40 W
- t_f min. 120 s
- f 2 000 MHz; Mc/s
- Δf $\pm 7,5 \%$
- $C_r \dagger$ ≈ 6 pF
- η $> 30 \%$

† Kapazität zwischen geerdetem Resonator und Kathode

Capacitance between grounded resonator and cathode

Capacité entre cavité résonnante mise à la terre et cathode

Mechanische Daten
 Mechanical Data
 Caractéristiques mécaniques

Röhrenkühlung: Strahlung; und schwacher Luftstrom**

Tube cooling: Radiation; and low-velocity air flow**

Refroidissement du tube: Radiation; et léger courant d'air **

Gewicht } netto } 45 g
 Weight } net }
 Poids } verpackt }
 } gross } ≈ 160 g
 } emballé }

Socket: 4 Stifte
 Base: 4 pins
 Culot: 4 broches

Montage der Röhre: beliebig
 Tube mounting position: arbitrary
 Montage du tube: arbitraire

** bei }
 with } I_a max.
 pour }



Normale Betriebsdaten
Typical Operating Conditions
Caractéristiques normales de service

Sender / Transmitter / Emetteur

Table with 4 columns: Parameter, Unit, and three values. Parameters include Va, Ia, H, and Po.

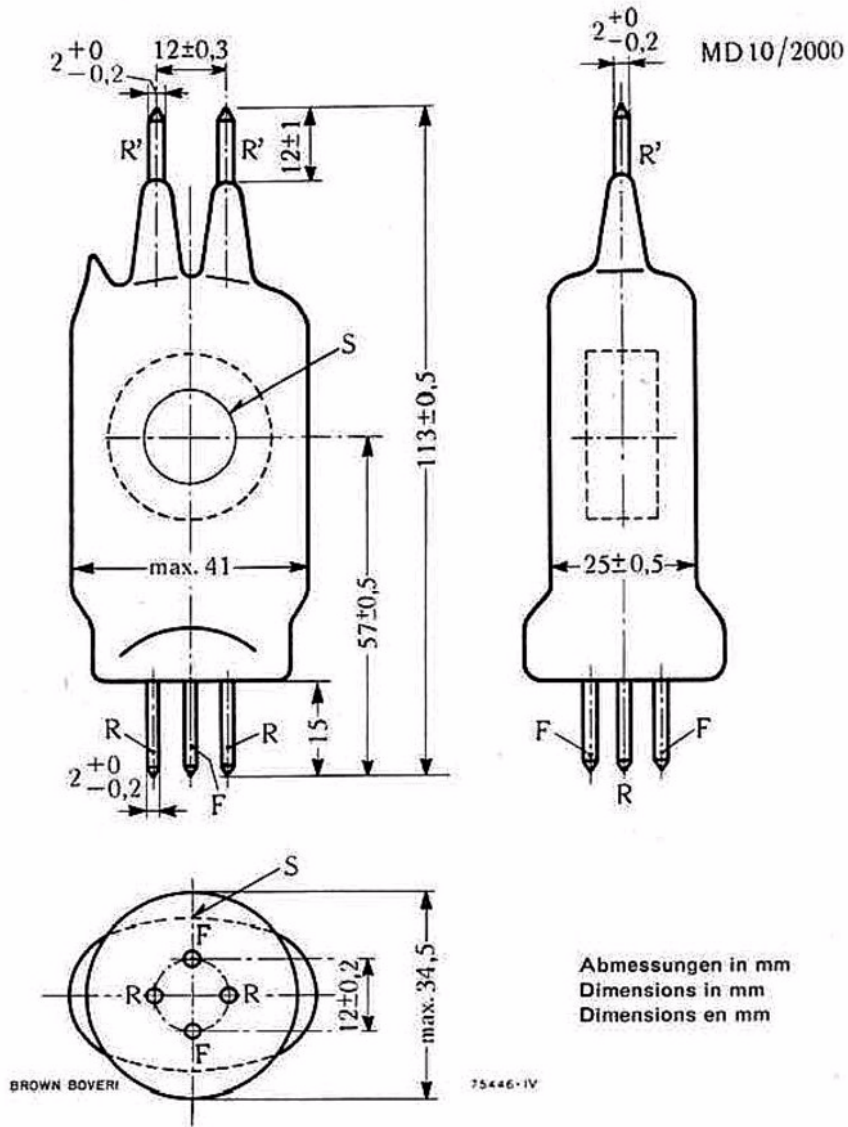
Überlagerungszosillator im Empfänger / Heterodyne Oscillator in Receiver / Oscillateur hétérodyne pour récepteur

Table with 2 columns: Parameter and Value. Parameters include Va, Ia, and H.

