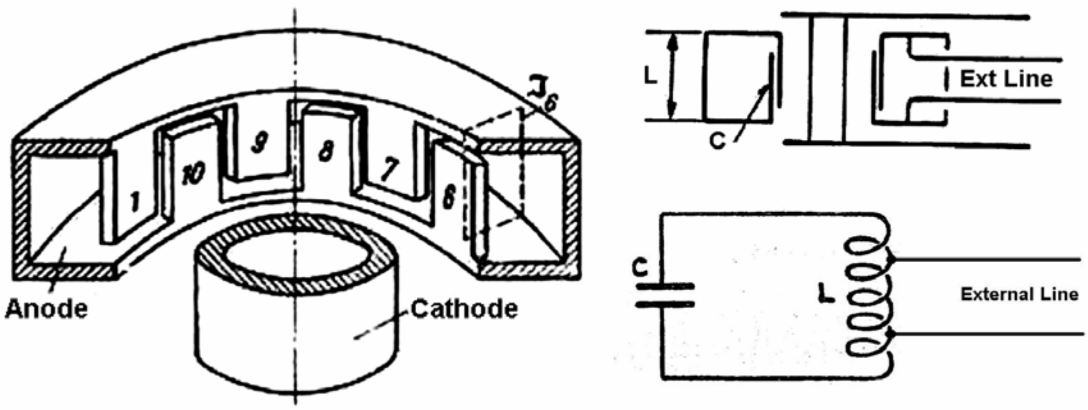
MF150/2400 - ‘Turbator’ CW Magnetron

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:

- **3.5 V @ 6.5 A filament**
- **2400 MHz ± 50 MHz**
- **100 W output power**

Pinout and other information can be derived from the datasheet of the MF100-2000 and from the couple of pages from ‘The Brown Boveri Review’, Dec. 1941 on the early developments of the ‘Turbator’ magnetron.

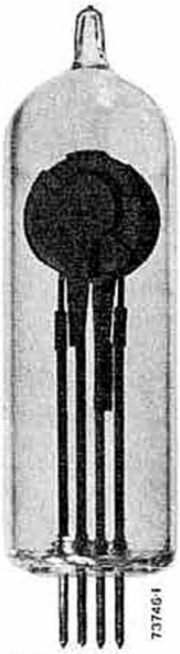
The collection includes other ‘Turbator’ samples.

BROWN BOVERI

Turbator

Beschreibung

Der Industrieturbator MF 100/2000 ist ein Mikrowellen-Generator vom Magnetron-Typ, mit einer festen, nicht durchstimmbaren Betriebsfrequenz von ca. 1750 MHz; dabei vermag er eine Ausgangsleistung von max. 120 W abzugeben. Die Röhre benötigt nur Heiz- und Anodenspannung. Zur Schwingungserzeugung ist ein Magnetfeld erforderlich, wobei darauf zu achten ist, dass die Achse der Kathode mit der Achse des Magnetfeldes zusammenfällt. Der Turbator ist wie eine normale Empfängerröhre gebaut, von kleinen räumlichen Abmessungen, und lässt sich dementsprechend sehr leicht auswechseln. Er ist in ein entsprechendes Gehäuse, in dem sich der Permanent-Magnet befindet, einzubauen. Die HF-Energie ist über einen Symmetrie-Asymmetrie-Transformator und ein HF-Koaxialkabel von 50 bis 60 Ohm Wellenwiderstand an einen angepassten Lastwiderstand zu führen. Es genügt, die Röhre während des Betriebes mit einem Ventilator zu kühlen. Der Turbator MF 100/2000 eignet sich vornehmlich zum Bau von Mikrowellen-Diathermiegeräten wie auch für verschiedene industrielle Zwecke, wie Hochfrequenzhärtung kleiner Werkstücke usw.



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Description

The industrial turbator MF 100/2000 is a microwave generator of the magnetron type having a fixed frequency of about 1750 Mc/s, not tunable. It will deliver a maximum power output of 120 W. The tube requires only filament and anode voltage. A magnetic field has to be applied for the production of oscillation; care is to be taken that the axis of the heater-cathode coincides with the axis of the magnetic field. The turbator has the advantage of having small dimensions, is designed as a usual receiving tube and may therefore easily be replaced. It is to be mounted in a suitable metal housing containing the permanent magnet. The high-frequency power output of the tube is to be led over a symmetrical-unsymmetrical transformer and over a 50–60-ohm concentric cable to a matched load. It is sufficient to cool the tube with a small fan during operation. The turbator MF 100/2000 is primarily suitable for use in diathermy apparatus and various industrial applications such as high-frequency heating of small work pieces, etc.

