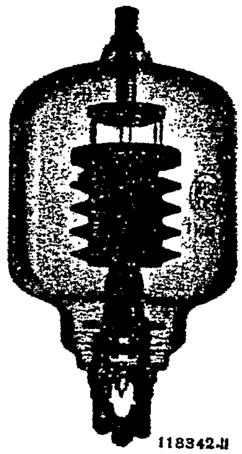
T 1000-1

Radiation Cooled Triode



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The T 1000-1 is a radiation-cooled triode equipped with a directly heated thoriated tungsten cathode and with ruggedly constructed graphite anode of large surface. It is used first of all in industriel applications such as in r.f. generators as oscillator. Maximum power output of 3 kW may be obtained at a frequency of 60 Mc/s. A special feature of this tube is its ability for pulse operation being of interest for plastic welding generators. In pulse operation the tube can deliver up to 4.4 kW r.f. pulse-power without requiring a spacial cooling system. The tube can work, however, also as r.f. or a.f. power amplifier in communication service.

General data:

Cathode thoriated tungsten, directly heated			
Filament voltage		8.5	V +5% -10%
Filament current	appr.	26	A
Cold cathode resistance	appr.	0.0415	Ω
Mutual conductance (2 kV/500 mA)	appr.	8.5	mA/V
Amplification factor	appr.	20	
Interelectric capacitances: Grid to anode . .		11	pF
Grid to cathode .		15	pF
Anode to cathode .		0.45	pF

Mechanical data:

Tube cooling		natural, radiation	
Temperature of glass bulb	max.	300	°C
Max. diameter		141	mm
Overall length		265	mm
Weight net		0.9	kg
Weight gross	appr.	3.6	kg
Base		special, 4 pins	

MAXIMUM RATINGS

D.C. anode voltag	6	kV
D.C. grid voltage	-1000	V
Peak cathode current	6	A
Filament starting current	50	A
Anode dissipation	1000	W
Grid dissipation	75	W
Frequency	60	Mc/s

TYPICAL OPERATING CONDITIONS

Class B, A.F. Power Amplifier and Modulator

Maximum Ratings:

D.C. anode voltage	5000	V
Signal D.C. anode current . .	950	mA
Anode input power with signal	3600	W
Anode dissipation	1000	W

Typical values for 2 tubes in push-pull

D.C. anode voltage	5000	4200	3300	2500	V
D.C. grid voltage . . . . . . approx.	-250	-210	-165	-125	V
Peak a.c. grid voltage (G_1-G_1)	1040	985	960	915	V
Signal d.c. anode current max.	1420	1500	1700	1800	mA
Zero signal d.c. anode current	200	200	200	200	mA
D.C. grid current . . . . . . approx.	230	260	335	385	mA
Driving power . . . . approx.	110	120	145	160	W
Load resistance (anode to anode)	8.8	6.9	4.7	3.2	k Ω
Power output	5240	4600	4000	3100	W

Class B, Modulated R.F. Amplifier

Maximum Ratings:

D.C. anode voltage	5000	V
Anode input power	1500	W
Anode dissipation	1000	W

Typical operating carrier conditions for use with a max. modulated factor of 1.0:

	Grounded cathode			Grounded grid			
D.C. anode voltage	5000	4000	3000	5000	4000	3000	V
D.C. grid voltage . . . . . . approx.	-250	-200	-150	-250	-200	-150	V
Peak a.c. grid voltage	280	270	260	280	270	260	V
D.C. anode current	300	370	420	300	370	420	mA
D.C. grid current . . . . . . approx.	100	160	192	100	160	192	mA
* Driving power . . . . approx.	22	41	54	280	365	395	W
Power output	560	540	455	630**	620**	535**	W
Frequency	60	60	60	60	60	60	Mc/s

Class C, R.F. Power Amplifier, Anode modulated

Maximum Ratings:

D.C. anode voltage	4200	V
D.C. grid voltage	-500	V
D.C. anode current	600	mA
D.C. grid current	225	mA
Anode input power	2500	W
Anode dissipation (carrier condition)	650	W

* Peak value for modulation factor of 1.0
** driving power included

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Typical operating carrier conditions for use with a max. modulated factor of 1.0:

