

POWER AMPLIFIER PENTODES

TYPES
6760 AND 6761
(JUNE 2, 1955)

Types 6760 and 6761 are in the miniature 9-pin construction. They are designed for longlife operation and reliable service under vibration conditions. The tubes are intended for use as output tubes in telephone equipments and industrial applications, especially in broad-band amplifiers. Except for heater ratings the 6760 is identical with the 6761.

MECHANICAL DATA

Cathode: Coated Unipotential
Base: RETMA E9-1, Small Glass Button 9-pin
Bulb: T - 6 $\frac{1}{2}$
Max. Diameter: 7/8 "
Max. Overall Length: 2-3/4 "
Max. Seated Height: 2-1/2 "
Basing Connections: RETMA 9 CE
Mounting Position: Any

Pin No 1 - Plate	Pin No 6 - Plate
Pin No 2 - Grid No 1	Pin No 7 - Grid No 2
Pin No 3 - Cathode and Grid No 3	Pin No 8 - Cathode and Grid No 3
Pin No 4 - Heater	Pin No 9 - No Connection
Pin No 5 - Heater	

ELECTRICAL DATA

Direct interelectrode capacitances, without external shield

Grid No 1 to Plate: g1 to p	0.4	uuF
Input: g1 to h + k + g2 + g3	11	uuF
Output: p to h + k + g2 + g3	5	uuF

Maximum ratings

Plate Voltage	250	volts
Grid No 2 Voltage	200	volts
Plate Dissipation	10	watts
Grid No 2 Dissipation	1.5	watts
Cathode Current	100	milliamps
Heater - Cathode Voltage	100	volts

Typical operation. Class A1 amplifier. TYPE 6760 TYPE 6761

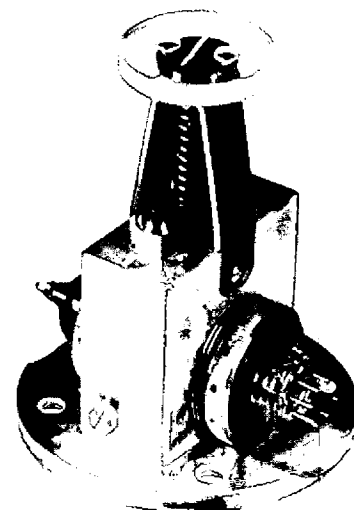
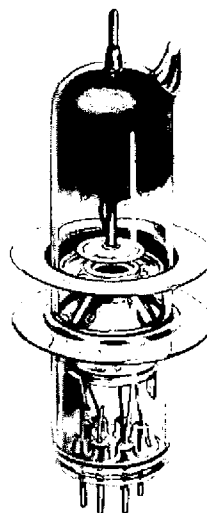
Heater Voltage	18.0	6.3	volts
Heater Current	0.35	1.0	amps
Plate Voltage	130	130	volts
Grid No 2 Voltage	130	130	volts
Cathode Bias Resistor	100	100	ohms
Plate Current	70	70	milliamps
Grid No 2 Current	3.5	3.5	milliamps
Transconductance	12.000	12.000	umhos
Grid No 1 Voltage approx. for Ib = 10 uA	-25	-25	volts
Load Resistor	2000	2000	ohms
Power Output at 10 % Distortion	3.0	3.0	watts

The type 6811 is a microwave oscillator of the single cavity reflex type, designed with an external cavity for pulse and CW operation within the frequency range 2,500 to 5,000 Mc/s. The tube is provided with a control grid in front of the cathode which makes the tube suitable for pulse operation. The output power in pulsed operation is 1 watt.

In CW operation the output power is about 0.1 watt.

The type is designed for use both as transmitting tube and as local oscillator in a microwave relay system.

It is built up on a 7-pin miniature base and needs no special aircooling arrangements. Special attention has been given to longlife performance.



GENERAL PRECAUTIONS

As the control grid of the tube has a positive potential with respect to the cathode, the grid voltage should never be applied prior to the resonator voltage. In pulsed operation with 800 volts resonator voltage the control grid should have a negative bias of about 10 volts.

ELECTRICAL CHARACTERISTICS

Frequency range with suitable cavities	2500-5000	Mc/s
Frequency change with temperature	0.6	Mc/°C
Frequency change from start of cold tube until cont. working conditions are reached	Below 20	Mc/s
Frequency change with resonator voltage	0.1	Mc/volt

HEATER RATINGS

Heater Voltage	6.3 ± 5%	volts
Heater Current	0.6	amps

CAPACITANCES

Control Grid to Cathode	3	uuF
Control Grid to Resonator	3	uuF

MAXIMUM RATINGS IN PULSED OPERATION

Resonator Voltage DC	825	volts
Resonator Current (pulse value)	100	milliamps
Control Grid Voltage (pulse value)	+ 25	volts
Control Grid Current (pulse value)	20	milliamps
Reflector Voltage DC	Max. - 700	volts
	Min. - 50	volts
Duty Cycle at above ratings	1/10	
Average Power Input	9	watts
Heater - Cathode Voltage	90	volts
Bulb Temperature	90	°C

REFLEX KLYSTRON

VELOCITY VARIATION OSCILLATOR



MAXIMUM RATINGS IN CW OPERATION

Resonator Voltage	375	volts
Resonator Current	30	milliamps
Control Grid Voltage	+ 12	volts
Control Grid Current	5	milliamps
Reflector Voltage	Max. - 700	volts
	Min. - 10	volts
Heater - Cathode Voltage	90	volts
Bulb Temperature	90	°C

TYPICAL OPERATION. FREQUENCY 4000 Mc/s. PULSED OPERATION

Resonator Voltage DC	800	volts
Resonator Current (pulse value)	70	milliamps
Control Grid Bias for Cutoff	- 10	volts
Control Grid Voltage (pulse value)	25	volts
Control Grid Current (pulse value)	10	milliamps
Reflector Transit Mode	2 3/4	
Reflector Voltage	- 150	volts
Power Output (pulse value)	1	watt
Electronic Tuning (to half power points)	30	Mc/s
Modulation Sensitivity	Min. 0.4	Mc/volt
Control Grid Resistance	2000	ohms

TYPICAL OPERATION. FREQUENCY 4000 Mc/s. CW OPERATION

Resonator Voltage	350	volts
Resonator Current	22	milliamps
Control Grid Voltage	5-10	volts
Control Grid Current	3.5	milliamps
Reflector Transit Mode	3 3/4	
Reflector Voltage	- 100	volts
Power Output	0.09	watt
Electronic Tuning (to half power points)	20	Mc/s
Modulation Sensitivity	Min. 0.5 *	Mc/volt
Control Grid Resistance	2000	ohms

MECHANICAL CHARACTERISTICS

Base: Small Glass Button Miniature 7-pin

Pin No	Connected to	Pin No	Connected to
1	Control Grid	5	Heater
2	Cathode	6	No Connection
3	Heater	7	Cathode
4	Cathode	Reflector to be connected to pin on top of tube.	

Mounting Position:	Any
Resonator:	External with inductive tuning
Bulb:	Glass
Overall Dimensions:	See Outline Drawing
Cooling:	Freely Circulating Air

* Defined as the ratio between frequency change and change in reflector voltage when this is varied between half power points.