Es sind keine Schwingungskreise, wie Kapazitäten und Induktivitäten und dergleichen, notwendig, da die HF-Energie in der Röhre erzeugt und vom Resonator mit Paralleldraht-System, das zugleich als Anodenspannungszuführung dient, am Fusse des Glaskolbens direkt herausgeführt wird (R). Das Paralleldraht-System (R'), das am oberen, dem Röhrenfuss gegenüberliegenden Ende herausgeführt ist, ermöglicht eine einfache Durchstimmung. Zur Weiterleitung der Energie auf einen Verbraucher (Strahlungsgebilde) muss ein Symmetrie-Unsymmetrie-Transformator verwendet werden, der die Energie von einer Paralleldraht-Leitung auf ein konzentrisches Kabel (50-60 Ohm) überträgt und zugleich die Anpassung bewirkt. Ein Leerlauf des Generators mit vollem Anodenstrom muss unbedingt vermieden werden. FF = Heizzuleitung.

No tuning elements such as capacitors or inductances are necessary as the r.f. energy is generated by the tube itself which comprises a single annular cavity resonator. The supports of the resonator are constructed as a Lecher wire system which serves simultaneously as anode leads and output coupling (R). The parallel wire system on the upper end of the tube (R') makes possible a simple tuning operation. To utilize the generated energy, a symmetrical-unsymmetrical transformer is required to match the parallel wire line to a 50-60-ohm concentric cable for the high-frequency output. Care should be taken that under all circumstances off-load operation of the generator should be avoided with full-load current. FF = Filament lines.

Aucun élément d'accord tel que capacité ou inductance n'est nécessaire, car l'énergie HF est produite à l'intérieur du tube lui-même, constitué d'une cavité résonnante annulaire. Les supports de la cavité résonnante servent à la fois de fils d'amenée du courant anodique et de circuit de couplage HF (R). Le réglage de la fréquence se fait simplement en déplaçant le court-circuit sur la ligne de Lecher qui sort à la partie supérieure du tube, opposée au culot, (R'). Un circuit d'adaptation (transformateur symétrique-dissymétrique) est à prévoir pour permettre de sortir l'énergie HF à l'aide d'un câble coaxial de 50 à 60 ohms sur une charge ohmique de 50 ohms. Il est à observer que le turbator ne doit pas être mis en service sans réduire le courant anodique dès que la charge s'annule. FF = Circuit de chauffage.



