FQW 15-1, FQS 15-1

Transmitting Tetrode for Water or Vapour Cooling

The transmitting tetrode capable of generating a useful power output (class C unmodulated) of up to 55 kW is available for 2 cooling systems:

1. FQW 15-1 for forced water cooling; anode dissipation 17 kW

2. FQS 15-1 for vapour cooling; anode dissipation 30 kW

The tube is designed for communication, particularly for use in SSB-single-sideband transmitters, at frequencies up to 60 Mc/s.

The high power sensitivity of the tetrode allows it to be used in r.f. services with very little driving power. The tube can also be used for industrial applications.

General Electrical Data:

Cathode thoriated tungsten, directly heated

Filament voltage		7.5	V ± 5%
Filament current	appr.	155	A
Filament cold resistance		6×10^{-3}	Ω
Mutual conductance (2,5 A/6 kV, V_{g2} = 800 V)	appr.	35	mA/V
Amplification factor (G_2–G_1)	appr.	6	
Capacities:			
Cathode to grid 1		50	pF
Grid 1 to grid 2		65	pF
Cathode to grid 2		25	pF
Anode to grid 1		0,85	pF *
Cathode to anode		0,09	pF *
Grid 2 to anode		25	pF

* measured with a screen-plate 40 x 40 cm in the screen-grid plane

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Mechanical Data:

		FQW 15-1	FQS 15-1	
Tube cooling		Water	Vapour	
Temperature of glass bulb	max.	250	250	°C
Weight net		4.1	[illegible]	kg
Weight gross	appr.	10	[illegible]	kg
Weight of the water cooling jacket W 15b		10	-	kg

Maximum Ratings:

D.C. anode voltage (V_a)	15	kV
D.C. voltage grid 1 (V_{g1})	-1	kV
D.C. voltage grid 2 (V_{g2})	2.2	kV
Anode dissipation (P_a)	17 (20)	kW
Dissipation of grid 1 (P_{g1})	250	W
Dissipation of grid 2 (P_{g2})	800	W
Peak cathode current (I_{kp})	35	A
Frequency (f)	60	MHz

Values in brackets valid for FQS 15-1

TYPICAL OPERATING CONDITIONS

Class B, A.F. Power Amplifier and Modulator

Maximum Ratings:

D.C. anode voltage	16	kV
D.C. signal screen voltage	1600	V
Signal D.C. anode current	5	A
Anode input power	[illegible]	kW
Anode dissipation FQW 15-1 (FQS 15-1)	17 (30)	kW
Screen grid dissipation	800	W

Typical values for 2 tubes in push-pull:

D.C. anode voltage		15	12.5	10	kV
D.C. screen voltage		800	800	800	V
D.C. grid 1 voltage	appr.	-200	-195	-180	V
Peak a.c. grid 1 voltages (G.-G.)		760	850	840	V
Zero signal d.c. anode current		1	1	1	A
Signal d.c. anode current max.		7.2	8.4	9	A
D.C. screen current	appr.	0.5	0.7	0.9	A

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Kl. B push-pull

D.C. grid 1 current . . . . .appr.	0,3	0,4	0,5	A
Driving power . . . . .appr.	90	150	180	W
Load resistence (anode to anode). .	5	3.5	2.6	kΩ
Power output	80	78	66	kW

Class B, R.F. Linear Power Amplifier Single Side Band Suppressed Carrier

Maximum Ratings:

D.C. anode voltage	15	kV
D.C. screen voltage	1600	V
D.C. control grid voltage	-600	V
D.C. signal anode current	3.5	A **
Power input	50	kW
Anode dissipation	17	kW
Screen dissipation	800	W
Grid resistance (tube not conducting)	15	kΩ

Typical Operation Ratings:

D.C. anode voltage	15	12,5	10	kV
D.C. screen voltage	1600	1600	1600	V
D.C. control grid voltage . . . . . .appr.	-345	-335	-325	V
Peak A.C. control grid voltage . .	340	330	320	V
Max. Signal D.C. anode current . .	3	3	3	A
Zero- Signal d.c. anode current . .	0.5	0.5	0.5	A
Max. Signal D.C. screen current . .appr.	0.2	0.2	0.2	A
Max. Signal D.C. control grid current appr.	0	0	0	A
Max. signal dricing power	0	0	0	W
Max. signal useful power output . .	32	26	20	kW
Frequency	30	30	30	MHz

* Adjust stated Zero-Signal anode current

** modulated with a single sine wave tone (100 % modulated)

Class C, R.F. Power Amplifier, Anode- and Screen-Modulated

Maximum Ratings:

D.C. anode voltage	12,5		kV
D.C. screen voltage	800		V
Peak screen grid voltage	600		V
D.C. grid 1 voltage	-600		V
D.C. anode current	5,5		A
D.C. control grid current	0,5		A
Anode input power	60		kW
Anode dissipation (carrier condition) FQW 15-1 (FQS 15-1)	12	(20)	kW
Grid resistance (tube not conducting) .	15		kΩ

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

D.C. anode voltage	12,5	10	8	kV
D.C. screen voltage	800	800	800	V
D.C. grid 1 voltage	-275	-270	-260	V
Peak R.F. control grid voltage	585	590	580	V
D.C. anode current	4,7	5	5	A
D.C. screen grid current . . . . .appr.	0,7	0,6	0,7	A
D.C. grid 1 current . . . . .appr.	0,4	0,4	0,4	A
R.F. driving power . . . . .appr.	195	200	205	W
Power output	45	36	28	kW
Frequency	30	30	30	MHz
[illegible]	[illegible]	72	70	

The screen grid voltage should be taken from the modulated anode voltage through the screen grid resistance (Potentiometer).