FIG. 1

AVERAGE CHARACTERISTICS

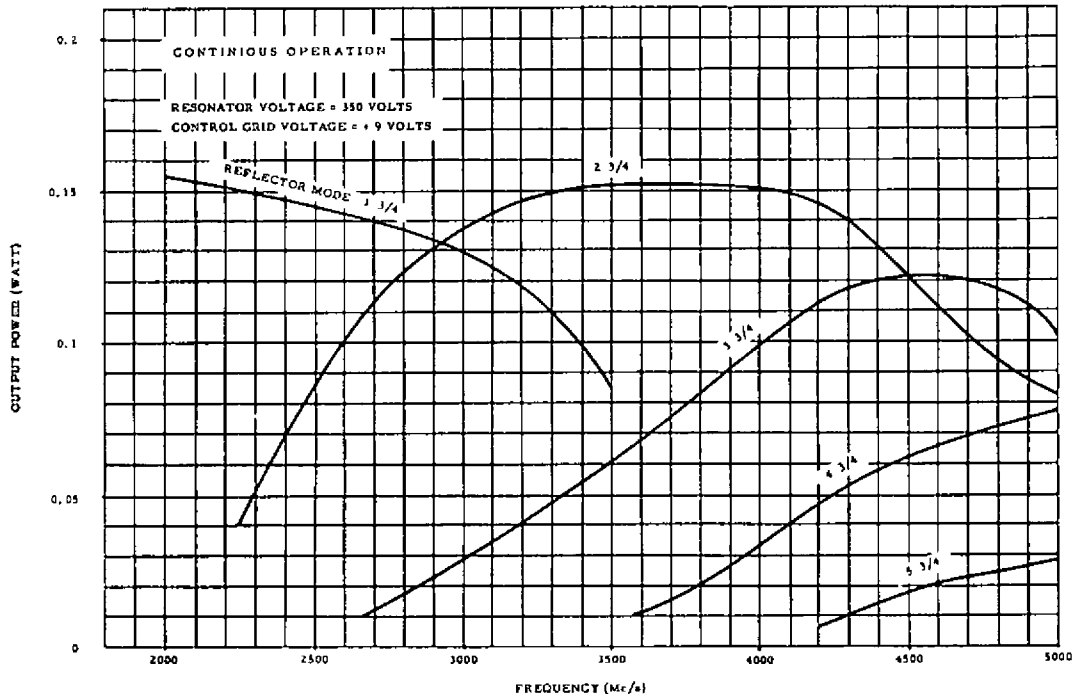


FIG. 2

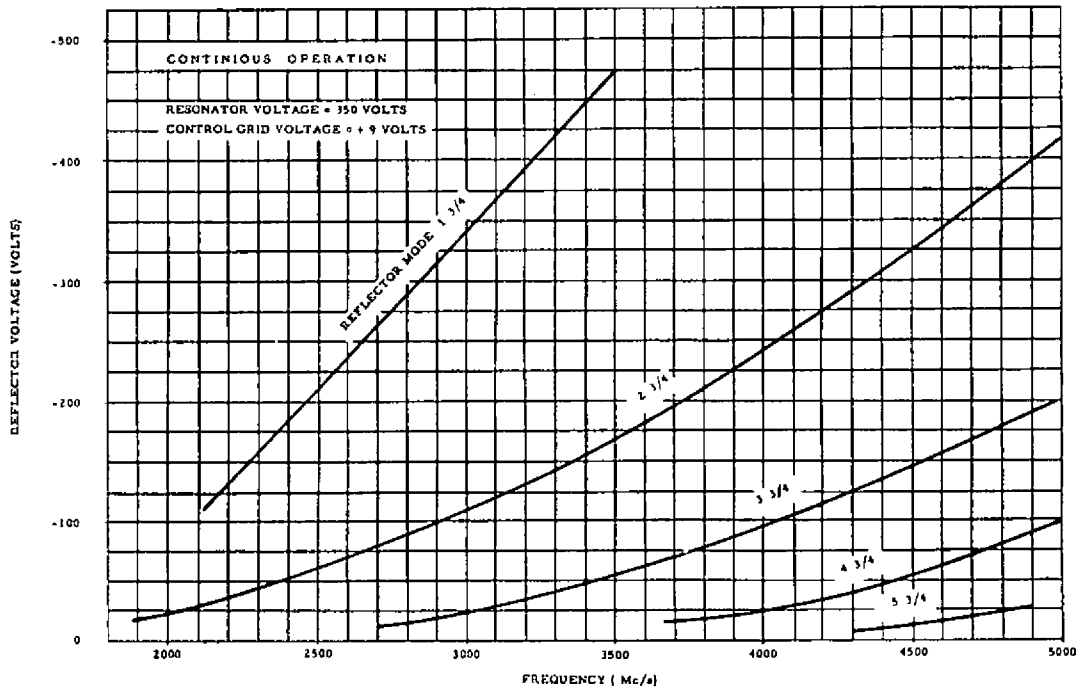


FIG. 3

AVERAGE CHARACTERISTICS

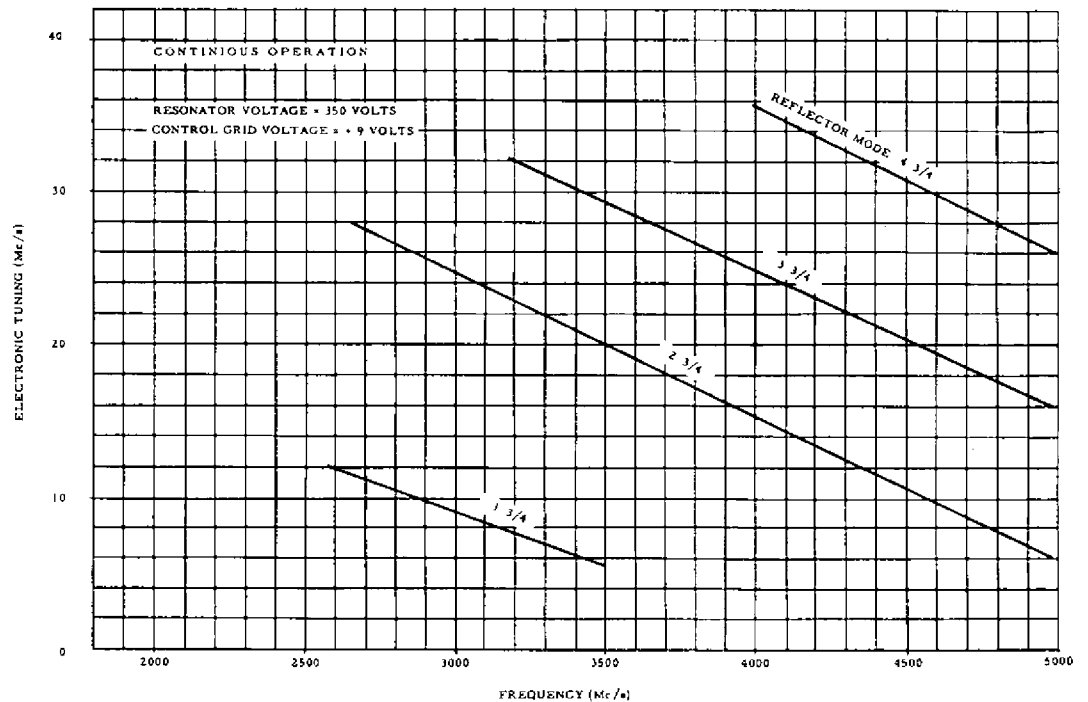


FIG. 4

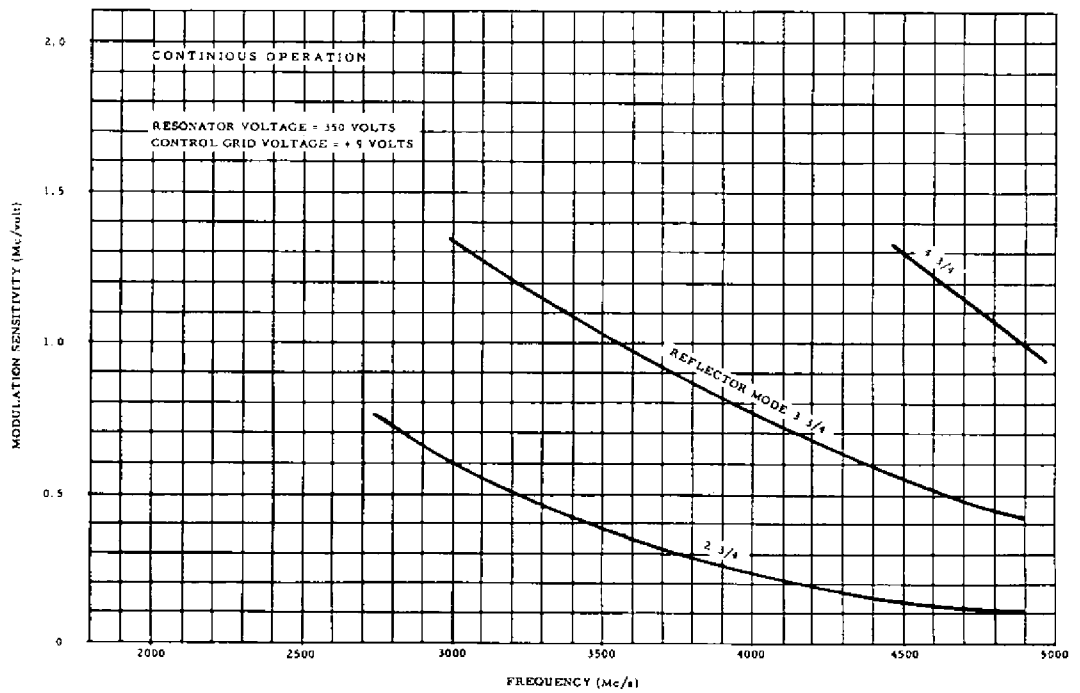


FIG. 5

AVERAGE CHARACTERISTICS

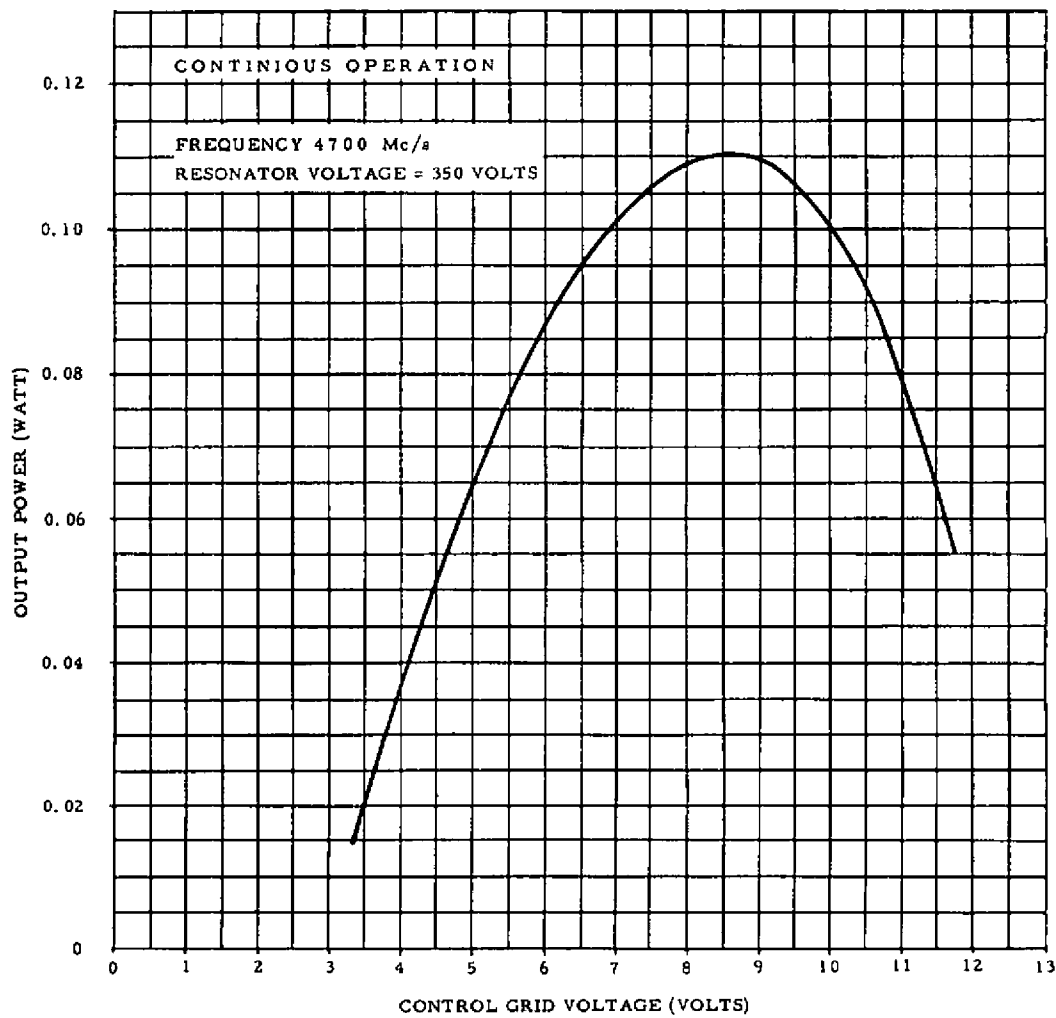


FIG. 6

AVERAGE CHARACTERISTICS

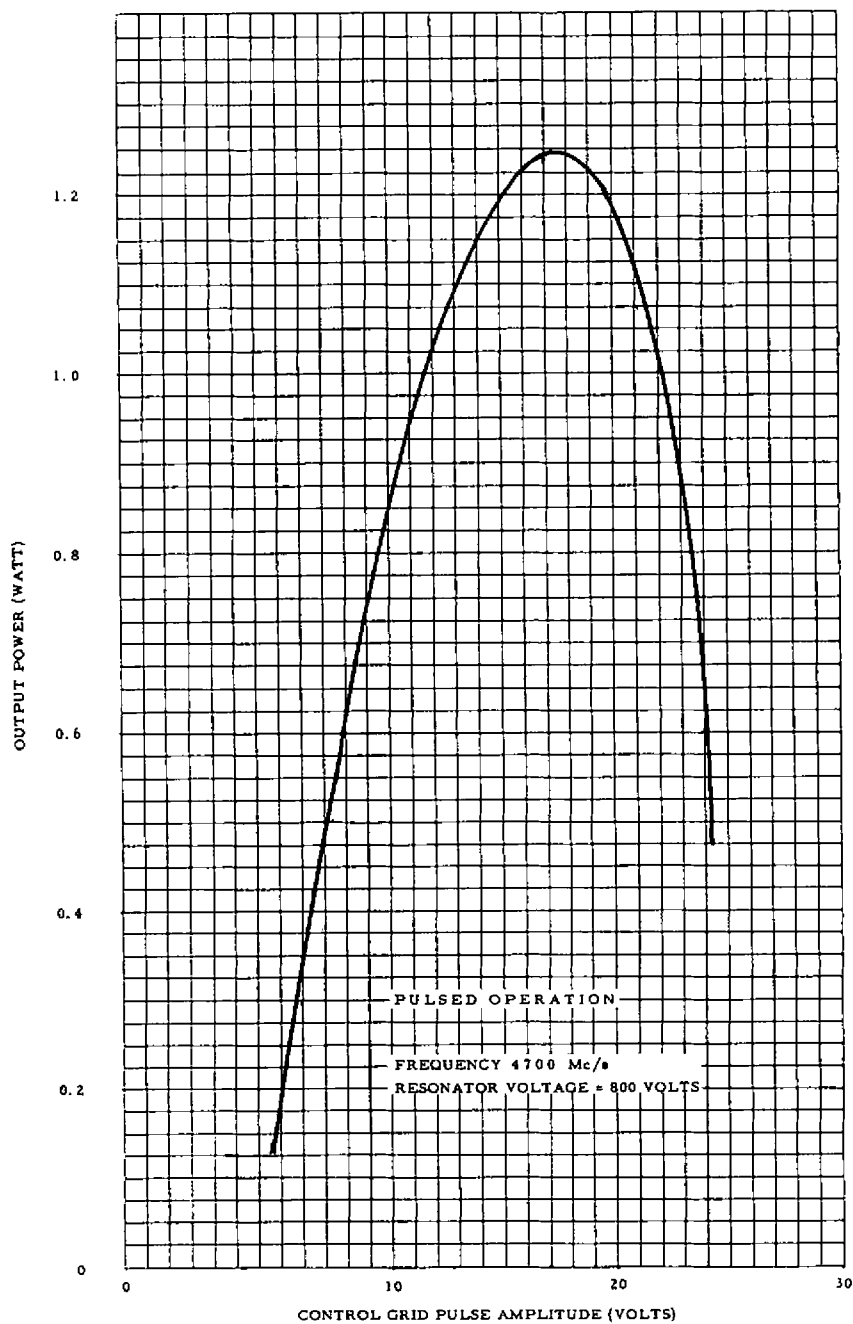


FIG. 7

AVERAGE CHARACTERISTICS

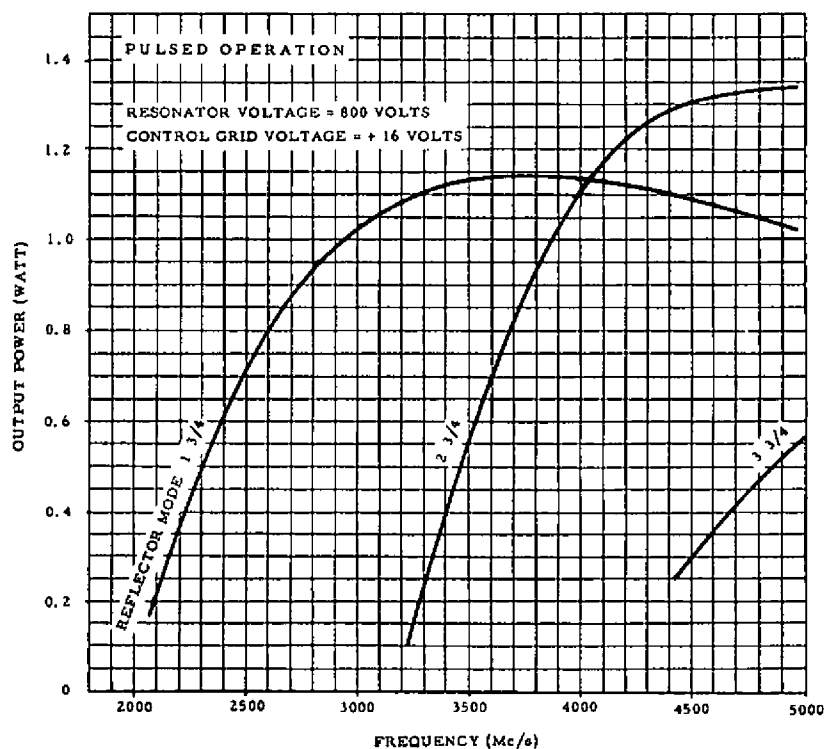


FIG. 8

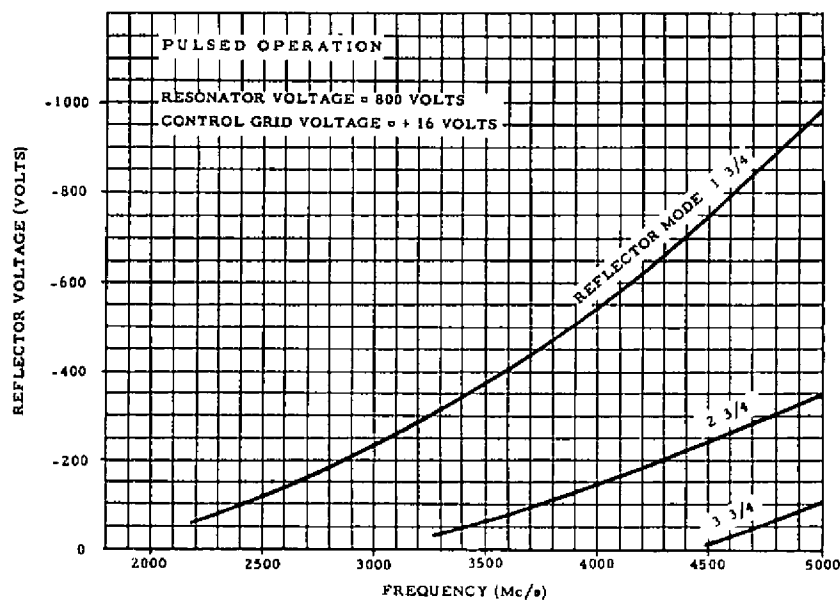


FIG. 9

AVERAGE CHARACTERISTICS

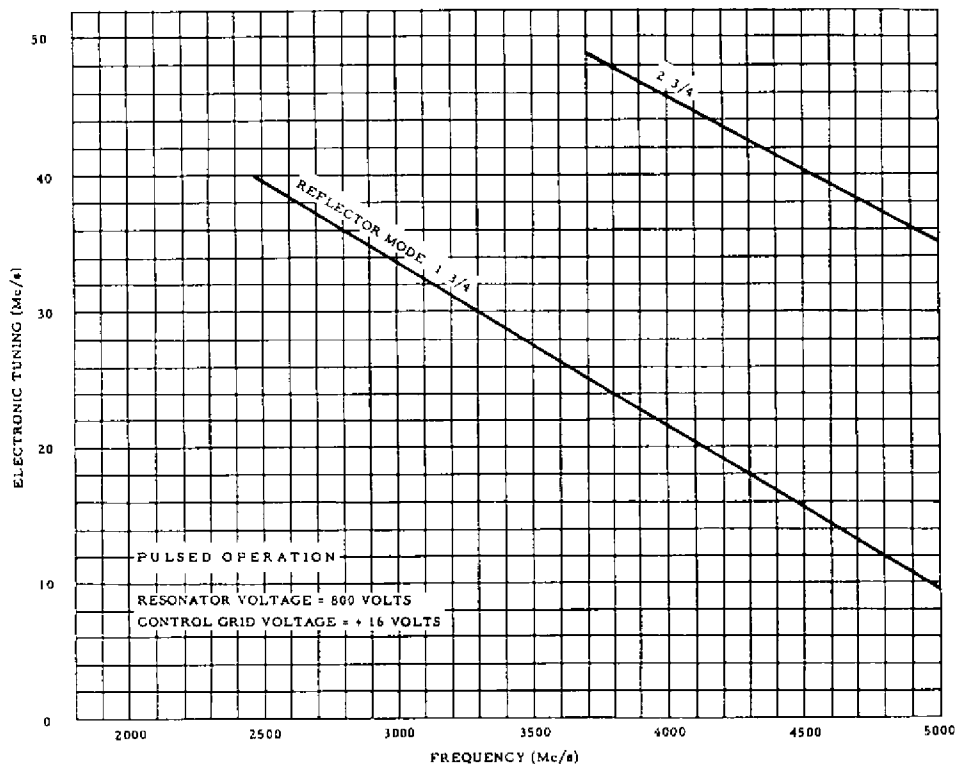


FIG. 10

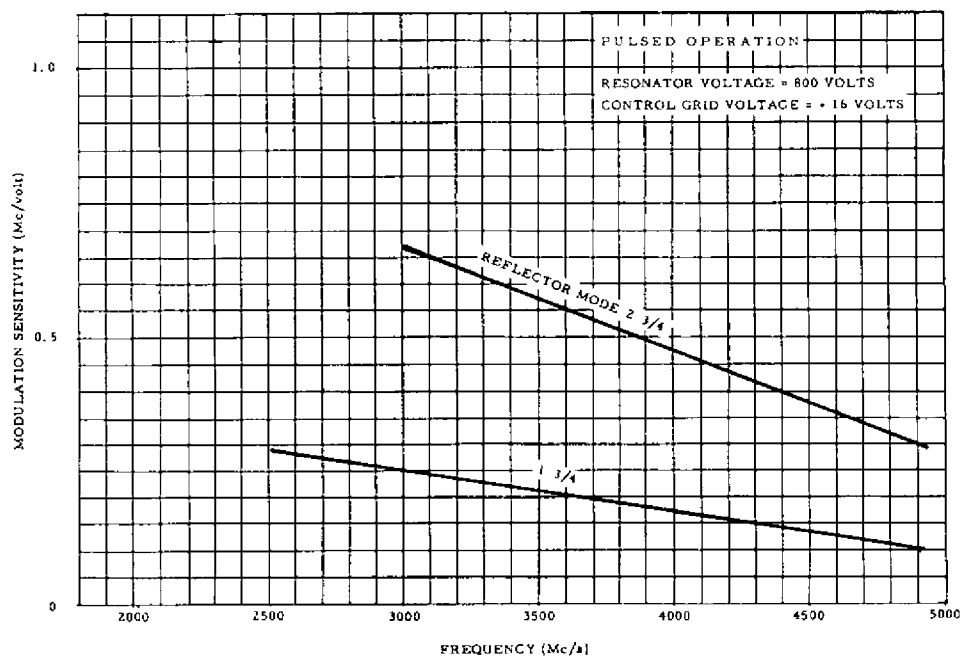


FIG. 11

AVERAGE CHARACTERISTICS

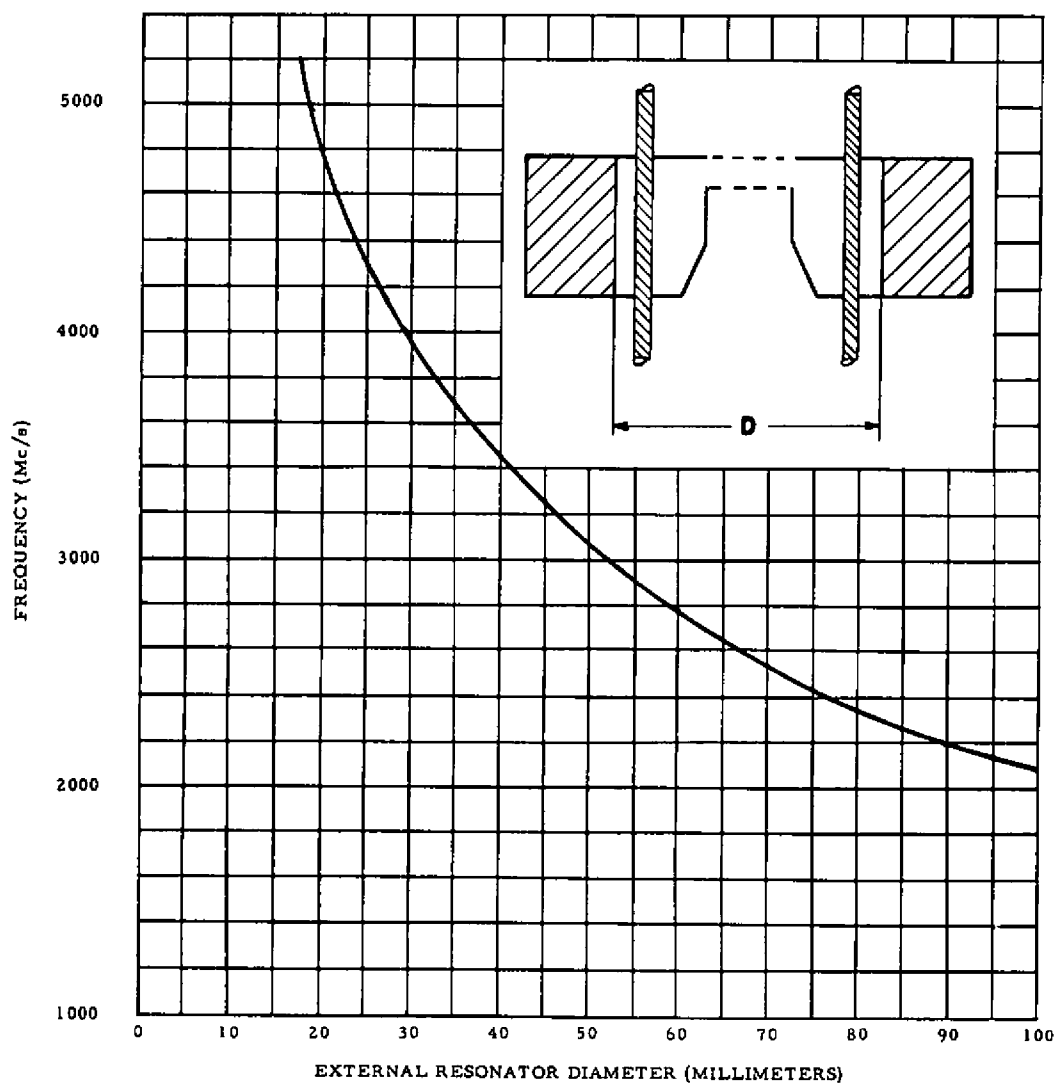


FIG. 12

TECHNICAL INFORMATION**CATHODE**

The resonator of the 6811 can be either operated at ground potential with the cathode negative by the amount of the resonator potential or at resonator potential with the cathode grounded. Cathode lead and heater are brought out separately. The heater cathode voltage may not exceed 90 volts. The cathode can of course be externally connected to the heater. In all cases, where the resonator is at ground potential, the heater transformer must be insulated to withstand the maximum resonator voltage. In applications, where the resonator has a positive potential with respect to ground it has to be insulated from the waveguide system and protections must be made against the resonator voltage.

GRID

In the 6811 the control grid is operating at a positive potential. Positive grid voltage should never be applied before the resonator voltage, otherwise damage of the grid and the cathode may be the result. In pulsed operation at 800 volts resonator voltage the grid should have a negative bias of about 10 volts. In pulsed condition the average power input may not exceed 9 watts and at 800 volts resonator voltage the maximum duty cycle is 1/10.

CAVITY