Ansicht von unten / Bottom view / Vue d'en bas
S = Signet / stamp / sceau

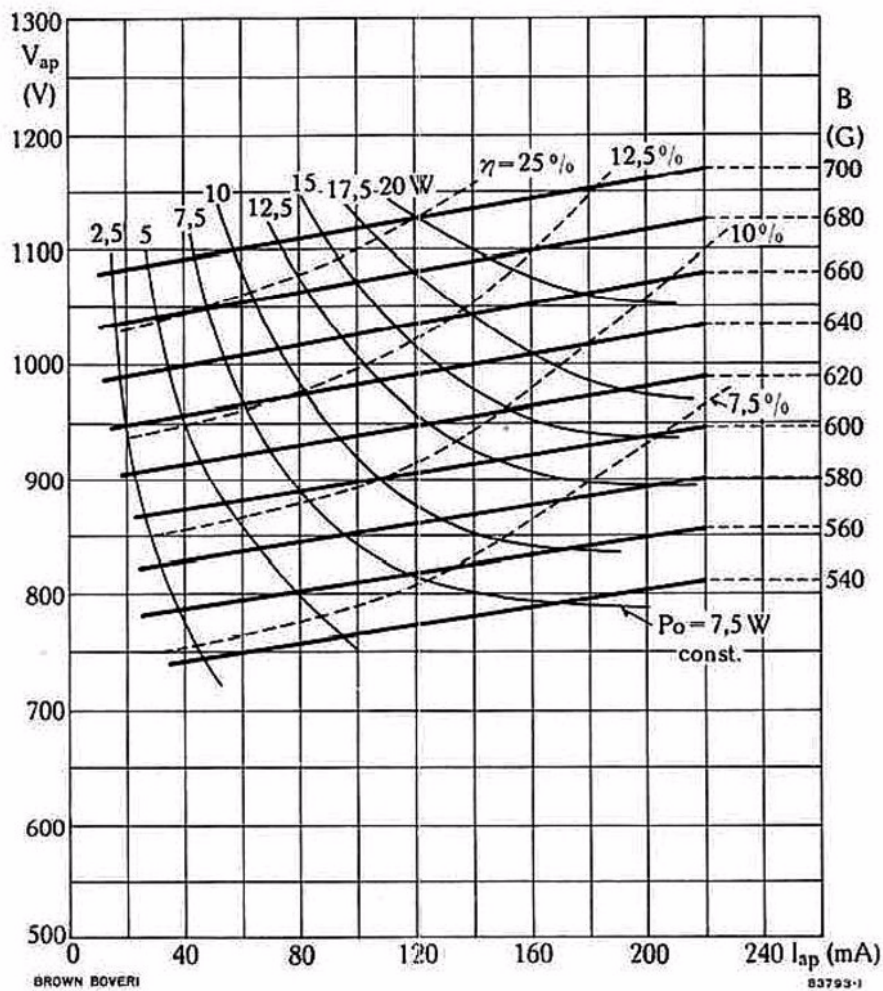


Kennlinien des Turbators MD 10/2000
Performance Chart for the Turbator MD 10/2000
Le réseau de caractéristiques du turbator MD 10/2000

$$V_{ap} = f(I_{ap})$$

Impulsbetrieb / Pulse Operation / Service par impulsion ($f = 2000$ MHz; Mc/s,
 $V_f = 1,7$ V)

Parameter: a) B (Gauss), b) η (%), c) P_o (W)

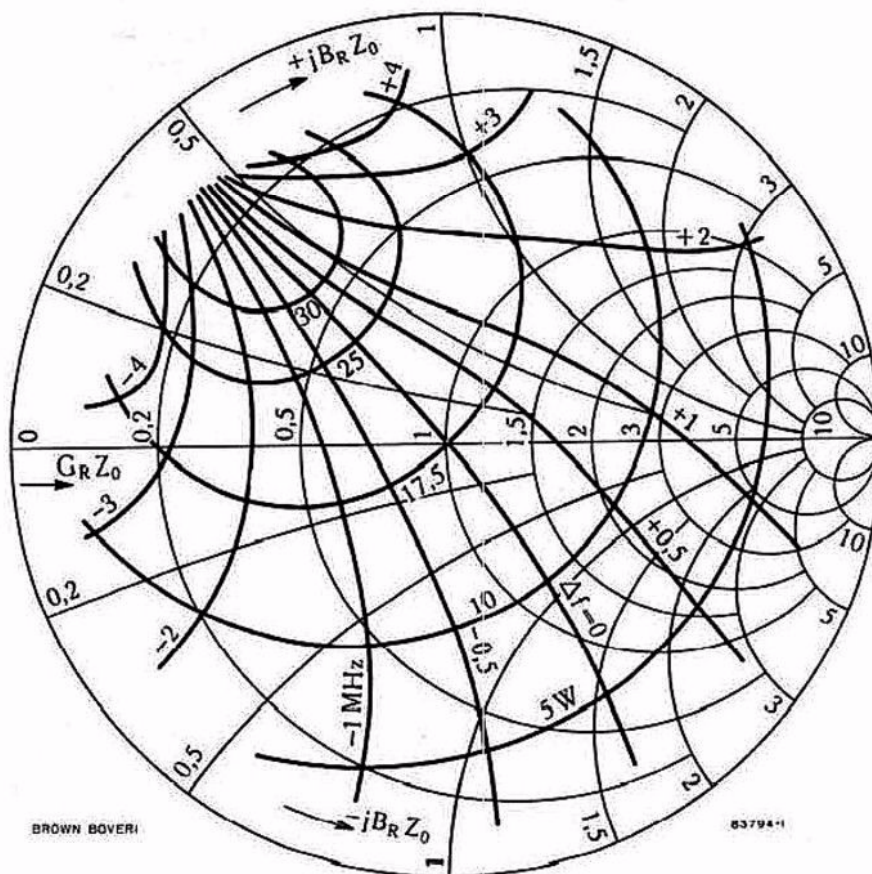


Rieke-Diagramm des Turbators MD 10/2000
Rieke Diagram for the Turbator MD 10/2000
Diagramme de Rieke du turbator MD 10/2000

Aufgenommen in der Abschlussebene des Ausgangssteckers im Senderausgang, im Impulsbetrieb bei 2000 MHz.