Class C, R.F. Power Amplifier unmodulated or FM

(with filtered d.c. anode voltage)

Maximum Ratings:

D.C. anode voltage	15		kV
D.C. screen voltage	1,2		kV
D.C. grid 1 voltage	-1		kV
D.C. anode current	5,5		A
D.C. grid 1 current	0,5		A
Anode input power	75		kW
Anode dissipation FQW 15-1 (FQS 15-1)	17	(30)	kW
Screen grid dissipation	300		W
Grid resistance (tube not conducting) .	15		kΩ

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Typical operation (at full load)

D.C. anode current voltage	15	12,5	10	kV
D.C. screen voltage	800	800	800	V
D.C. grid 1 voltage	-290	-280	-270	V
Peak a.c. control grid voltage . .	600	590	595	V
D.C. anode current	4,7	5	5,2	A
D.C. screen current	0,6	0,6	0,6	A
D.C. grid 1 current	0,4	0,4	0,4	A
R.F. driving power	195	200	225	W
Power output	55	47	37	kW
Frequency.	30	30	30	Mc/s

Data for higher frequencies than 30 MHz on request.

"The Typical Operating Conditions" listed here are only examples for average operating conditions. If a tube has to be operated under conditions different from those listed, even with higher values of certain parameters, the relevant operating data will be given on request.

OPERATING INSTRUCTIONS

Mounting: The transmitting tetrode FQW 15-1/FQS 15-1 should be mounted vertically the terminals directed upwards. The deviation from the vertical should not be more than 2 mm/s. Provision should be made to prevent subjecting the tube to appreciable vibration produced by the air duct system, machines or other sources. The 2 heater pins FF as well as the grid 1 pins (G_1 G_1) of the tube should be provided with connection clips with cooling vanes such as Brown Boveri HG 450 218 R1 (Fig.1) to which a flexible stranded lead or a flexible metal strip has to be carefully connected. The screws should be retightened after some time. These connections, as well as the similar ones to the concentric grid terminal, should be of ample cross-section to prevent excessive heat production at high frequencies. All connections to grid and cathode must not be oxidised, should be clean and make good electrical contact. Previous to making the connections, these terminals should be polished, i.e. with a soft cloth (but never with emery-paper).

No mechanical strains should be imposed on the seals of the pins and the gridring. The installation of all wires and connections must be made so that they are flexible and will not be close to or touch, the bulb.

1. The Water-cooling System of the tube type FQW 15-1

<u>Mounting:</u> The FQW 15-1 must be operated only with the water cooling jacket type K 15b (Fig. 1) in which the tube should be mounted with its anode downwards.

The cooler should be held in a suitable insulated anti-vibration mounting.

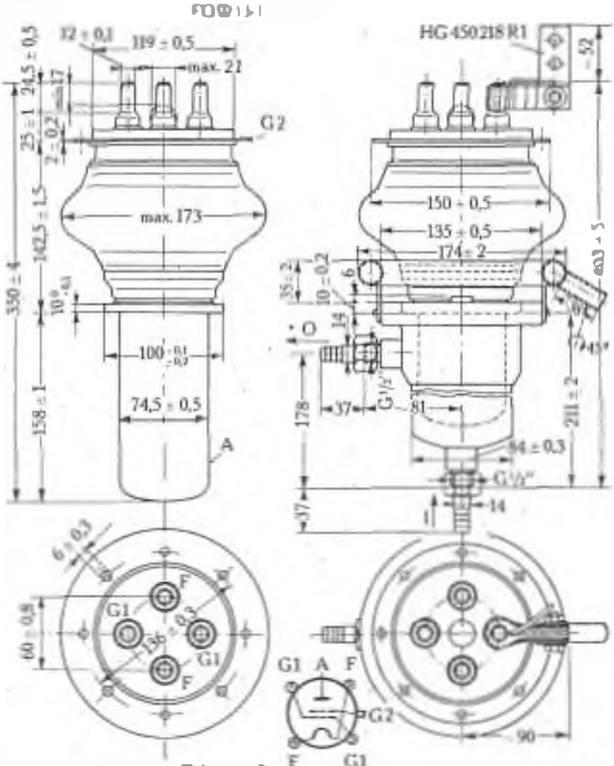


Fig. 1

I - Water entrance

O - Water outlet

The lower tubular projection on the jacket serves as the cooling-water inlet and the upper lateral one as the outlet. By appropriate shaping of the cooler, the cooling-water is made to circulate from the bottom to the top of the anode, thus keeping the latter uniformly cool. To prevent "scaling" of the anode, <u>distilled water</u> should be used whenever possible. Scaling hinders the cooling of the anode and can lead to the destruction of the tube as a result of overheating. It builds up a hard yellow spotted layer on the otherwise copper-red anode. In many cases the scale can be removed with a 10 % hydrochloric acid solution or with trisodium phosphate. The anode should afterwards be rinsed with distilled water. Special care should be taken with older tubes as their filaments may have become brittle. Cooling-water with more than 8 degrees hardness should never be used directly. The best method is, however, to use only distilled or deionized water. Calcareous water should be cleaned by incorporating a water cleaner.

The cooling jacket must be insulated, both the inlet and the outlet by a feed pipe system which carries the water through tuning chokes of insulating material so that the loss current is kept to a minimum. No electric field should influence this choke. For more detailed information see Brown Boveri Electron Tube Handbook, chapter 2.

The quantity of cooling water necessary is dictated by the power loss of the tube (anode + grid + heating). The quantity of cooling water required, Q, can be safely taken as about 12 litres/min. The flow must be great enough in all cases to ensure that the temperature of the water at the outlet remains below 60°C (140°F). The cooling water quantity required is lowered, the smaller the value of the anode dissipation and the lower the inlet temperature of the water. This latter must in any case never exceed 30°C (70°F). The speed of the cooling water flow is also important. The water cooling system should be interlocked with the power supply, so that neither filament nor anode voltage can be applied to the tube except while it is being cooled. The safety device should also shut off the power supply if during operation the cooling becomes insufficient. In as far as possible, each tube should be provided with the following devices·

1. A thermal fuse which upon actuation can also operate the aforesaid safety device.

2. (Temperature-sensitive resistance devices for the remote indication of temperatures.)