The cavity of the 6811 is of the external type and the mechanical tuning has to be inductive. The dimensions of the 0.2 mms copper disks are seen on the outline drawing. These disks have to be tightly pressed against the resonator ring. The output coupling can be made either through an iris or a loop. In a following curve the inside diameter of the resonator for a certain frequency is given.

The tube needs no special aircooling arrangements except under extraordinary conditions. An inductive tuning can be arranged in the resonator and the tube can easily be tuned over 500 Mc range with the same resonator. Suggestions concerning the construction of the resonator can be given by the manufacturer.

ELECTRONIC TUNING

The frequency may be tuned by varying the reflector voltage. The maximum power output for a fixed mechanical tuner position will be obtained at only one reflector value. The electronic tuning range is defined in the following way:

The mechanical tuning and the reflector voltage are mutually adjusted for a maximum power output at a given frequency. If then the reflector voltage is varied above and below the value for maximum power output so that the power output is reduced to one half - the frequency change between the half power values is defined as electronic tuning range. The amount of the electronic tuning and the linearity of its variation with reflector voltage is dependent upon the type of load used and the coupling to the load. The electronic tuning also depends on the reflector transit mode of operation.

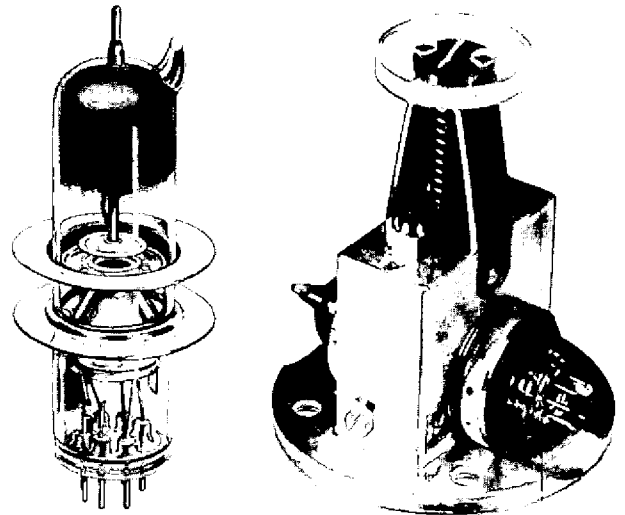
MODES OF OPERATION

Oscillations may be obtained in a given tube for several combinations of resonator and reflector voltages at a particular frequency. The regions where oscillations occur within the reflector voltage range are referred to as reflector modes, e.g. $1 \frac{3}{4}$, $2 \frac{3}{4}$ and $3 \frac{3}{4}$. The curves show characteristics of the output power and reflector voltages for different reflector modes. The electronic tuning range increases with the reflector mode number whereas the output power decreases.