Description

Le turbator MF 100/2000 pour utilisation industrielle est un générateur micro-ondes du type magnétron à fréquence fixe d'environ 1750 Mc/s, et fournissant une puissance utile maximum de 120 W. Le tube ne nécessite que des tensions de chauffage et d'anode. Pour la production des oscillations, un champ magnétique est nécessaire; le tube doit être monté dans un boîtier métallique contenant l'aimant permanent de telle manière que l'axe du filament soit parallèle aux lignes de force du champ magnétique. Le turbator est construit comme un tube récepteur ordinaire de dimensions fortement réduites. Son remplacement est donc très facile. Un circuit de couplage (transformateur symétrique-dissymétrique) est à prévoir pour permettre de sortir l'énergie HF à l'aide d'un câble coaxial d'impédance 50–60 ohms sur une charge adaptée. Un refroidissement du tube par un petit ventilateur est suffisant en fonctionnement. Le turbator MF 100/2000 peut être utilisé avantageusement comme générateur dans des appareils de diathermie ou également pour différents appareils industriels comme les générateurs HF pour la trempe par chauffage HF, etc.

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Allgemeine Daten
General Data
Caractéristiques générales

Elektrische Daten
Electrical Data
Caractéristiques électriques

Kathode / Cathode: Wolfram thoriert direkt geheizt / Thoriated tungsten directly heated / Tungstène thorié chauffage direct

V_f (≃)		3,5 V ± 5%
I_f (≃)	≈	6,5 A*
t_f	min.	10 s**
P_a	max.	200 W
Cr***	≈	5 pF
f	≈	1750 MHz Mc/s

* max. zulässige Reduktion von I_f infolge Rückheizung durch Elektronenbombardement: 0,6 A (bei V_f = 3,5 V, I_a = 0,1 A, R_i [Heizspannungsquelle] < 0,5 Ω)

Max. admissible drop in I_f as a result of electron bombardment of the cathode: 0.6 A (with V_f = 3.5 V, I_a = 0.1 A, R_i [heater supply circuit] < 0.5 Ω)

Réduction max. admissible de I_f due au bombardement électronique de la cathode: 0,6 A (avec V_f = 3,5 V, I_a = 0,1 A, R_i [de l'alimentation de chauffage] < 0,5 Ω)

** bei / with / avec I_a max.; bei I_a < 20 mA ... t_f = 0

*** Kapazität zwischen Resonator und Kathode

Capacitance between resonator and cathode

Capacité entre cavité résonnante et cathode

Mechanische Daten
Mechanical Data
Caractéristiques mécaniques

Röhrenkühlung ..... durch Ventilator
Tube Cooling .... by fan
Refroidissement du tube .... par ventilateur

Ventilator-Kühlluftmenge und Luftdruck:

Quantity of air and static pressure of the fan cooling system:

Quantité d'air et pression statique du système de ventilation:

Q	≈	1 m³/min
p	≈	2,5 mm/H_2O

Gewicht / Weight / Poids	netto / net	80 g
	verpackt / gross / emballé	≈ 1300 g

Sockel:	4 Stifte
Base:	4 pins
Culot:	4 broches

Montage der Röhre: beliebig; die Achse der Kathode muss mit der Achse des Magnetfeldes zusammenfallen

Tube mounting position: arbitrary; the axis of the heater-cathode should coincide with that of the magnetic field

Montage du tube: arbitraire; l'axe du filament étant confondu avec l'axe du champ magnétique

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Normale Betriebsdaten
Typical Operating Conditions
Caractéristiques normales de service

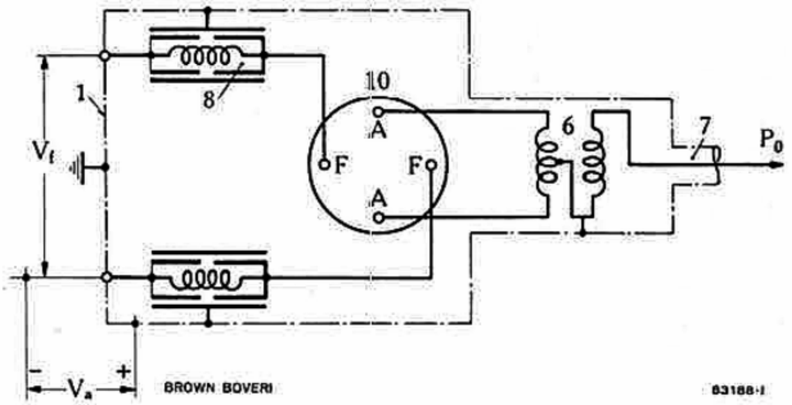
V_a	≈	2,2 ... 2,5	kV*
I_a	max.	100	mA**
H		1450	Oersted ± 50
P_o	≈	100	W
f		1750	MHz Mc/s ± 50

* regelbar zur Leistungsregelung von 0 bis max. P_o
adjustable for regulation of power output from 0 to max. P_o
réglable pour pouvoir assurer le réglage de la puissance utile P_o de 0 à la valeur max.

** Betrieb mit ungefilterter Anodengleichspannung oder reiner Wechselspannung ist erlaubt, wenn $I_a \leq 50$ mA (max. Impuls-Spitzenleistung ≈ 130 W).

Operation with unfiltered or pure a.c. anode voltage is allowed, provided that $I_a \leq 50$ mA (max. peak pulse power output ≈ 130 W).