3. A relay-operated flow-meter (differential manometer according to the Venturi system),

Additional Cooling of the header and the grid ring is necessary. This is obtained:

(a) by blowing a stream of cooling air (of about Q = 0.2 m^3/min) through both inlets to the cooling-air ring bolted to the cooling jacket. The air leaves the ring through an annular series of small inner openings and the resultant air blast effectively cools the glass bulb and the grid ring.

(b) by means of a stream of air which is blown at a rate of about Q = 0.3 m^3/min through a tubing of about 20 mm Ø onto the tube head in a distance of 80 mm.

The following maximum allowable temperatures should never be exceeded:

Glass-to metal seals:
of the gridring and the anode . . . . 150°C
Glass bulb . . . . 250°C
Cooling water inlet . . . . 60°C

The temperatures should be measured by means of a thermocouple and galvanometer or thermistor sensors.

2. The Vapour Cooling System of the Tube type FQS 15-1

The anode of the tube is fitted with a fin-radiator of special shape (Fig.2), allowing high specific loading of the anode. The tube has to be mounted with its anode down into its Boiler type SG 15a (Fig.3). As the pressure inside the cooling system does not rise materially above the atmospheric pressure, the tube is allowed to sit on the boiler by its own weight without any mechanical fastening. The condensed cooling water enters through the long bottom Pyrex tube (3a in Fig. 4) and dry-steam leaves the boiler above through the short Pyrex tube (3b) of greater diameter .

Cooling of the tube is effected by allowing water to evaporate under the influence of the heat generated at the external anode. The water is in a closed circuit, which normally does not require any pump or rotating mechanism subject to wear. Evaporation-cooling system depends merely upon maintenance of proper distilled-water level (P) and flow of cold water through the water condenser. Ebullition at the special tube anode maintains circulation. The quantity and consumption of the cooling medium is extremely small. The circulation of the water, and thus the dissipation of heat automatically adapts itself to the amount of heat which has to be dissipated. For this reason and on account of the high heat transfer coefficient, a higher Pa max. can be allowed than with other cooling systems. A notable feature is that the evaporation process takes place almost silently and the tube is not subjected to vibration. A great advantage is the ability to utilize the hot water for space heating in the building. Simple safety devices are quite sufficient.

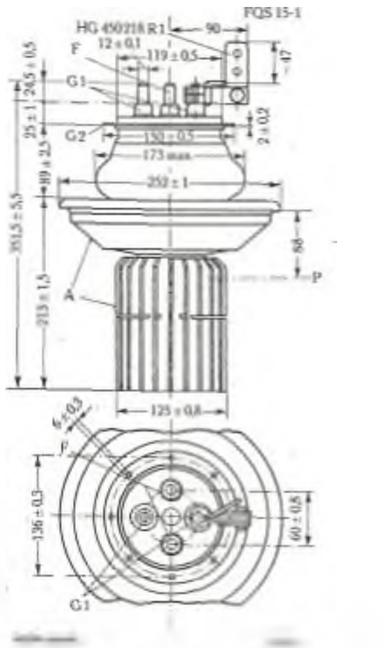
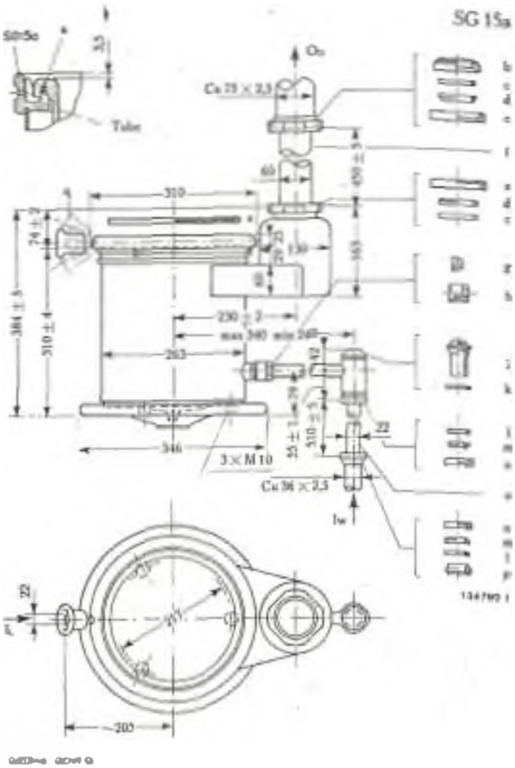


Fig. 2 (FQS 15-1)

P - Water level to be held constant



Legend to SG 15a (Fig. 3):

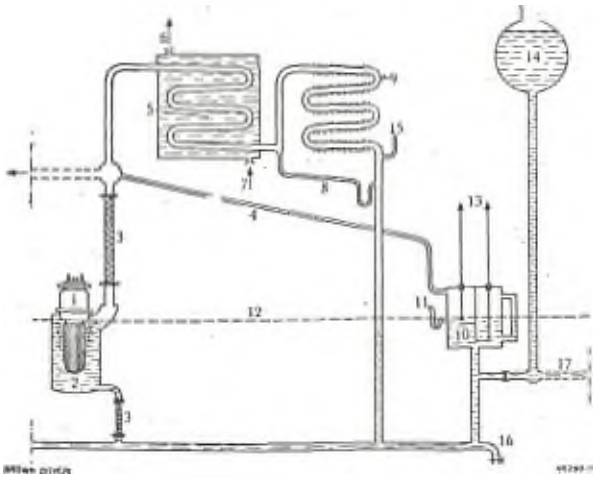
a, c, k, l	gasket
b	threaded ring
d, m	pressure ring
e, n	nut
f, o	insulating glass tubing
g	clamping ring
h	connection nut
i	antielectrolytic connection
p	pressure sleeve
q	air cooling ring
I_w	condensed water inlet
O_D	vapor outlet
I_L	air entrance

Fig. 3 (Boiler SG 15a)

Additional Cooling of the header and the gridring is necessary. This is obtained by blowing a stream of air of about 0.3/min through tubing of 20 mm in diameter on to the tube head. The distance between the tubing and the ring should be about 80 mm. Dirt and moisture should be removed from the cooling air by filtres.