LIFE

The reflex klystron 6811 has been designed for longlife performance and lifetests of the tube have exceeded 10,000 hours.

The type 6812 is a microwave oscillator of the single cavity reflex type, designed with an external cavity for CW operation within the frequency range 2500 - 5000 Mc/s. The output power is about 0.1 watt. The tube is designed for use as a local oscillator. It is built up on a 7-pin miniature base and needs no special aircooling arrangements. Special attention has been given to longlife performance.



ELECTRICAL CHARACTERISTICS

Frequency range with suitable cavities	2500-5000	Mc/s
Frequency change with temperature	0.6	Mc/°C
Frequency change from start of cold tube until cont. working conditions are reached	Below 20	Mc/s
Frequency change with resonator voltage	0.1	Mc/volt

HEATER RATINGS

Heater Voltage	6.3 [±] 5%	volts
Heater Current	0.6	amps

MAXIMUM RATINGS

Resonator Voltage	375	volts
Resonator Current	30	milliamps
Reflector Voltage	Max. - 700	volts
	Min. - 10	volts
Heater - Cathode Voltage	90	volts
Bulb Temperature	90	°C

TYPICAL OPERATION, FREQUENCY 4000 Mc/s.

Resonator Voltage	350	volts
Resonator Current	22	milliamps
Focus Cylinder	0	volt
Reflector Transit Mode	3 3/4	
Reflector Voltage	- 100	volts
Power Output	0.09	watt
Electronic Tuning (to half power points)	20	Mc/s
Modulation Sensitivity	Min. 0.5	Mc/volt

MECHANICAL CHARACTERISTICS

Base: Small Glass Button Miniature 7-pin

Pin No	Connected to	Pin No	Connected to
1	Focus Cylinder	5	Heater
2	Cathode	6	No Connection
3	Heater	7	Cathode
4	Cathode	Reflector to be connected to pin on top of tube.	

Mounting Position:

Any

Resonator:

External with inductive tuning

Bulb:

Glass

Overall Dimensions:

See Outline Drawing

Cooling:

Freely Circulating Air

Note: Modulation Sensitivity is defined as the ratio between frequency change and change in reflector voltage when this is varied between half power points.