Obtained in pulse operation at 2000 Mc/s; reference point: extreme edge of the outer coaxial conductor of the transmitter.

Etabli pour un fonctionnement en impulsions à 2000 Mc/s; plan de référence: conducteur extérieur du raccord coaxial à la sortie de l'émetteur.



III. DESIGNS AND PROPERTIES.

1. The "Transator".

Fig. 1 shows a generator for 25 cm wave length and 1.2 watt high-frequency output. Here, the manner in which the oscillations are produced is particularly easy to follow and we give some closer details on the subject, with the help of the example in question. A ray of electrons streams up axially from the cathode lodged in the lower part of the valve, passing through an electronic lens system which also makes the modulation possible. The oscillation circuit is composed, according to Fig. 2, of a Lecher system, the lower side of which is short-circuited, and the two double

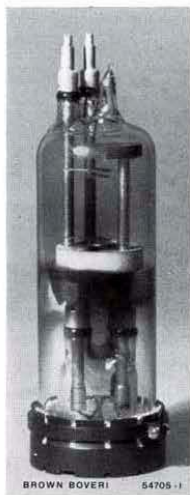


Fig. 1. — Transator for decimetre wave lengths.

The cathode is embedded in a new kind of ceramic holder. The holes through the accelerating electrode and through the four grids are for attaining effective concentration of the electron ray.



Fig. 2. — Oscillation system of the transator shown in Fig. 1.

It is designed as a Lecher system of quarter-wave length. The simple and strong construction also permits of keeping the losses low.

grids. Calculation shows that it is possible to generate stationary oscillations by means of coupling with the electron ray¹.

The high-frequency voltage generates on the lower double grid a velocity control of the electrons, but does not control the current, however. In the space up to the next double grid, the electrons travel at different speeds, slow and fast electrons following one

another, faster and slower electrons combine in the space between the two pairs of grids and in the space between the two upper grids we get the desired conglomerations of electrons. This acts, as has been already mentioned, as conduction capacity for the resonance circuit. A part of the voltage induced on the capacity is tapped by the lower control electrode, which causes the oscillations to be started and maintained.

The feed back is very visible here. The high-frequency energy is led out through the agency of a Lecher system by direct coupling to the resonance circuit. The anode in the upper part of the tube serves to absorb the electrons. The combination of these elements into an organic whole has the advantage of very great simplicity when compared to one formed of two separate resonance circuits tuned to one another.

Fig. 3 shows a generator built to this principle. Here the resonance circuit is represented by a concentric Lecher system closed on both sides and through which the flux of electrons streams transversally. It is a special type of cavity resonator, the inherent wave of which is equal to the double length of the cylinder. The control electrode is formed by the double wall of the lower electron penetration space, the conduction electrode by the double wall of the upper electron penetration space. The length of the transit space is determined by the diameter of the interior tube. The energy led out is taken by direct coupling to the resonance circuit. The combination:—

control electrode, transit space, conduction electrode and feed back form along with the resonance circuit a very simple system from the constructive point of view. Further, on account of its geometrical simplicity and also because there are no losses by radiation, it is possible to calculate it quantitatively completely.² Determined dimensions are given for the radii of the two concentric tubes for a given voltage of acceleration and a given length of wave. From this, the loss resistance of the system can be calculated. For a 6 cm wave it attains $6 \cdot 10^4$ ohms. This leads to

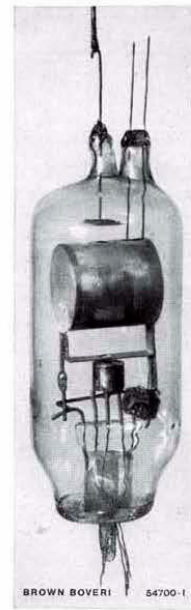


Fig. 3. — Transator with cylindrical resonator.