Also the maximum allowable temperatures, as indicated for FQW 15-1, should never be exceeded.

Vapour cooling System:



Legend to Fig. 4:

1 - Brown Boveri vapour-cooled tube type FQS 15-1

2 - Boiler type SG 15a (Fig. 5) or type SGK 15a (Fig. 6)

3 - Insulating glass tubings (at the bottom the long Pyrex tube, of l = 500 mm - water entrance 3b, and Ø = 20 mm, above the short tube Ø = 55 mm - vapour outlet 3a)

4 - Equalizing pipe (inclination 50 mm/m)

5 - Water condenser (heat exchanger)

6 - Secondary hot-water circuit of the heat exchanger, outlet (for space heating)

7 - Inlet

8 - Condensate return pipe (inclin. 50 mm/m)

9 - Additional condenser for cooling by air (where necessary)

10 - Water-level monitoring tank (Fig. 5)

11 - Overflow with siphon

12 - Normal Water level held constant "P" (see Fig. 2), the tube must be covered with water up to the mark "P"

13 - To protection unit (which acts as soon as item "12" changes)

14 - Water reservoir

15 - Air outlet (min. 10 mm Ø)

16 - Water drain cock (min. 15 mm Ø)

17 - Connection for a further system

18 - Check valve remote controlled

The cooling medium is destilled water.

Instead of the classical boiler (SG 15a) a simplified system, especially designed for industrial equipment, can be used, called "Boiler-condenser" (Type SGK 15a). (Fig. 6)

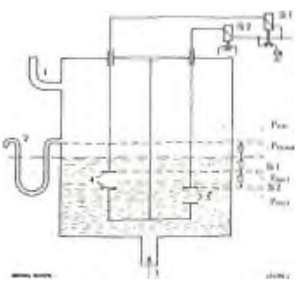


Fig. 5 (Water-level Monitoring Tank)

Mode of Operation of the Water-level Monitoring Tank (Fig. 5):

The water-level marked "P normal" is the level which must be held constant during operation. The level to which water differs from type to type. It is marked by the letter "P" in the dimensional outline of each tube type. If the level has fallen to P/min the electric circuit is interrupted between electrodes 4 and as a result a signal is produced in the protection unit by the contacts S11. Should the level drop down to mark Pmin 2, the current is interrupted between electrodes 5, and contact Si2 of the protection unit immediately disconnects the power supply to the tube. An increase of the water level is only allowed up to mark "P max." The overflow with siphon (2) prevents this mark from being exceeded.

1 = equalizing pipe, 3 = condensed water inlet.

It is important to keep the water level constant.

Boiler with Integral Condenser (Simplified system) SGK 15a

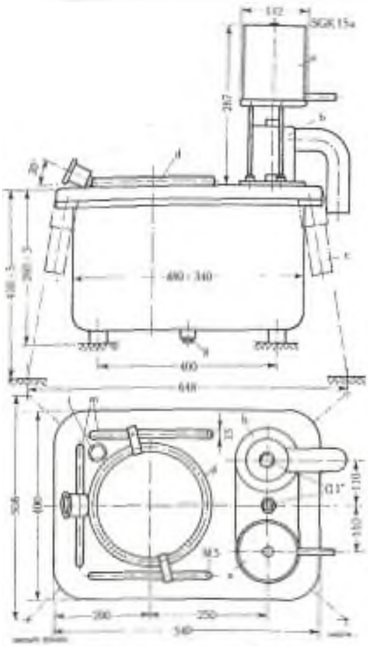


Fig.6

3. General Indications for water-cooled and vapour-cooled tubes

Filament Circuit: The filament is of thoriated tungsten and the filament voltage should by adjusted to the nominal value of 7.5 V ± 5 % at maximum loading. The voltage should be checked by connecting a precision (moving iron magnet) instrument across the filament terminals.

A too high initial filament surge current can harm the tube. It is therefore necessary to provide means to limit this surge by gradual increase of the filament voltage. This may be done, for example, in 2 - 3 steps with a tapped transformer, damping resistors or a high inductance transformer.

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In intermittent operation it is recommended that the filament voltage be left at its nominal during standby periodes of up to 30 minutes, and at the reduced 6 V value during standbys of up to 2 hours. The filament voltage may be switched off during breaks of more than 2 hours. When resuming operation, the aforesaid starting-up instructions should again be observed.

For RF operation, the filament leads should each be shunted with a non-inductive capacitor of 200-1000 pF, so that all the filament wires carry an equal rf load.

The anode voltage should not be applied until 1 minute after the filament has reached its operating temperature. In any case the anode voltage has to be switched-on before the screen grid voltage.

A magnetic over-current relay should be provided to protect the tube against overload, it should disconnect the anode and screen grid voltage within 50 ms if flash-overs should occur. The anode voltage is only allowed to be switched on after a damping period of min. 0.1 s. In no case the full screen-grid voltage should be applied to the tube if the anode voltage is zero or too low to prevent overloading of the screen grid.

A protective resistor of 25 ohms should be connected in the anode circuit of the tube. This resistance will damp peak overloads that could appear under short-circuit conditions during the operating period of the over-current relay. Overloads with subsequent damage to the tube, which could arise during careless tuning or switching-on of the transmitter circuits, can be prevented by reducing the anode voltage to half its nominal value. This may be effected, for example, by inserting a normally out-of-circuit additional anode resistor.

A new transmitting tube should initially be heated for 20 minutes at rated filament voltage before applying any other voltage. At the end of this period, the anode voltage can be applied and gradually raised to its nominal value.

Grid Circuit: The grid terminal of the FQW 15-1/FQS 15-1 is designed as a broad circular flange, which is favourable for operating conditions prevailing at high radio frequencies and in grounded grid curcuits. 8 holes are provided on the circumference of the grid flange to which the connecting flexible metal strips should be screwed on. The connections must ensure a good contact and must not exert any mechanical strain on the flange and its glass-to-metal seals. In r.f. operation, all of the 8 holes of the grid flange should be connected so that the r.f. currents are evenly distributed over the whole area of the gridring. No soldering is permitted at the grid terminal. At r.f. operation the grid connector HG 302139 R2 can be used.