FIG. 1

AVERAGE CHARACTERISTICS

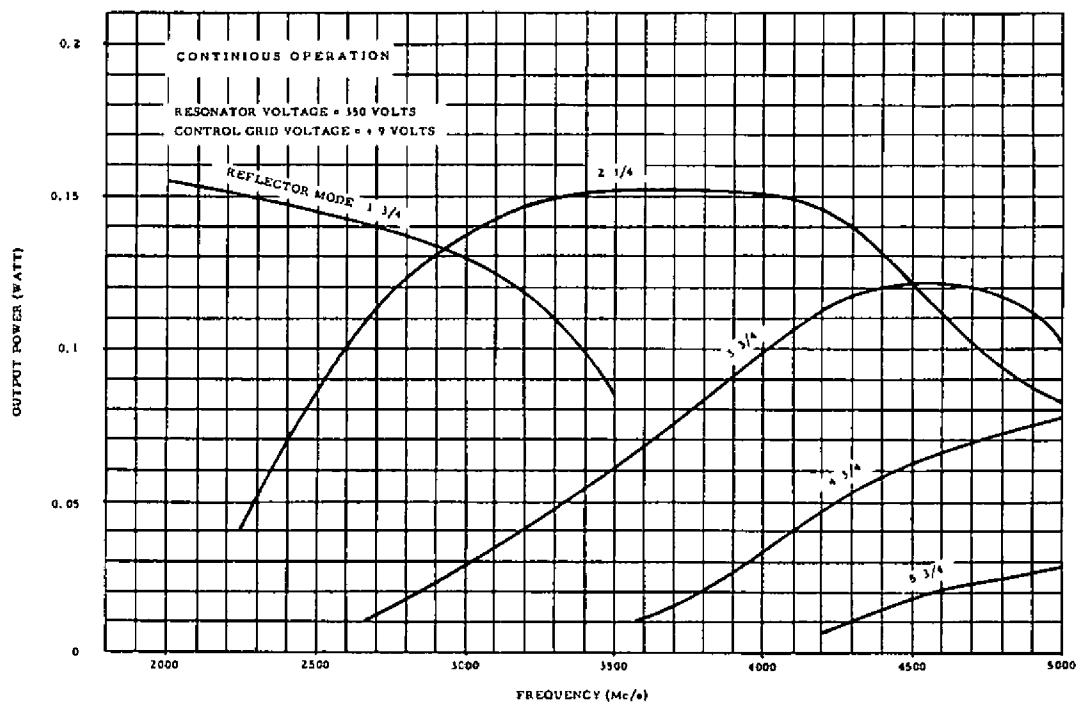


FIG. 2

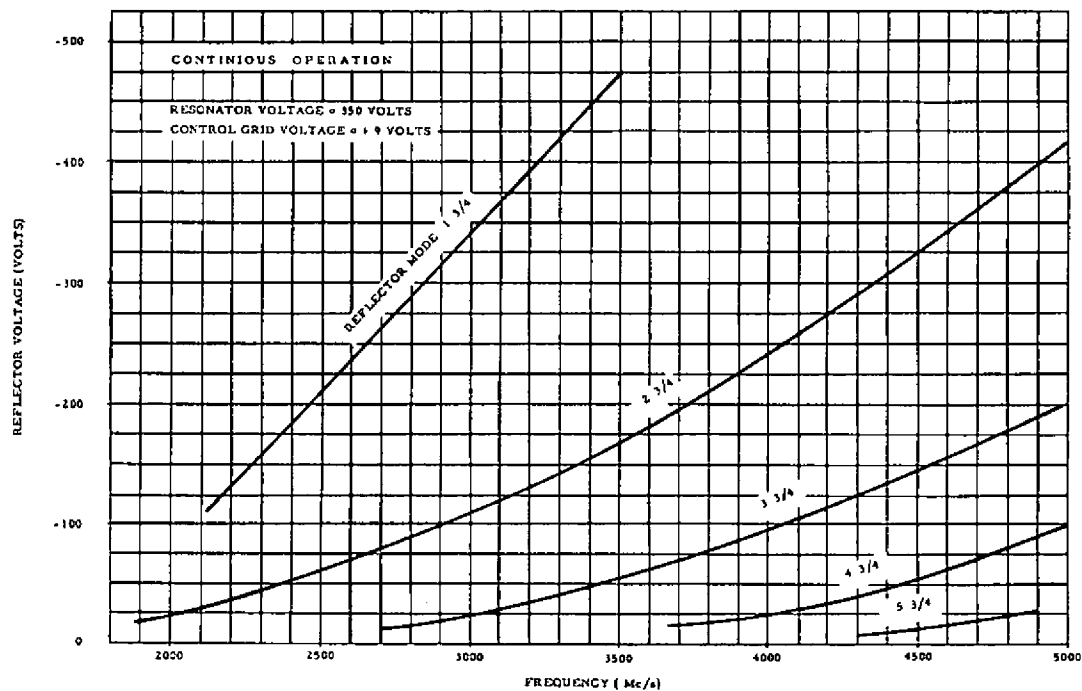


FIG. 3

AVERAGE CHARACTERISTICS

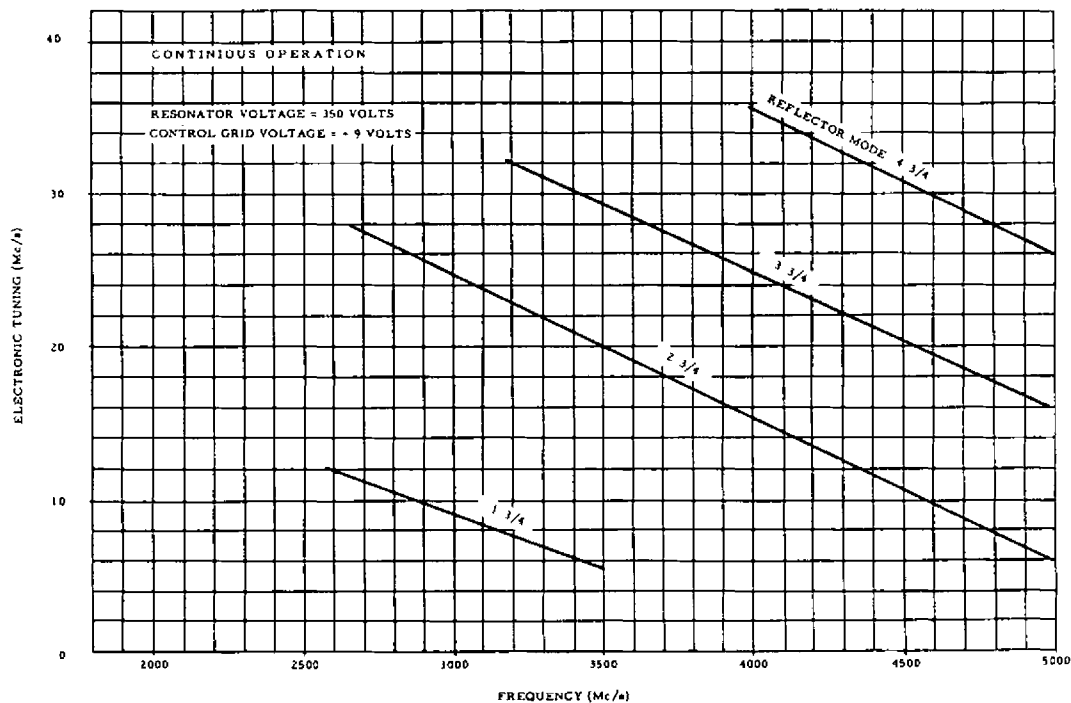


FIG. 4

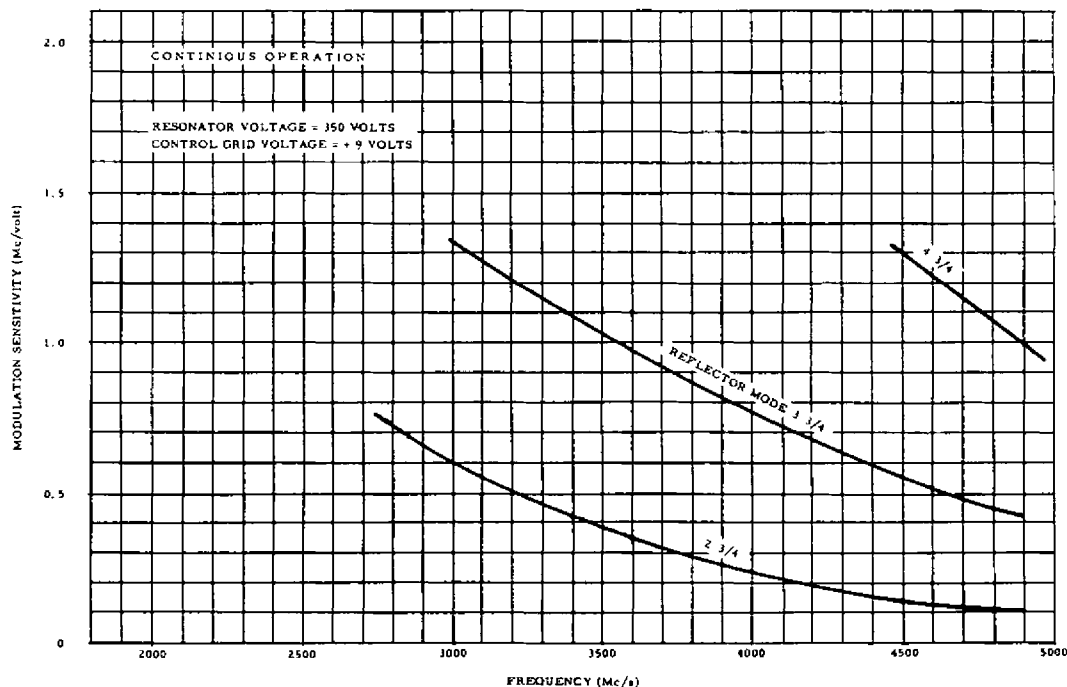


FIG. 5

AVERAGE CHARACTERISTICS

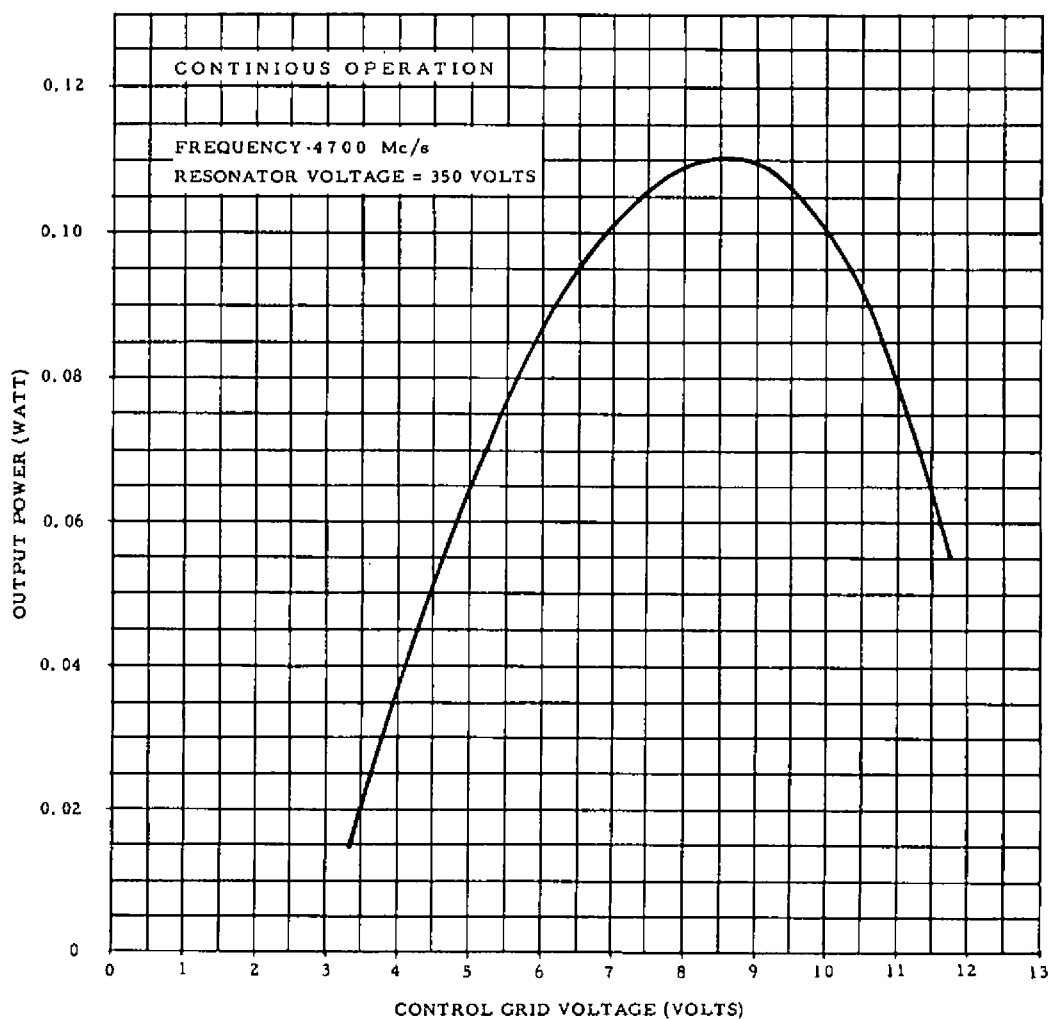


FIG. 6

AVERAGE CHARACTERISTICS

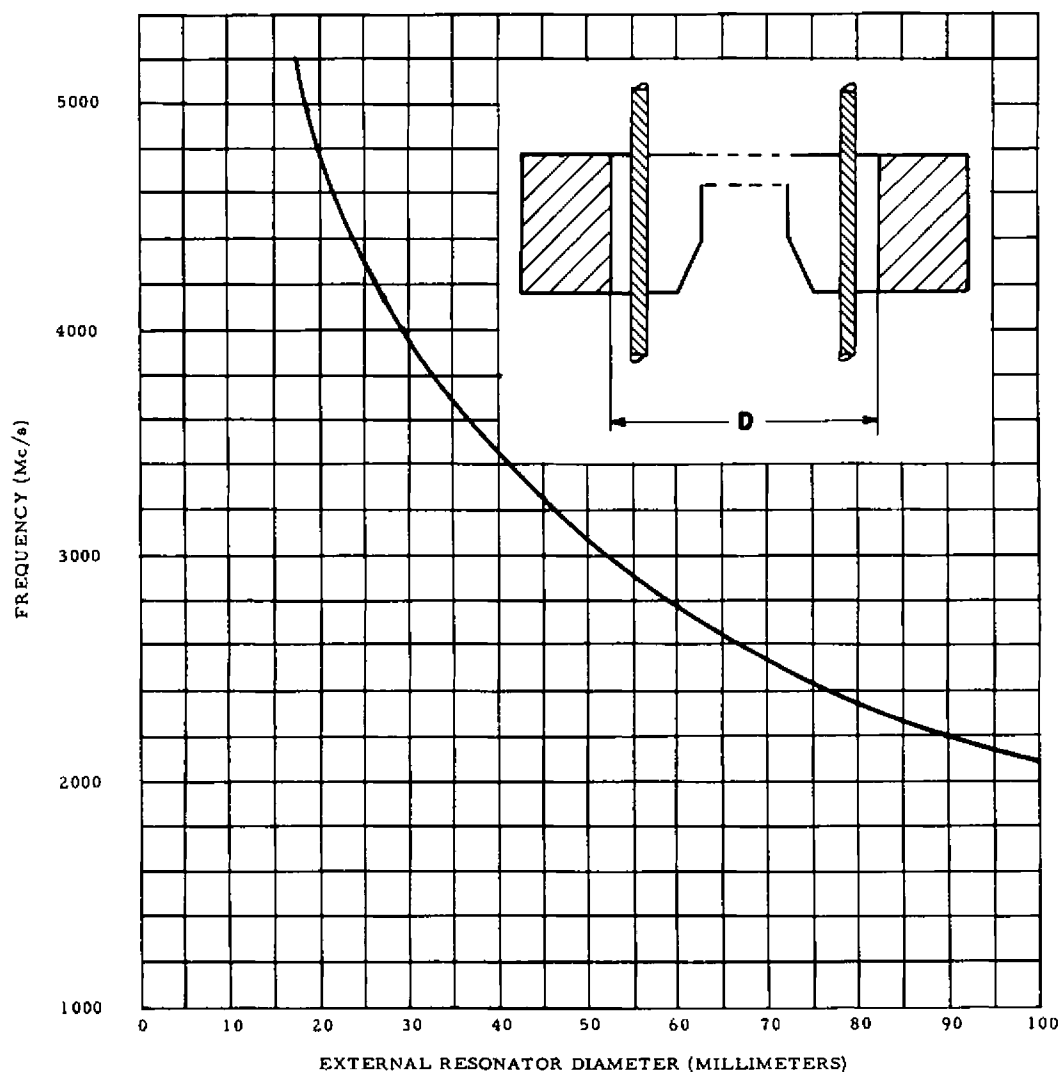


FIG. 7

TECHNICAL INFORMATION**CATHODE**

The resonator of the 6812 can be either operated at ground potential with the cathode negative by the amount of the resonator potential or at resonator potential with the cathode grounded. Cathode lead and heater are brought out separately. The heater cathode voltage may not exceed 90 volts. The cathode can of course be externally connected to the heater. In all cases, where the resonator is at ground potential, the heater transformer must be insulated to withstand the maximum resonator voltage. In applications, where the resonator has a positive potential with respect to ground it has to be insulated from the waveguide system and protections must be made against the resonator voltage. The focus cylinder (pin No 1) has to be connected outside the tube to the cathode (pin 2, 4 or 7).

CAVITY

The cavity of the 6812 is of the external type and the mechanical tuning has to be inductive. The dimensions of the 0.2 mms copper disks are seen on the outline drawing. These disks have to be tightly pressed against the resonator ring. The output coupling can be made either through an iris or a loop. In a following curve the inside diameter of the resonator for a certain frequency is given.

The tube needs no special aircooling arrangements except under extraordinary conditions. An inductive tuning can be arranged in the resonator and the tube can easily be tuned over 500 Mc range with the same resonator. Suggestions concerning the construction of the resonator can be given by the manufacturer.

ELECTRONIC TUNING

The frequency may be tuned by varying the reflector voltage. The maximum power output for a fixed mechanical tuner position will be obtained at only one reflector value. The electronic tuning range is defined in the following way:

The mechanical tuning and the reflector voltage are mutually adjusted for a maximum power output at a given frequency. If then the reflector voltage is varied above and below the value for maximum power output so that the power output is reduced to one half - the frequency change between the half power values is defined as electronic tuning range. The amount of the electronic tuning and the linearity of its variation with reflector voltage is dependent upon the type of load used and the coupling to the load. The electronic tuning also depends on the reflector transit mode of operation.

MODES OF OPERATION

Oscillations may be obtained in a given tube for several combinations of resonator and reflector voltages at a particular frequency. The regions where oscillations occur within the reflector voltage range are referred to as reflector modes, e.g. 1 $\frac{3}{4}$, 2 $\frac{3}{4}$ and 3 $\frac{3}{4}$. The curves show characteristics of the output power and reflector voltages for different reflector modes. The electronic tuning range increases with the reflector mode number whereas the output power decreases.

LIFE

The reflex klystron 6812 has been designed for longlife performance and lifetests of the tube have exceeded 10,000 hours.

The 6927 is suitable for use as highfrequency amplifier, oscillator or mixer. With the grids in push-pull and the plates connected in parallel the tube may be used as a mixer at frequencies as high as 600 Mc/s. It is intended for use in equipments, requiring very long life with low probability of failure and is especially designed for dependable service under vibration conditions. When such a tube is desired as a replacement for the commercial type 6J6, the type 6927 is very suitable within its ratings.

When used under the conditions stated below the average life is warranted to be more than 10,000 hours.

Reference is made to "information about L M Ericsson longlife tubes".

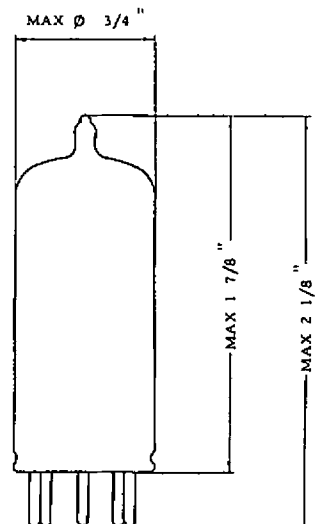
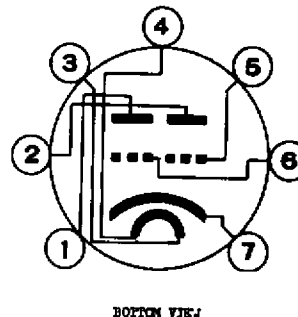
MECHANICAL DATA

Base: Small Button Miniature 7-pin, RETMA No. E7-1

Bulb: T 5 1/2

Mounting Position: Any

Pin No	Connected to
1.	Plate of Section 2
2.	Plate of Section 1
3.	Heater
4.	Heater
5.	Grid of Section 1
6.	Grid of Section 2
7.	Cathode



CAPACITANCES	WITH SHIELD*	WITHOUT SHIELD
Grid to Plate, each Section	1.5	1.5 uuF
Input, each Section	2.6	2.0 uuF
Output, Section 1	1.6	0.45 uuF
Output, Section 2	1.0	0.40 uuF

RANGE VALUES FOR CAPACITANCES	MIN	AVE	MAX	
WITHOUT SHIELD				