	Grounded cathode			Grounded grid			
D.C. anode voltage . . .	4200	3300	2500	4200	3300	4200	V
D.C. grid voltage. . . .	-425	-380	-340	-425	-380	-340	V
Peak R.F. control grid voltage	705	660	620	705	660	620	V
D.C. anode current . . .	550	550	550	550	550	550	mA
D.C. grid current . . .appr.	105	110	115	105	110	115	mA
R.F. driving power . . .appr.	26	27	28	413	390	370	W
Power output	1890	1450	1060	2360**	1880**	1460**	W
Frequency	≦ 60	60	60	60	60	60	Mc/s

Class C, R.F. Power Amplifier unmodulated, or with frequency modulation

Maximum Ratings:

D.C. anode voltage . . .	5000	V
D.C. grid voltage . . .	-1000	V
D.C. anode current . . .	1000	mA
D.C. grid current . . .	200	mA
Anode input power . . .	4500	W
Anode dissipation . . .	1000	W

Typical operation (at full load)

	Grounded cathode				Grounded grid				
D.C. anode current . . .	5000	4000	3000	5000	5000	4000	3000	5000	V
D.C. grid voltage . . .	-535	-495	-450	-250	-535	-495	-450	-250	V
Peak a.c. control grid voltage	900	875	835	505	900	875	835	505	V
D.C. anode current . . .	800	900	900	650	800	900	900	650	mA
D.C. grid current . . .appr.	150	150	160	100	150	150	160	100	mA
R.F. driving power . . .appr.	130	125	125	50	765	780	790	300	W
Power output	3240	2660	1980	2400	4080**	3310**	2810**	2800**	W
Frequency	≦60	60	60	60	60	60	60	60	Mc/s
½ angle of anode current flow	65	65	65	90	65	65	65	90	°

** driving power included

Class C, R.F. Oscillator with filtered d.c. anode voltage

Maximum ratings: (as above)

Typical operation: (at full load)

D.C. anode voltage . . .	5000	4000	3000	V
Peak a.c. grid voltage .	1025	975	925	V
D.C. anode current . . .	800	800	800	mA
D.C. grid current . . .appr.	135	140	145	mA
Grid resistor . . . . .appr.	4800	4300	3900	Ω
Grid dissipation	45	46	47	W
Power input	4000	3200	2400	W
Power output	3100	2400	1670	W
Frequency	≦ 60	60	60	Mc/s

These values are also valid for Class C R.F. Oscillator for industrial use with unfiltered anode voltage from three-phase half-wave rectifier.

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Class C, R.F. Oscillator for Industrial Use
with anode voltage from single-phase full-wave rectifier without filter

Maximum Ratings:

**	Anode voltage	5000	V
	D.C. grid voltage	-800	V
**	Anode current	750	mA
**	Grid current	200	mA
	Power input	4000	W
	Anode dissipation	1000	W

Typical Operation: (at full load)

	Transformer voltage (RMS)	2x5000	2x4000	2x3000	V
**	Anode voltage	4500	3600	2700	V
**	Anode current	650	650	650	mA
**	Grid current . . . appr.	100	100	105	mA
	Grid resistor . . . appr.	5500	4900	4350	Ω
	Power input	3600	2900	2150	W
	Anode dissipation	930	840	700	W
	Grid dissipation	32	33	34	W
	Power output	2800	2200	1520	W
	Frequency	≦ 60	60	60	Mc/s

Class C, R.F. Oscillator for Industrial Use
Self rectifiying, with a.c. anode voltage supply

Maximum Ratings:

	Transformer voltage (RMS)	5700	VV
	D.C. grid voltage	-800	V
**	Anode current	400	mA
**	Grid current	120	mA
	Power input	2500	W
	Anode dissipation	1000	W

Typical Operation (at full load)

	Transformer voltage (RMS)	5700	4600	3400	V
**	Anode current	370	370	370	mA
**	Grid current . . . appr.	60	62	65	mA
	Grid resistor . . . appr.	5100	4600	4000	Ω
	Power input	2350	1890	1400	W
	Anode dissipation	565	500	430	W
	Grid dissipation	22	23	24	W
	Power output	1850	1450	1000	W
	Frequency	≦ 60	60	60	Mc/s

** Arithmet. mean value

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Class C, R.F. Oscillator, Pulse Operation
with filtered d.c. anode voltage or
from three-phase rectifier, unfiltered

Maximum Ratings:

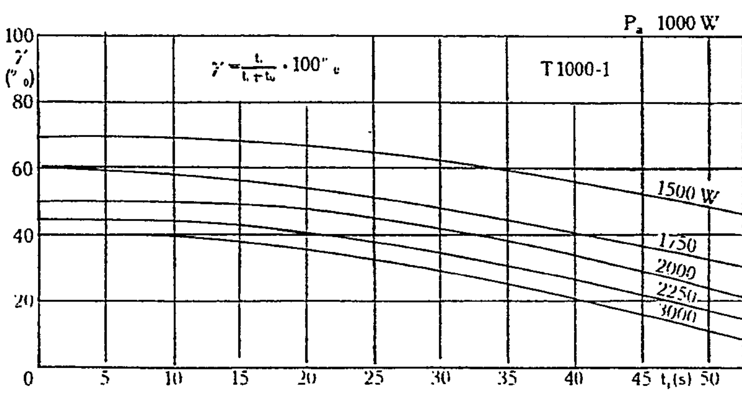
D.C. anode voltage	5000	V
Grid bias	-450	V
D.C. anode current	1500	mA
D.C. grid current	300	mA
Anode input power	7000	W
Anode dissipation	3000	W

Typical operating conditions (at full load)

D.C. anode voltage	5000	4000	3000	V
Peak a.c. grid voltage	400	400	400	V
D.C. anode current	1350	1400	1400	mA
D.C. grid current	175	170	175	mA
Grid resistance	1400	1200	850	Ω
Input power	6750	5600	5100	W
Anode dissipation	2610	2450	2500	W
Grid dissipation	60	60	60	W
Power output	4400	3400	2850	W
Frequency ≦	60	60	60	Mc/s

These data may be used in connection with the curves $\gamma = f\ (t_i)$

Pulse operation $\gamma = f\ (t_i)$



OPERATING INSTRUCTIONS

Installation: The triode T 1000-1 should be mounted in a vertical position with the anode upwards. It may be mounted with the base up, but only if an appropriate fixing for the tube is provided. When the tube is inserted in its socket (type NBT 400169 Pl), it should be done in such a way as to avoid the danger of bulb cracks. The anode is connected over a spring clip (Brown Boveri NBT 400100 Pl) to a flexible lead. It is important that all the tube pins and all connections make good electrical contact to avoid overheating of the grid connections by r.f. currents. The tube must be protected against severe vibrations and shocks. Care must be taken that no lead is laid in vicinity of the glass bulb.

Cooling: Up to anode dissipation (P_a) of 400 W an appropriate natural cooling is sufficient. With higher anode dissipations additional cooling is recommended. This should be provided by blowing a small air stream onto the anode cap. A second weak air flow directed from below upwards onto the glass bulb should be provided to keep the temperatures within the limits indicated below:

anode cap with anode connector put on . . .	220 °C *
glass bulb	300 °C *
filament and grid terminals	160 °C *

* In case of $P_a >$ 400 W, bulb, foot and anode cap must be cooled by an air stream. The necessary air flow from below upwards should be about 1.2 m^3/min.

Only allowed if the tube is sufficiently shielded against electrical fields and the free space around the tube is minimum 7 cm. The temperatures should be measured by means of a thermocouple or a thermistor sensor.

Heating: The filament voltage, as measured directly at the filament pins with a precision voltmeter, should be 8.5 volts. In view of the main application of the tube being in industrial service a wider range for filament voltage fluctuations of +5 % and -10 % is allowable. However, further decrease in filament voltage would become very dangerous and could result in a rapid loss of cathode emission, whilst overvoltages decrease tube life, as well as too frequent switching on and off.