Care should be taken, that at no load (e.g. in industrial service) the screen-grid dissipation is not exceeded. This can easily be obtained by limiting the screen-grid current to that value which corresponds to the rated screen-grid dissipation. Also the increased temperature has to be taken into consideration which arises from the heating up by the r.f. current at high frequencies.

Operation

Class B, AB Amplifier and Modulator: The negative grid voltage may be either produced by a battery or by a rectifier of good voltage stability; potentiometers to adjust the voltage for each tube separately should be provided. No high resistance grid voltage sources should be employed.

Class C, Anode Modulated RF Amplifier: The modulating voltage in class C amplifiers is imposed on the output and applied to the anode in series to the DC anode voltage.

The most recommended means is a combination of grid resistor and rectifier, since it offers best protection against overloads and also reduces distortion.

Class B, Single-Sideband Amplifier (SSB):

With SSB operation the r.f. carrier which plays no part in the communication of information, is omitted and one of the two sidebands is filtered out. The main advantages of this kind of modulation are:

The bandwidth is reduced to 50 % of that for AM, reproduction is not affected by selective fading, distortion and self-whistle are reduced. Another favourable effect is that only half as much noise energy is absorbed from the uniform noise. Moreover considerable saving in total power input, weight dimensions and cost of the transmitter is effected. Of considerable importance is the degree of linearity of the stages. This problem can be solved by using tubes of special design (such as FQW 15-1 / FQS 15-1) operated in class AB_2.

The operating conditions are given for operation "without" or "with" signal whereby an uniform sine-wave tone of 1000 Hz is used; see also Brown Boveri Electron Tube Handbook 1967 page 2-76/2-77.

Class C, Unmodulated Amplifier: The negative grid voltage may be produced in similar ways as mentioned for class C anode modulated. Best results regarding protection against overloading are obtained with a combination of grid resistor and rectifier. To secure the tube against overloads, the fixed grid voltage (rectifier) should be at least 300 V at e.g. 10000 anode Volts.

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Parasitic oscillations can be suppressed by means of a non-inductive resistor of 30-50 Ω ohms connected as near as possible to the grid.

Triode-connection. In this case the screen-grid is connected to the anode. Curves and data on request.

Storage: In the interest of timely replacement claims in case of transport damages it is advisable to inspect each tube immediately upon arrival and test it electrically in the equipment for which it is intended. Storage of the tube is best done in dry places where no great temperature fluctuations occur. The tube is with advantage stored in its original packing. Tubes held in stock should be taken into operation for a short time only once after the first 6 months of stocking, as too frequent changes of tubes and removing them from their operating position exposing the tubes to shock and impact increase the risk of damage.

Maximum Ratings in the Tube Data. Each of the maximum ratings listed in the tube data gives the limiting value which cannot be exceeded without seriously affecting the working life of the tube.