Grid to Plate, each Section	1.2	1.5	1.8	uuF
Input, each Section	1.4	2.0	2.6	uuF
Output, Section 1	0.25	0.45	0.65	uuF
Output, Section 2	0.25	0.40	0.55	uuF

* Close-fitting external shield connected to pin No. 7.

from JETEC release #1756, Oct. 15, 1956

MAXIMUM RATINGS (EACH SECTION)

Plate Voltage	200	volts
Plate Current	15	milliamps
Plate Dissipation	1.3	watt
Heater - Cathode Voltage	90	volts
Bulb Temperature (at hottest point)	150	°C
Grid Circuit Resistance	0.5	megohm

TYPICAL OPERATION (EACH SECTION)

Heater Voltage **	6.3 $\pm$ 5%	6.3 $\pm$ 5%	volts
Heater Current	0.330	0.330	amp
Plate Supply Voltage	100	130	volts
Cathode Bias Resistor ^o	68	100	ohms
Plate Current	6.5	7.7	milliamps
Plate Resistance	7500	7200	ohms
Transconductance	5000	5300	umhos
Equivalent Noise Resistance	500	470	ohms

OPERATION RANGE VALUES (EACH SECTION)

Heater Voltage	6.3			volts
Plate Supply Voltage	130			volts
Cathode Bias Resistor ^o	100			ohms
	MIN	AVE	MAX	
Heater Current	295	330	365	milliamps
Plate Current	4.7	7.7	10.7	milliamps
Transconductance	4200	5300	6400	umhos
Transconductance, End of Life Point ⁺	3600	-	-	umhos
Insulation Current, Heater to Cathode at E _{hk} = ± 100 volts.	-	-	20	uamps
Grid Current	-	-	- 0.5	uamp
Cutoff Plate Current at Grid Voltage = - 15 volts	-	-	0.2	milliamp
Vibration Output at 2.5 g and 25 c/s R _p = 2,000 ohms (both Sections)	-	10	-	millivolts

** As the life of the tube partly depends on the cathode temperature it is advised to keep the heater voltage within close limits. An Average Life of 10,000 hours is warranted provided that the heater voltage is kept within the given tolerance $\pm$ 5%.

^o Value is for both Sections operating as specified.

⁺ In view of warranty, the life of a tube corresponds to the time a tube has been operating until the transconductance has decreased to the End of Life Point. The average life for a group of tubes is defined as the total life of the group divided by the number of tubes in the group.

The 6928 is intended for use in medium power applications, where very long life with low probability of failure is desired. It is especially designed for dependable service under vibration conditions. When such a tube is desired as a replacement for the types 6AQ5 and 6005, the 6928 is most suitable within its ratings.

When used under the conditions stated below the average life is warranted to be more than 10,000 hours.

Reference is made to "information about L M Ericsson longlife tubes".

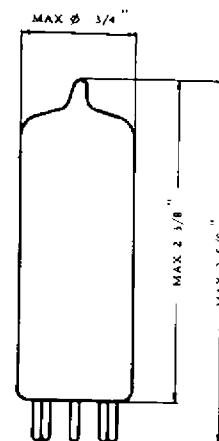
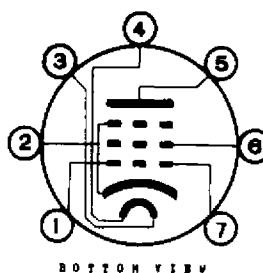
MECHANICAL DATA

Base: Small Button Miniature 7-pin, RETMA No. E7-1

Bulb: T 5 1/2

Mounting Position: Any

Pin No	Connected to
1.	Grid No 1
2.	Cathode and Grid No 3
3.	Heater
4.	Heater
5.	Plate
6.	Grid No 2
7.	Grid No 1



CAPACITANCES

WITH SHIELD*

WITHOUT SHIELD

Grid No 1 to Plate	0.17	0.35	uuF
Input	8.0	7.6	uuF
Output	11.0	6.0	uuF

RANGE VALUES FOR CAPACITANCES MIN AVE MAX

Grid No 1 to Plate	-	0.17	0.35	uuF
Input	6.4	8.0	9.6	uuF
Output	8.8	11.0	13.2	uuF

MAXIMUM RATINGS

Plate Voltage	200	volts
Grid No 2 Voltage	200	volts
Plate Dissipation	8	watts
Grid No 2 Dissipation	1	watt
Heater - Cathode Voltage	90	volts
Bulb Temperature (at hottest point)	200	C
Grid No 1 Circuit Resistance	0.5	megohm

* Close-fitting external shield connected to pin No. 2

from JETEC release #1756, Oct. 15, 1956

TYPICAL OPERATION

Heater Voltage**	6.3 $\pm$ 5%	6.3 $\pm$ 5%	volts
Heater Current	0.360	0.360	amp
Plate Supply Voltage	130	180	volts
Grid No 2 Supply Voltage	130	180	volts
Cathode Bias Resistor	200	220	ohms
Plate Current	23	32.5	milliamps
Grid No 2 Current	2	3	milliamps
Plate Resistance	80,000	80,000	ohms
Transconductance	3400	3900	umhos
Amplification Factor Grid No 2 to 1	10	10	
Load Resistance	6000	6000	ohms
Power Output	1.0	2.1	watts
Total Distortion	7	8	%

OPERATION RANGE VALUES

Heater Voltage	6.3			volts
Plate Supply Voltage	130			volts
Grid No 2 Supply Voltage	130			volts
Cathode Bias Resistor	200			ohms
	MIN	AVE	MAX	
Heater Current	320	360	400	milliamps
Plate Current	16	23	30	milliamps
Grid No 2 Current	-	-	5.5	milliamps
Transconductance	2600	3400	4200	umhos
Transconductance, End of Life Point [†]	2200	-	-	umhos
Insulation Current Heater to Cathode				
at $E_{hk} = \pm 100$ volts	-	-	50	uamps
Grid No 1 Current	-	-	- 1	uamp
Cutoff Plate Current at Grid No. 1				
Voltage = - 40 volts	-	-	0.2	milliamp
Vibration Output at 2.5 g and 25 c/s				
($R_p = 2,000$ ohms)	-	50	-	millivolts

** As the life of the tube partly depends on the cathode temperature it is advised to keep the heater voltage within close limits. An Average Life of 10,000 hours is warranted provided that the heater voltage is kept within the given tolerance $\pm$ 5%.