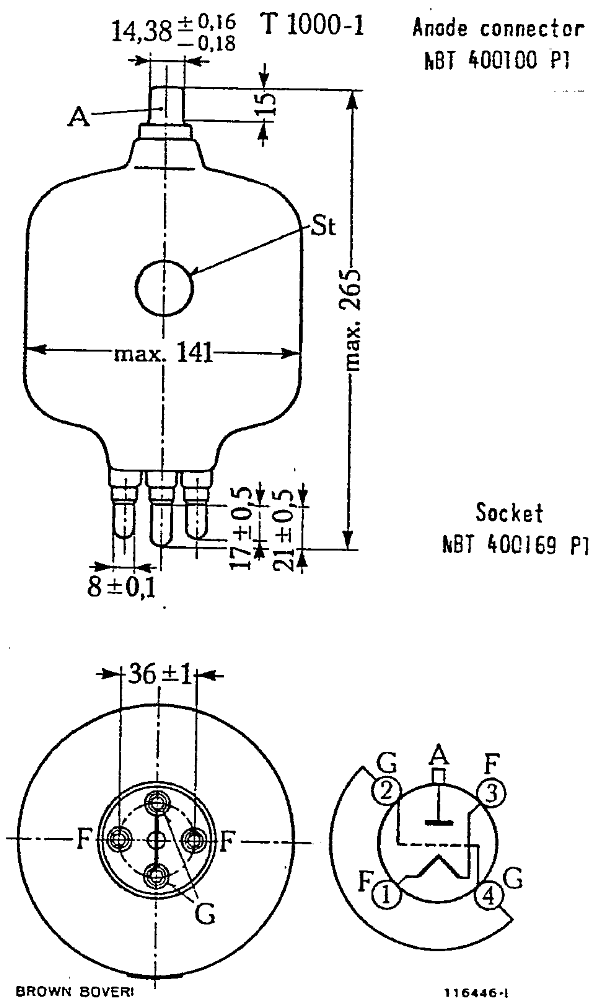
In cases where it is unavoidable to switch the apparatus often on and off, a filament starter or at least a series resistor or better a high reactance filament transformer should be used to limit the high starting current through the filament when the circuit is first closed. It is usually economically advantageous to provide good regulation of the filament voltage, especially at full load.

During standby periods up to 15 minutes it is recommended not to switch off the filament voltage but to heat the tubes with full or reduced voltage of 6 V during such periods.

<u>Anode:</u> The anode voltage can be switched on together with filament voltage. When adjusting and tuning the equipment, it is recommended that the anode voltage be reduced in order to prevent damage to the tube. It is also advisable to use a protective resistance of about 25 ohms in series with the anode lead and to protect the tube by an overcurrent relay. Overheating of the T 1000-1 by severe overload may decrease the filament emission. Its activity can sometimes be restored by operating the filament at rated voltage for ten minutes or more with no voltage on the grid or anode.

<u>Grid:</u> The tube is equipped with 2 grid pins which gives advantages in high frequency operation. They are connected in parallel by a metal strap in the middle of which the grid connections has to be fixed.

If the load resistance is subject to great variations, it will be necessary to ensure that under no load conditions the max. grid dissipation is <u>not</u> exceeded.



INDUSTRIAL OPERATION

<u>Class C, oscillator:</u> In r.f. generators the bias is best produced by means of a grid resistor as in this way the bias varies within certain limits with the load. It may be useful to employ non-linear elements in the grid circuit, such as tungsten filament lamps or cold conductor resistors. The mean grid current I_g and the a.c. grid voltage V_{gp} should be adjusted to half their maximal values since in those equipments unavoidable wide load variations may occur. This prevents an increase of the grid current and grid dissipation P_g above the rated limits if the load should suddenly drop to zero.

The values given in the data for I_g refer to full load and represent the mean value over a longer period. At no load I_g will then become somewhat greater. I_g at no load is limited by the permissible maximum grid dissipation P_g.

The higher the anode voltage of the tube, the better will be the efficiency in all modes of operation and the smaller can be the currents at a given output, thus prolonging tube life. The adjustment to the output circuit is also easier to obtain at high anode voltage.

The circuit losses in the output and losses due to possible incorrect matching have to be deducted from the rated power output (calculated in the data in respect to the anode) when the power available at the load is desired.

If the tube is supplied from a three-phase half-wave rectifier having a reduced ripple of 0.177 V_m (in the d.c. output voltage V_m), the same data can be applied as in case of filtered d.c. voltage from a single-phase full-wave rectifier. However, in the case of the three-phase rectifier no filtering need be provided.

Parasitic oscillations can be minimized by connecting non-inductive resistors of about 30 ohms in the grid circuit as close as possible to the grid.

Pulse operation: The following classifications can be made: Operation with long pulses and operation with short pulses. Operation with long pulses (in the literatur also defined as "intermittent pulse operation") being the most important one. It is used in industry, particularly with HF generators for plastic welding. It is characterized by:

- the duration of the pulse (duration of service or pulse time) t_i: it depends on the anode dissipation P_a; in practice it is made between 1 and 50 sec for which the sets of pulse curves are designed.