Va = anode voltage

Ia = anode current

Vg1 - control grid voltage

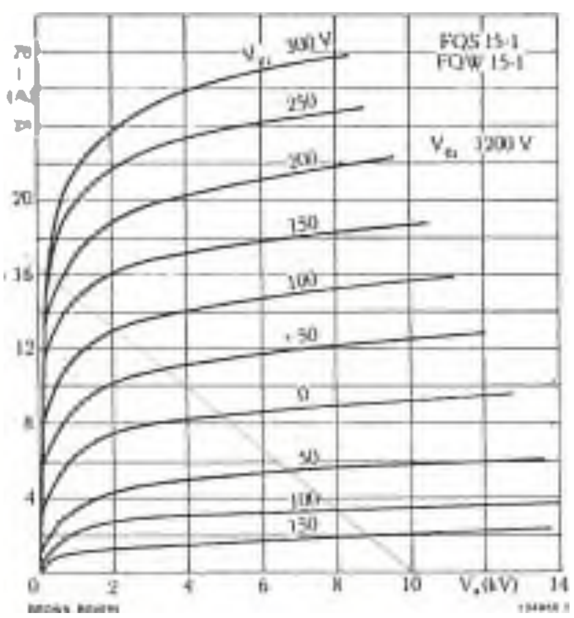
Vg2 - screen-grid voltage

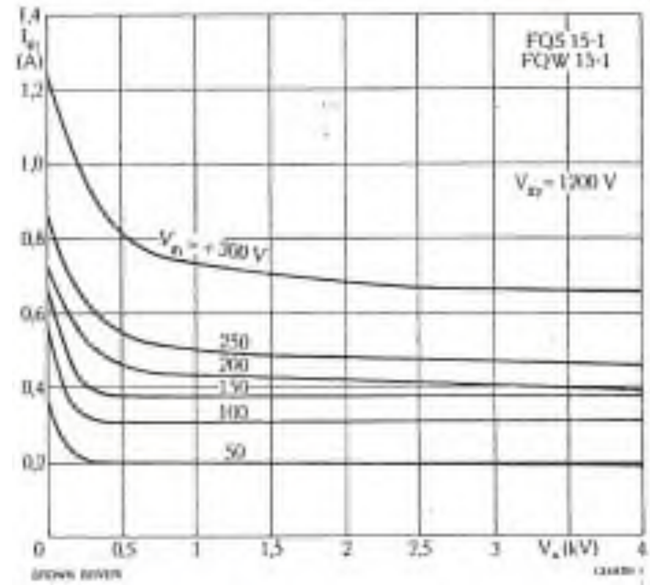
Ig1 - control grid current

Ig2 = screen-grid current

Ikp = peak cathode current

$U_{S_{20}} = 1200 V$


FQS 15-1
FQW 15-1
V_g1 = 1200 V
V_a (kV)
BROWN BOVERI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FQW 15-1
V_g2 = 1200 V
I_g1 (A)
V_a (kV)
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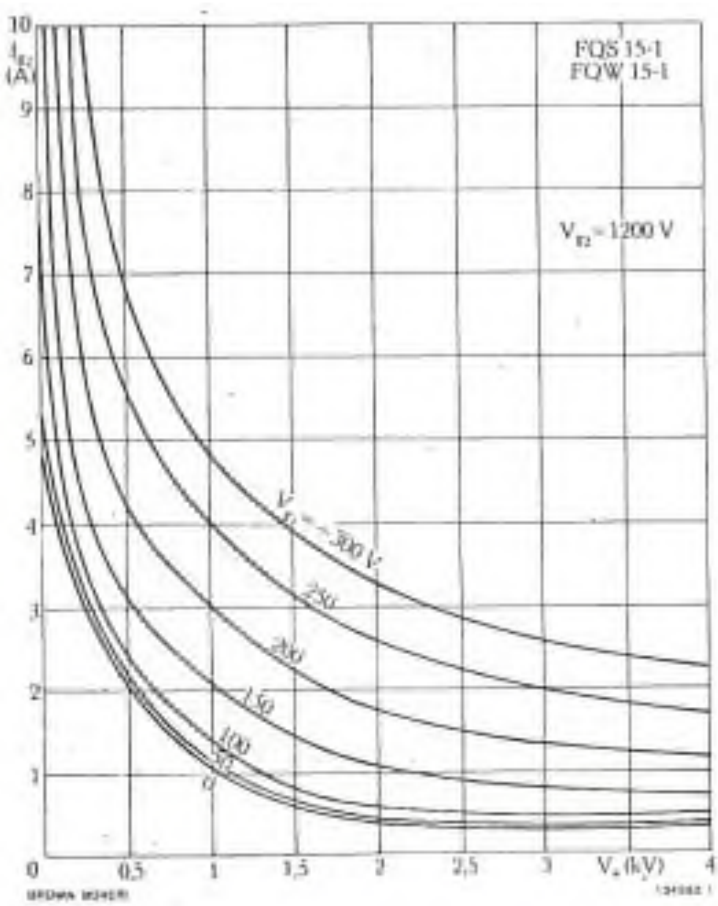
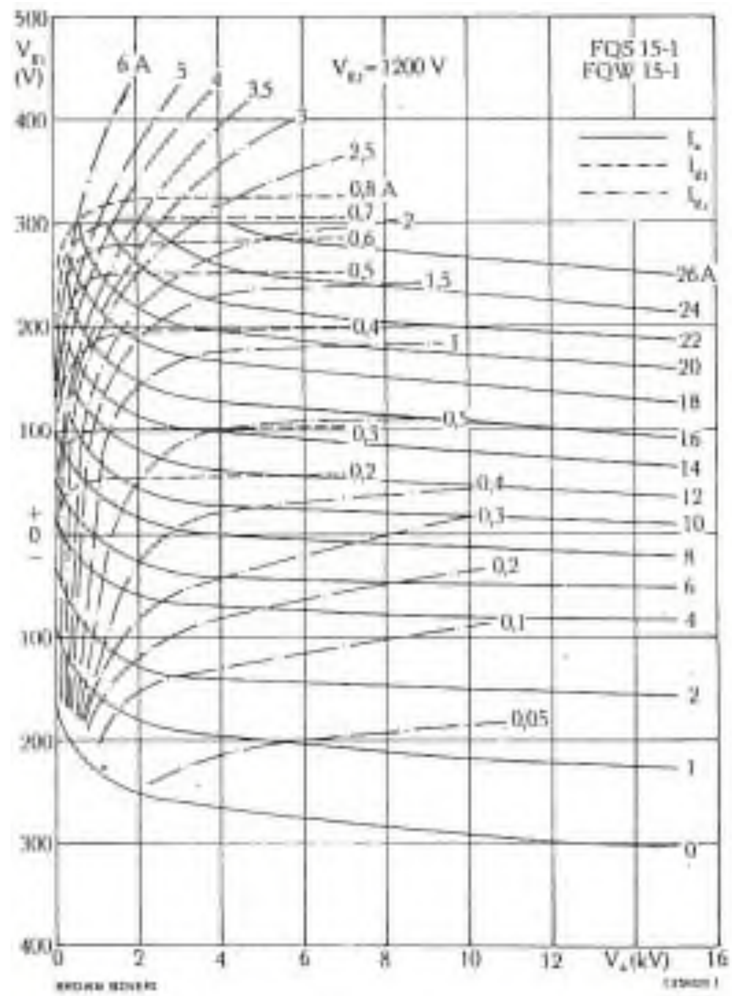