⁺ In view of warranty, the life of a tube corresponds to the time a tube has been operating until the transconductance has decreased to the End of Life Point. The average life for a group of tubes is defined as the total life of the group divided by the number of tubes in the group.

The 7150 is a tetrode intended for use in broadband amplifiers from audio frequencies up to about 300 Mc/s.

Thanks to pentode-like characteristics 7150 is very useful in output stages. When triode-connected it is also very suitable as low-noise amplifier in input stages. The low capacitance between plate and cathode makes it fitted for use in grounded grid circuits.

The figure of merit is outstanding, especially at intermediate frequencies owing to the low output capacitance.

The 7150 also offers small transit time loading and low cathode lead inductance. These features have been obtained by using close-spaced structure and triple cathode leads. Accordingly, the input conductance is low - approximately 1100 micromhos at 70 Mc/s.

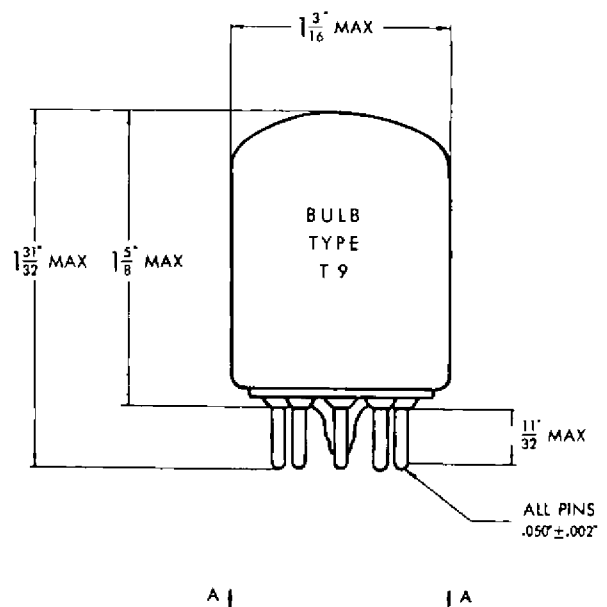
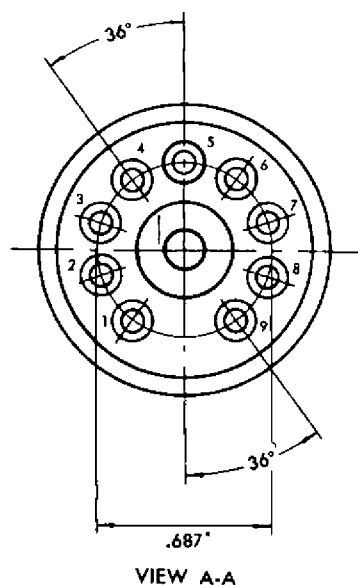
MECHANICAL DATA

Base: 9-pin, as per drawing below.

Bulb: T-9

Mounting Position: Any

Pin No	Connected to	Pin No	Connected to
1.	Plate	6.	Cathode
2.	Heater	7.	Cathode
3.	Cathode	8.	No Connection
4.	Grid No 1	9.	Grid No 2
5.	Heater & Int. Shield (see Note 1)		



Note 1: The internal shield connected to Pin No 5 should be grounded as there is a direct flow of electrons from the cathode to the shield when the latter is positive in relation to the cathode.

MAXIMUM RATINGS (Absolute Values)

Plate Voltage	165	volts
Plate Dissipation	4.5	watts
Grid No 2 Voltage	165	volts
Grid No 2 Dissipation	1.65	watts *
(Plate + Grid No 2) Dissipation	5.5	watts
Cathode Current	55	milliamps
Heater - Cathode Voltage	55	volts
Bulb Temperature (at hottest point)	140	°C
Grid No 1 Voltage, Positive Value	0	volt
Grid No 1 Voltage, Negative Value	- 25	volts
Grid Circuit Resistance, Fixed Bias	0.05	megohm
Grid Circuit Resistance, Cathode Bias	0.10	megohm

TETRODE CHARACTERISTICS

COLD CAPACITANCES (without external shield)

Grid No 1 to Plate	0.03	uuF
Input	16	uuF
Output	2	uuF

TYPICAL OPERATION

Heater Voltage	6.3	6.3	volts
Heater Current	450	450	milliamps
Plate Supply Voltage	135	125	volts
Grid No 2 Supply Voltage	135	125	volts
Grid No 1 Supply Voltage (see Note 2) + 8	0	0	volts
Cathode Bias Resistor	260	45	ohms
Plate Current	27.5	24	milliamps
Grid No 2 Current	8.5	7.5	milliamps
Transconductance	35,800	34,000	micromhos
Plate Resistance, approx.	0.03	0.03	megohm
Equivalent Noise Resistance	160	160	ohms
Input Conductance at 100 Mc, appr.	2200	2200	micromhos
Transit Time Loading at 100 Mc, appr.	200	200	micromhos
Figure of Merit at low frequencies,			
$g_m / C_{in} + C_{out}$	2.0	1.9	
Figure of Merit at intermediate freq.,			
$g_m / \sqrt{C_{in} \cdot C_{out}}$	6.3	6.0	

* Triode Connection = Grid No 2 connected to Plate.

Note 2: It is recommended to use the tube in combination bias as per column No 1 above.

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TETRODE CHARACTERISTICS
(Continued)

OPERATION RANGE VALUES

Heater Voltage	6.3			volts
Plate Supply Voltage	125			volts
Grid No 2 Supply Voltage	125			volts
Cathode Bias Resistor	45			ohms
	MIN	AVE	MAX	
Heater Current	410	450	490	milliamps
Plate Current	20	24	30	milliamps
Grid No 2 Current	-	7.5	13	milliamps
Transconductance	28,000	34,000	40,000	micromhos
Transconductance, End of Life Point	22,000	-	-	micromhos
Insulation Current, Heater to Cathode at $E_{hk} = -100$ volts	-	-	20	microamps
Grid No 1 Current	-	-	- 0.2	microamp
Cutoff Plate Current at Grid No 1 Voltage = - 5 volts	-	-	0.1	milliamp

TRIODE CHARACTERISTICS*
(Grounded Grid Operation)

COLD CAPACITANCES (without external shield)

Plate & Grid No 2 to Cathode	0.6	uuF
Input (Cathode to Grid, Heater & Int. Shield)	18	uuF
Output (Plate & Grid No 2 to Grid, Heater & Int. Sh.)	7	uuF

TYPICAL OPERATION

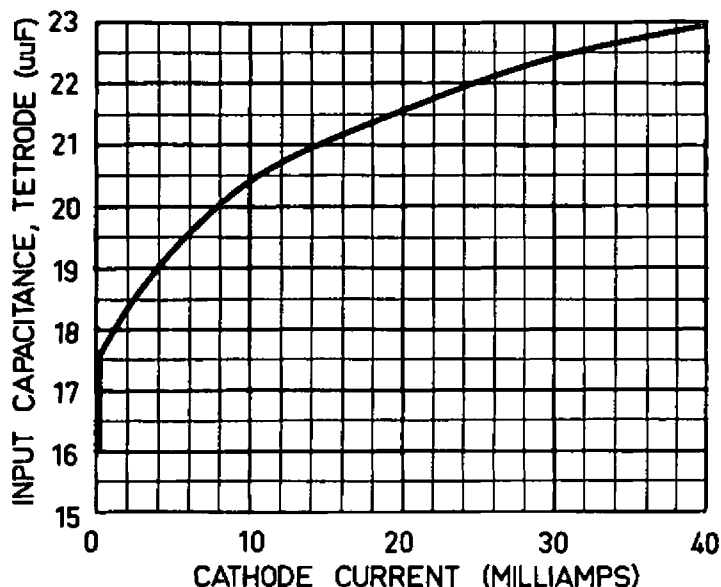
Heater Voltage	6.3	volts
Heater Current	450	milliamps
Plate Supply Voltage	125	volts
Cathode Bias Resistor	33	ohms
Plate Current	35	milliamps
Transconductance	47,000	micromhos
Amplification Factor	35	
Equivalent Noise Resistance	60	ohms

* Triode Connection = Grid No 2 connected to Plate.

SPECIAL DATAS AND CHARACTERISTICS

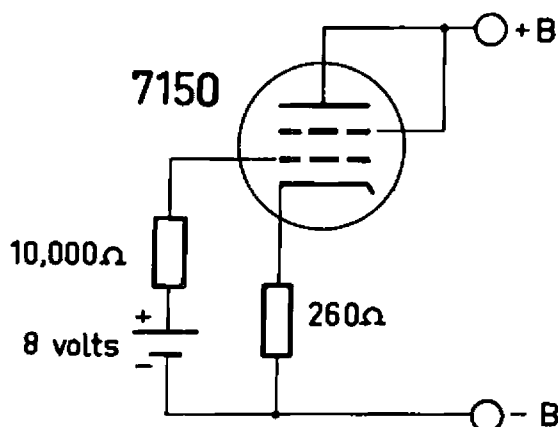
1. Capacitances in operation.

Space-charge effects in electron current flow cause an increase in tube capacitances. The input capacitance as a function of cathode current is shown below. At low frequencies approx. 8 μuF should be added for tube sockets and wiring capacitances. At intermediate frequencies approx. 5 μuF should be added for input circuit and 3 μuF for output circuit. For best value of figure of merit external shield should be excluded.