The resonator, designed as concentric Lecher system, is 3 cm long corresponding to a wave length of 6 cm.

¹ F. Lüdi, *Helv. Phys. Acta* Vol. XIII, Fascic. Sec. (1940) page 122. — F. Lüdi, *Helv. Phys. Acta* Vol. XIII, Fascic. Sext. (1940) page 498.

² F. Lüdi:— will be published shortly in the *Helv. Phys. Acta*.

an electron current of 14 mA for initiating the oscillation, this with a coupling of the load circuit which is practically zero. The frequency stability is determined, for this example, for one per cent velocity change of the electrons (corresponding to two per cent voltage change), at 0.1 per thousand. With a wave length of 6 cm, this corresponds to a change in frequency of $5 \cdot 10^5$ cycles. A relatively big change like this is, in principle, a feature of all self-excited transit time generators. It is due to the variation in the transit time of the groups of electrons which always corresponds to a change in the feed back phase.

The characteristic of both the generators described is the translation movement of the electrons passing through an oscillating system composed of one single resonator. This design is, therefore, known under the name of "Transator".

2. The "Turbator".

The resonator shown in Fig. 4¹ belongs to a generator designed according to another constructive principle. The emission of electrons takes place in the axis of the



Fig. 4. — Oscillation system of a turbator. The resonator is built of very heat resistant and well degassed metal.

system. Through the action of a constant radial electric field and of an axial magnet field a circular electron stream is produced. The segments S are so arranged alternatively on the sides of the cylindrical cavity resonator that an a.-c. voltage is produced between neighbouring segments. The action on the electrons is more complicated than in the former examples; it can also be explained theoretically.² The result is somewhat as follows:— The alternating field in the slits along with the constant magnet field produces an acceleration or retardation of the electrons in tangential direction, according to the initial phase, and a sorting effect is produced by this. We get concentrations and rarifications in the circular electron stream which was, originally, homogeneous. Contrary to the two first generators described, these agglomerations of electrons then deliver up successively their energy, originating from the electric constant field, to the alternating field of the cavity resonator. The

¹ F. Lüdi, Tagesbericht der schweiz. phys. Gesellschaft of 7th and 8th Sept. 1941.

² F. Lüdi, Helv. Phys. Acta, Vol. XIII Fasc. Sext. (1940) page 77.

feed back, although not visible, exists all the same. One and the same segment forms the control electrode and the conduction electrode. The appearance of this generator is somewhat like that of an a.-c. machine. The cavity resonator determining the frequency along with the segments resembles a stator while the rotation of the electron agglomerations corresponds to the movement of the rotor, thus the name of "Turbator" seems appropriate for this type of generator.

This extremely simple design has the following advantages:— the circular stream of electrons make an electronic lens system, such as the transator needs, superfluous.

The wave length is determined sharply by the cavity resonator, that is by its diameter and the capacity between the segments. As is known, a number of neighbouring waves appeared simultaneously in the older magnetrons, which is undesirable for transmission purposes. The combination into a whole of the segments and the cavity resonator is a very good solution both as regards the load of the anode and the possibilities for influencing the emission of electrons. Further, the result is a stout all-metal piece of apparatus.

A first generator of this type built, Fig. 4, has a high-frequency output of about 1 watt, at a wave length of 10.2 cm, measured by means of an adjustable cavity resonator, with an absolute precision of less than 0.1 mm. The tube oscillates stably without it being necessary to put stabilizing devices on the network connection; it reveals no back-heating effect. With a suitable control electrode, we get nearly a hundred per cent modulation control of the tube without any marked change in frequency. Here the magnet field is only 400—500 Gauss.

This weak field allows of using light permanent magnets, a factor of importance for the apparatus.

The generators which have been known for a long time under the names of *retarding-field tube* and *magnetron*, make use of another sorting mechanism for producing groups of electrons. Here, the so-termed false phase electrons are eliminated from the electron stream by means of a special electrode. This process is only partly successful. For this reason, only low outputs at poor efficiencies are attained.

Even here, however, it has been found possible to attain the advantageous relationship of the phase-focused electrons and the utilization of cavity resonators. Only by means of the most careful investigations, of all the elements which produce the oscillation, is it possible to reach this stage of progress as well as the other improvements described previously.

(MS 813)

Dr. F. Lüdi. (Mo.)