FQS 15-1
FQW 15-1
V_g2 = 1200 V
I_g2 (A)
V_a (kV)
BROWN BOVERI


FQS 15-1
FQW 15-1
V_g2 = 1200 V
V_g1 (V)
V_a (kV)
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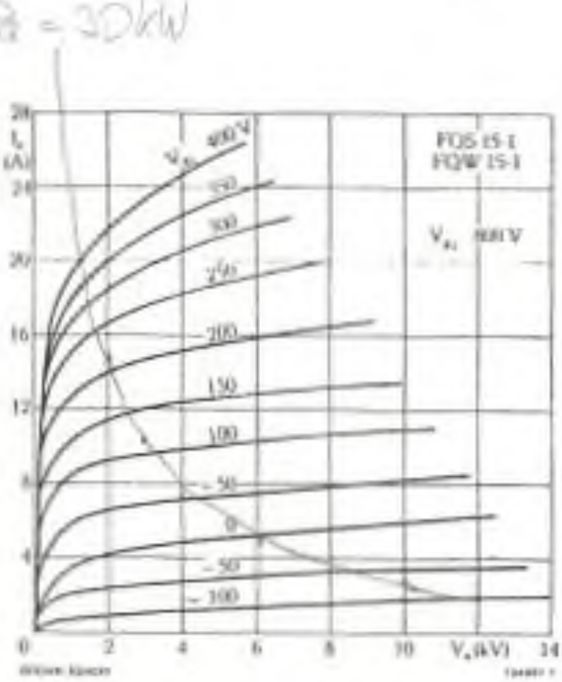
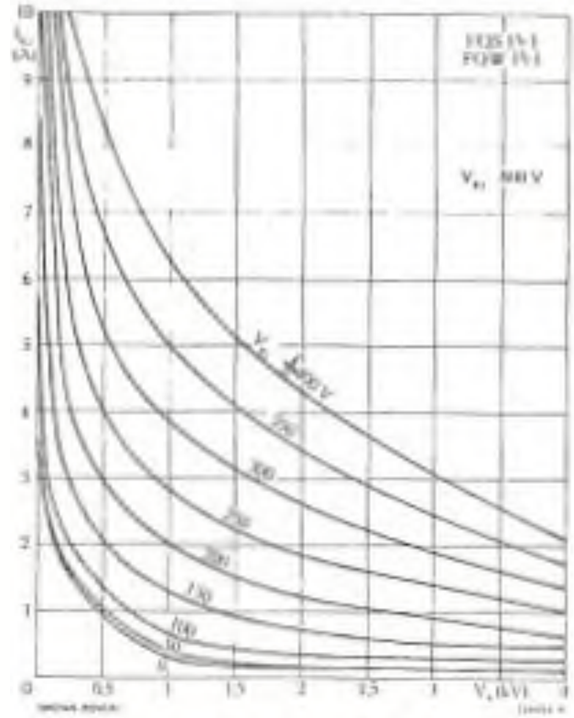
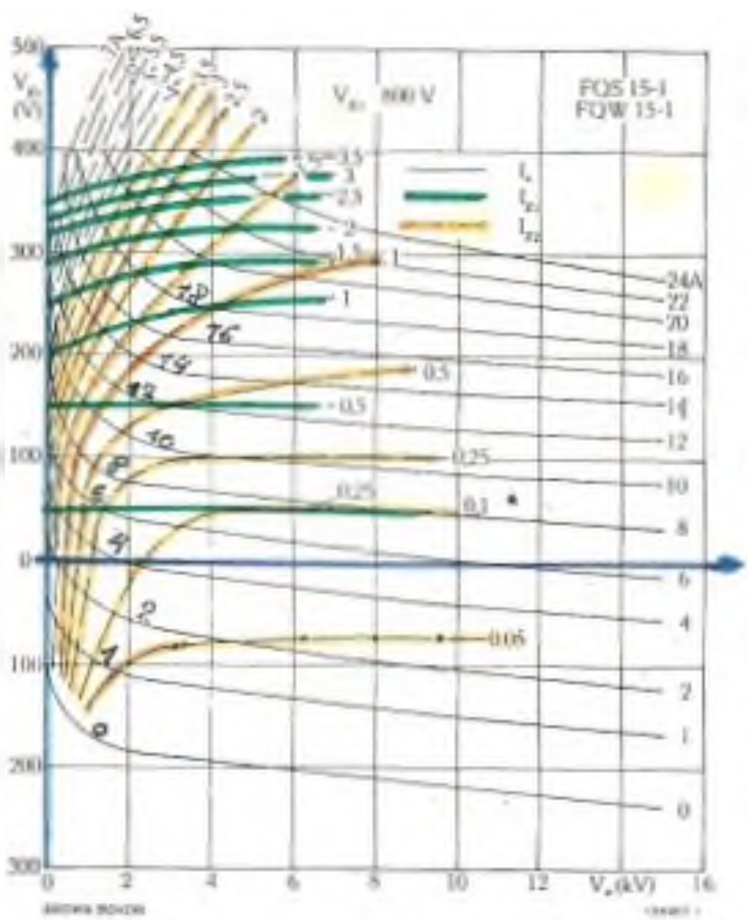
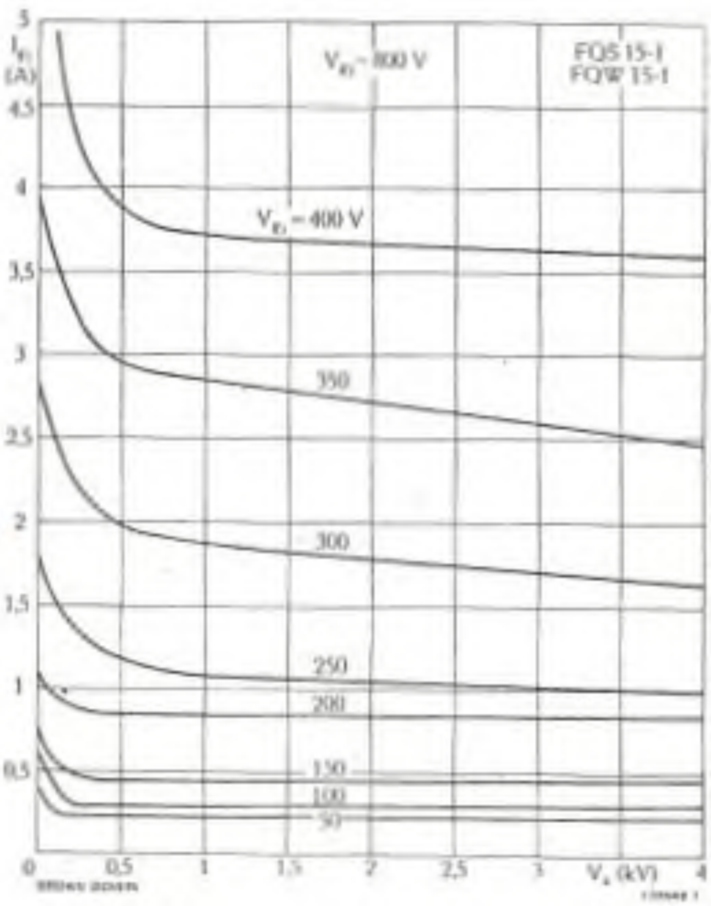
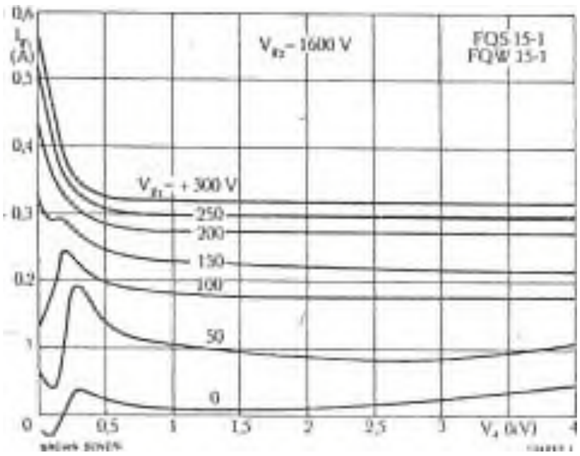
$U_{g2_0} = 800V$