Le service à tension anodique alternative brute ou non filtrée est permis, si le courant I_a ne dépasse pas 50 mA (puissance de sortie de crête par impulsions max. ≈ 130 W).



1 Gehäuse / Metal housing / châssis

6 Symmetrie-Asymmetrie-Transformator / Symmetrical-asymmetrical transformer Transformateur symétrique-dissymétrique

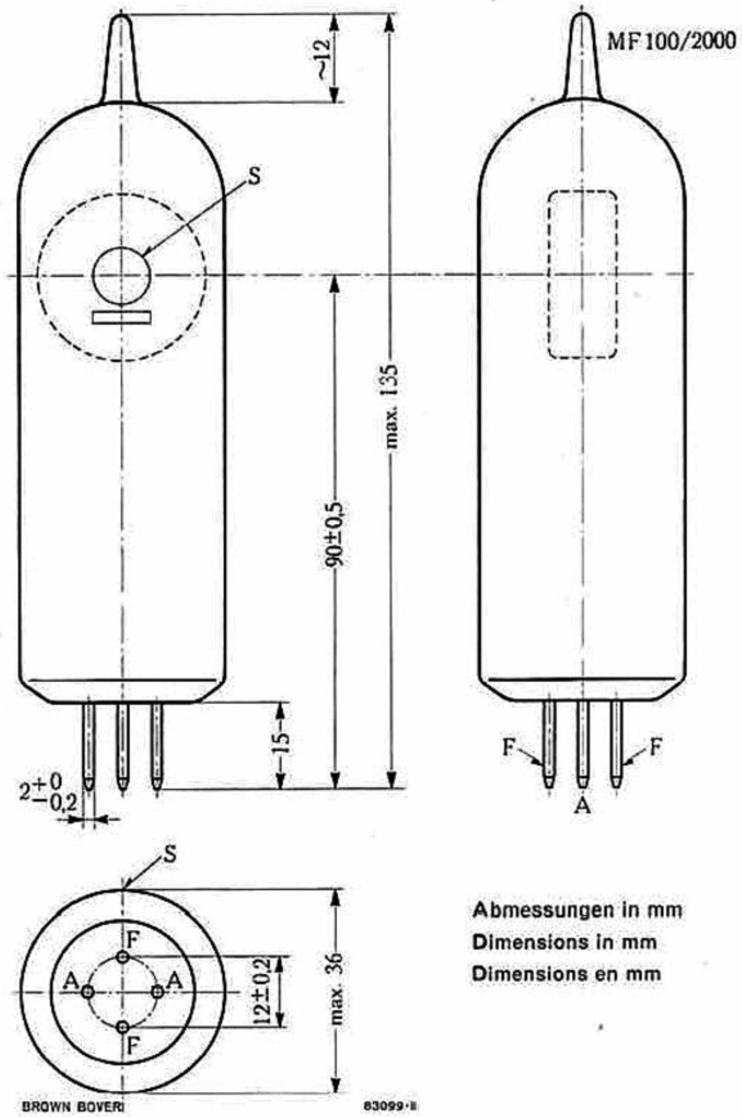
7 Anschluss für Koaxialkabel / Connection for r.f. coaxial output / Raccord pour câble coaxial

8 Heizzuleitungen mit HF-Filtern / Filament lines with r.f. chokes / Circuit de chauffage avec filtres HF

10 Turbatorfassung / Turbator tube socket / Support du turbator

AA Anodenspannungszufuhr über Paralleldrahtsystem / Anode leads (parallel wire system) / Fils d'amenée du courant anodique (ligne de Lecher)

FF Heizzuleitungen / Filament lines / Circuits de chauffage



Abmessungen in mm
Dimensions in mm
Dimensions en mm

Ansicht von unten / Bottom view / Vue d'en bas

S = Signet / stamp / sceau

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

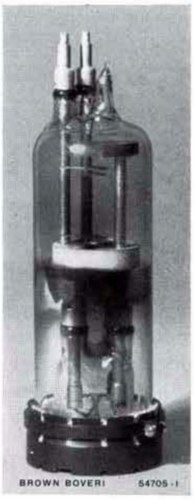


Fig. 1. — Transator for decimetre wave lengths.

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 ray[1].

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.

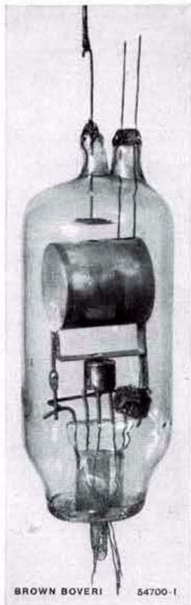


Fig. 3. — Transator with cylindrical resonator.

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

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 concentrical 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

[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 $0 \cdot 1$ 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 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. 4 [1] belongs to a generator designed according to another constructive principle. The emission of electrons takes place in the axis of the 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 aglomorations of electrons then deliver up successively their energy, originating from the electric constant field, to the alternating field of the cavity resonator. The 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.

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

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 $10 \cdot 2$ cm, measured by means of an adjustable cavity resonator, with an absolute precision of less than $0 \cdot 1$ 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-focussed 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.)*

[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.