- the relative duration of service (duty cycle) γ :

  $$\gamma \geqq \frac{t_i}{t_i + t_o}$$

  it is chosen according to the requirements of service (e.g. 0.5)

- the off-period (pause) t_o:
  defined as the time between two successive pulses.

The relations between t_i, t_o and P_a can be taken from the curves $\gamma = f(t_i)$ (see page 5) specially designed for pulse operation. As the electrodes of these tubes are allowed to cool in the off-periods the maximum values of I_a, I_g, P_{ia} as given for typical operation can be increased as indicated in the data for pulse operation. However, exceeding V_a and P_g is not permissible. To avoid overloading the grid it is advisable to choose higher θ_a ($\approx$80-90°) and to take care that the tube is sufficiently cooled so that the limiting values of the temperatures of the tube are in no case exceeded.

Example: Intermittent pulse operation of the industrial triode type T 1000-1 with t_i between 1-50 s. According to the data for long pulse operation the following max. values are permitted:

$$V_{a\,max} = 5\text{ kV } (5),\quad I_{a\,max} = 1.5\text{ A } (1),\quad I_{g\,max} = 0.3\text{ A } (0.25),$$
$$P_{a\,max} = 3\text{ kW } (1),\quad P_{g\,max} = 90\text{ W } (75).$$

(The values in brackets are those for normal continuous operation.)

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It is assumed that θ_a = 85°, V_a = 5 kV, I_a = 1.3 A, f = 27.12 Mc/s.
The calculation may be carried out in the same way as given in the Electron Tube Handbook § 5.2.2.4. for class B amplifier:

a) $I_{ap} \approx \pi \; I_a = 4$ A, $\eta \approx$ 0.7; $V_{ap} = \eta \dfrac{V_a}{0.785} = 4.4$ kV

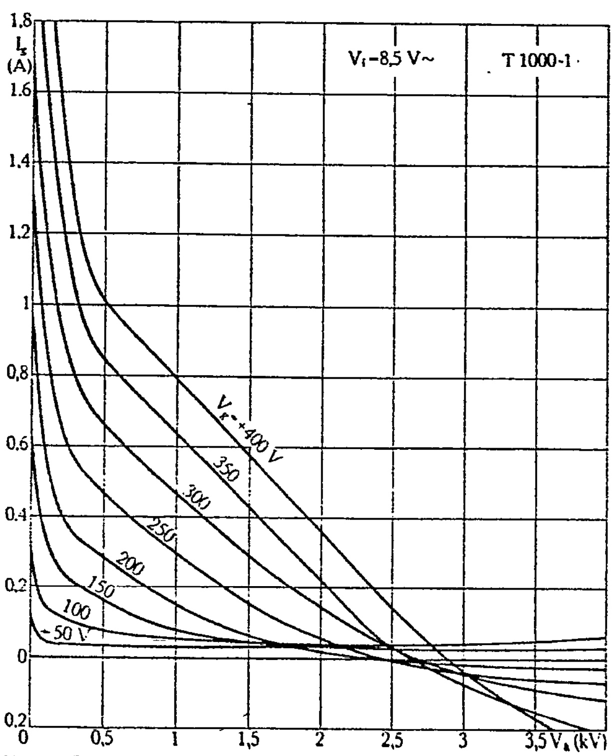
$P_o = 1/4 \; V_{ap} \cdot I_{ap} = 4.4$ kW, $P_{ia} = 6.75$ W

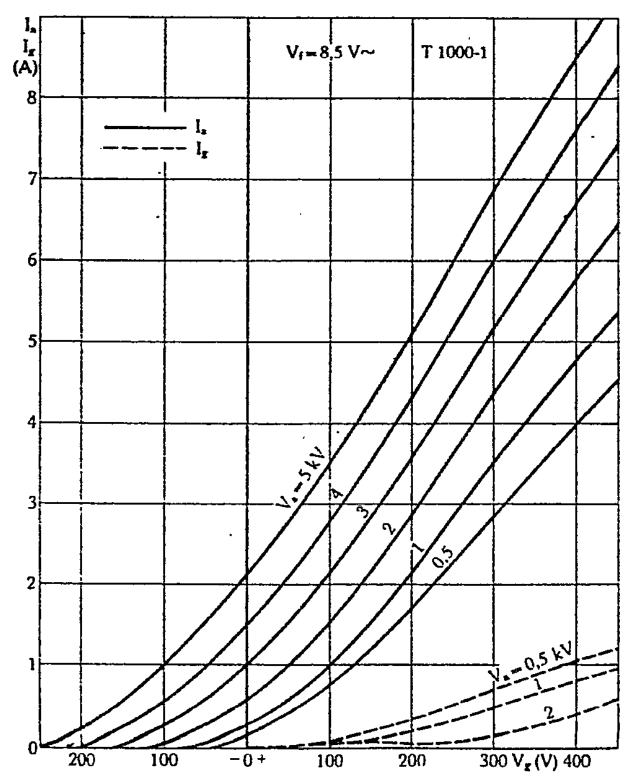
b) If a duty cycle τ = 0.3 (= 30%) is desired for instance, from the curve $\tau = f(t_i)$ for $P_{a\,max}$ = 3 kW (according to the above calculation): a duration of service t_i = 30 s could be allowed with a following pause:

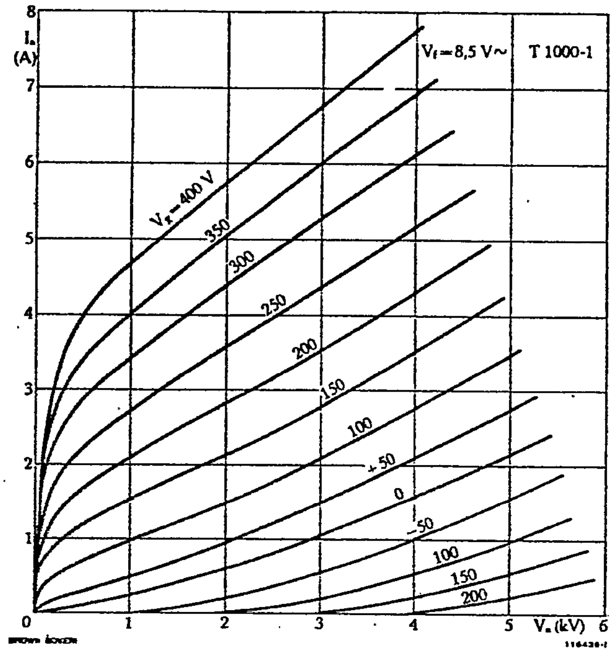
$$t_o \geqq \frac{t_i\,(1-\tau)}{\tau} \geqq 30 \cdot \left(\frac{1-0.3}{0.3}\right) \geqq 70 \text{ s.}$$

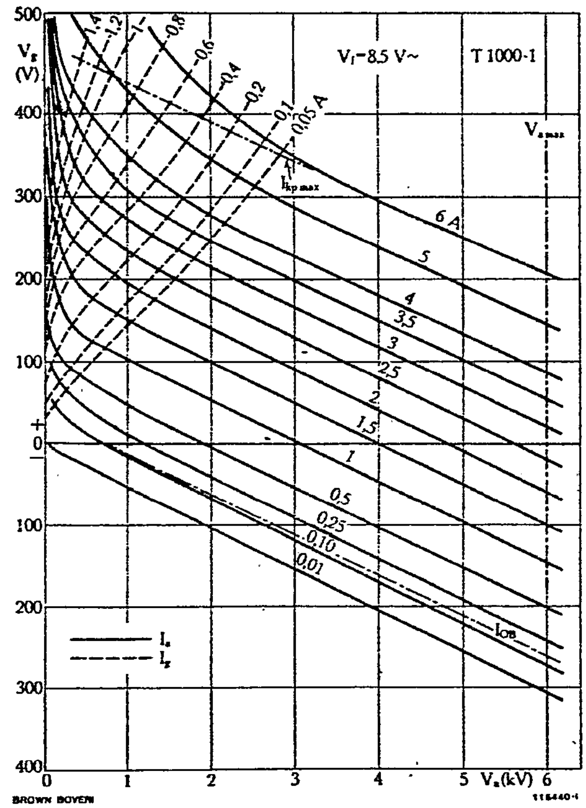
c) For operation, for instance, with t_i = 1 s corresponding to τ = 0.25 and t_o = 3 s it follows from the curves that these values are permissible as they lie below the corresponding P_a = 5 kW curve.

Maximum ratings listed for a particular type give the limiting values which cannot be exceeded without seriously effecting the tube life.









V_a = anode voltage

I_a = anode current

V_g = grid voltage

I_g = grid current

V_f = filament voltage