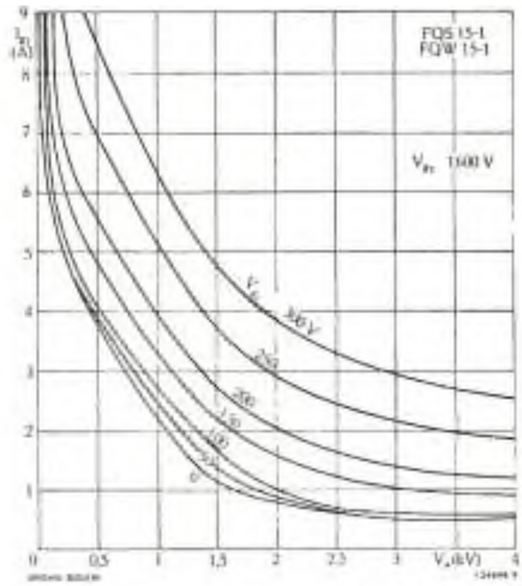


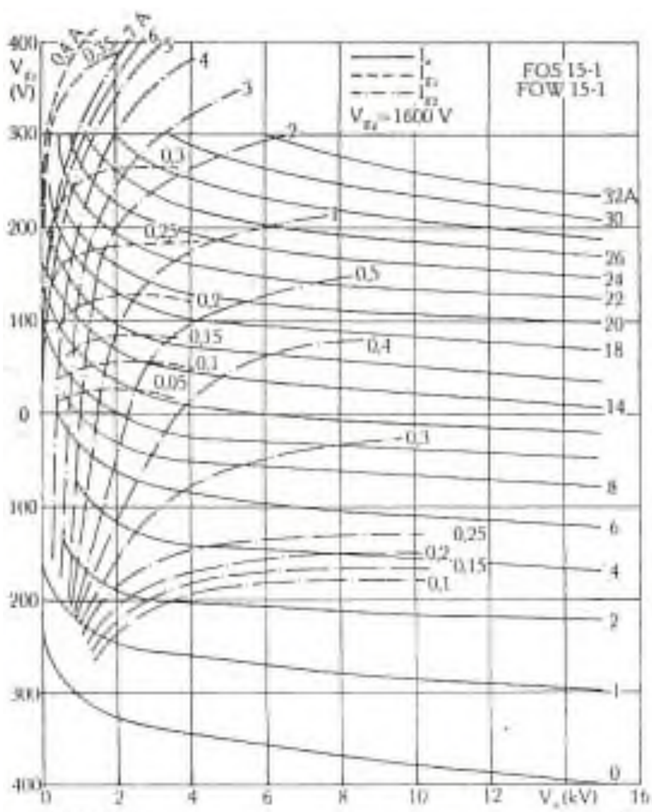


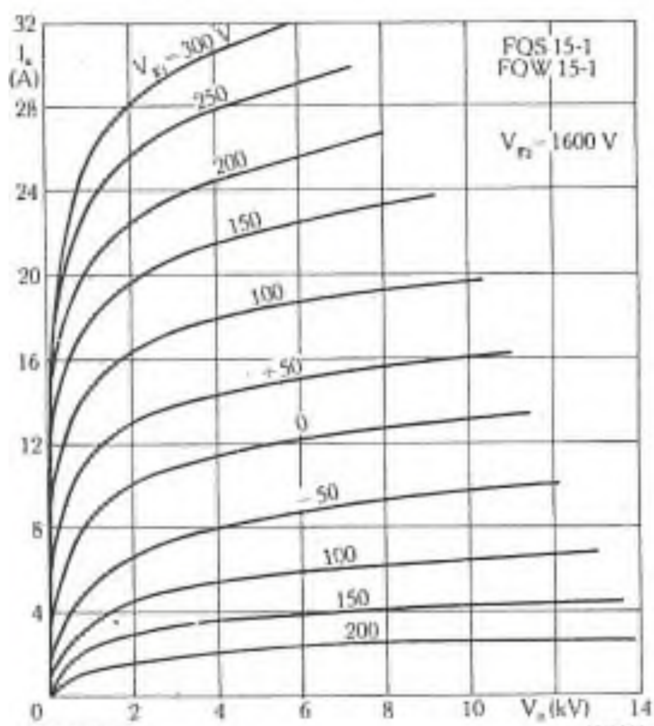





I_{g1} (A)
V_{g2} = 1600 V
FQS 15-1
FQW 15-1
V_{g1} = + 300 V
250
200
150
100
50
0
V_a (kV)
BROWN BOVERI


I_{g2} (A)
FQS 15-1
FQW 15-1
V_{g1} 1600 V
V_{g1} = 300 V
250
200
150
100
50
0
V_a (kV)
BROWN BOVERI


V_{g1} (V)
FQS 15-1
FQW 15-1
I_a
I_{g1}
I_{g2}
V_{g2} = 1600 V
32A
30
26
24
22
20
18
14
8
6
4
2
1
0
V_a (kV)
BROWN BOVERI


I_a (A)
FQS 15-1
FQW 15-1
V_{g2} = 1600 V
V_{g1} = 300 V
250
200
150
100
+ 50
0
− 50
100
150
200
V_a (kV)
BROWN BOVERI