2. Bias considerations.

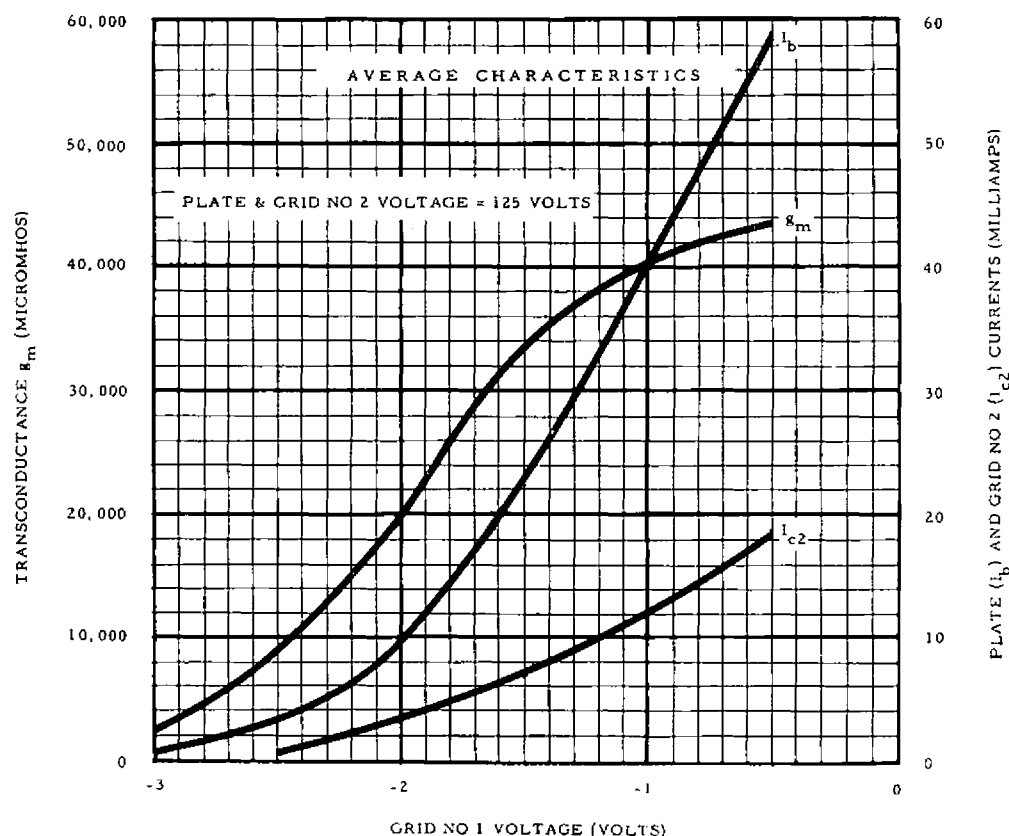
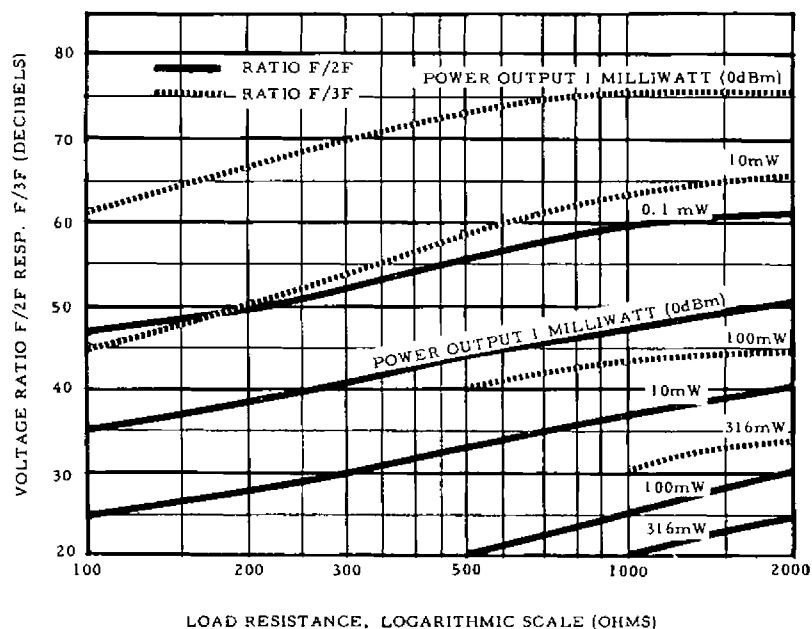
Because of the sensitivity to manufacturing variations of the operating characteristics of high transconductance tubes, the use of a 260 ohms cathode resistor in conjunction with a DC control grid return to a + 8 volts supply is recommended. This circuit is given below. To prevent burn out of grid wires owing to removal of Grid No 2 voltage with + 8 volts bias still applied, a limiting resistor of 10,000 ohms has been suggested in series with the bias supply. In applications, where the use of such resistor is not desirable, care should be taken that the grid bias is not applied before Plate and Grid No 2 voltages.



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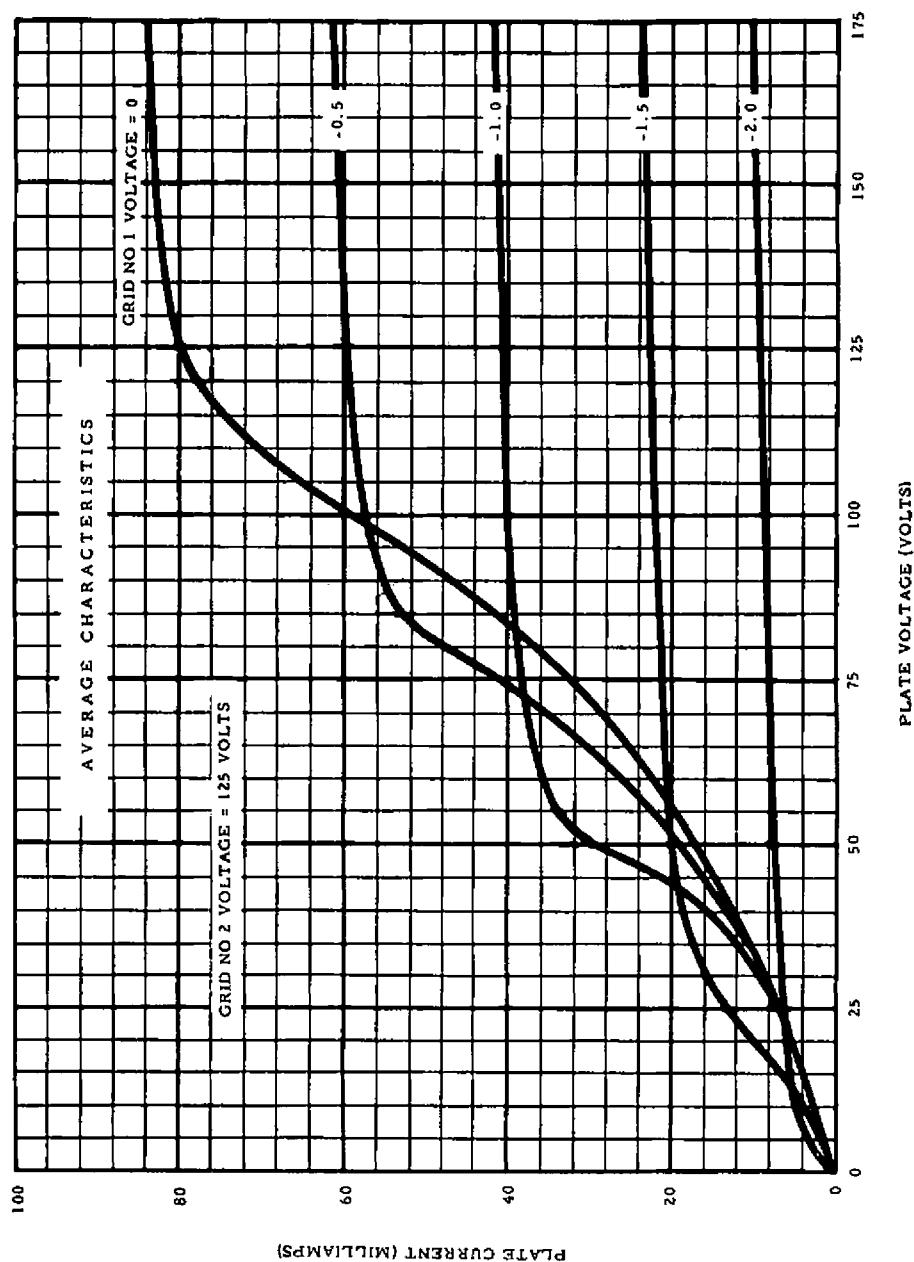
3. Harmonic Distortion.

The voltage ratio between fundamental frequency (F), and second harmonic (2F) respectively third harmonic (3F) as function of the load resistance at different power outputs under typical operating conditions is shown in the figure below.



TETRODE AMPLIFIER

DEPENDABLE LONGLIFETYPE

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THE PRINCIPLES OF THE TROCHOTRON RYG 10

During the development stage the trochotron RYG 10 was called AD 3. It is a high vacuum electron tube with an oxide-coated cathode /fig. 1/, designed to operate in a magnetic field as a ring counter with ten /or less/ positions. The ten symmetrically arranged electrodes are called spades and the round electrode outside these is called the plate.

The strength of the magnetic field has to be so large that, when all spades are at the working potential, no current flows to them. If from this condition the potential of one of the spades is lowered, a current - potential diagram similar to fig. 2 is obtained. It follows that three operating points /A, B and C/ are possible if a resistance is connected to the spade. Of these three points, however, only A and C are stable. The appearance of the electron beam when one spade is "locked down" /i.e. at the operating point A of fig.2/ is shown in fig.3. The reason for this behaviour is that electrons moving in crossed electric and magnetic fields mainly follow an equipotential line. The direction of the rotation of the beam may be reversed by rotating the direction of the magnetic field 180 degrees.

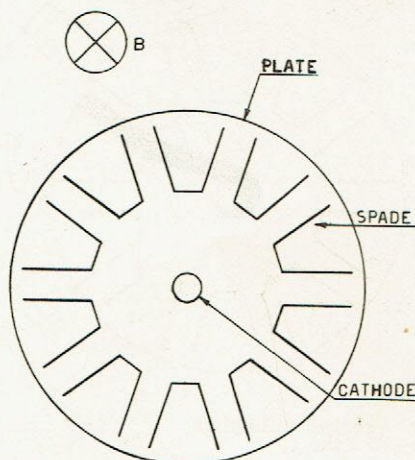


FIG 1 TROCHOTRON RYG 10, SHOWN IN A PLANE PERPENDICULAR TO THE CATHODE.

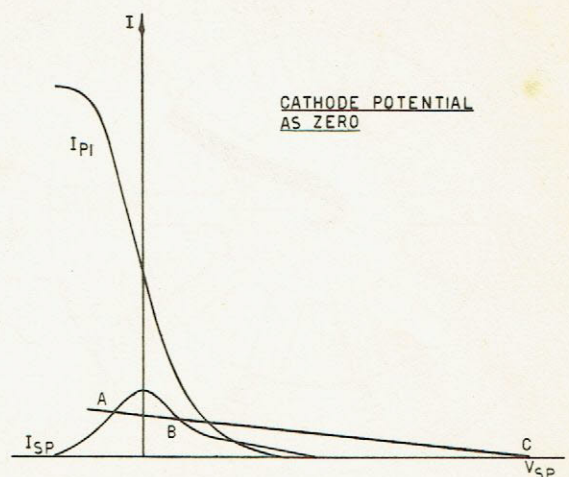


FIG 2 CURRENT TO ONE SPADE AND TO THE PLATE AS A FUNCTION OF THE POTENTIAL OF THE PERTINENT SPADE. PLATE POTENTIAL HAS ABOUT THE SAME VALUE AS THAT FOR OTHER SPADES.

It is now possible to make a simple stepping device. To each spade is connected an RC circuit as in Fig.4. Assume at first that spade n in fig. 4 is "locked down". Most of the electron current from the cathode thus goes to the plate /confer Fig.2/ If the plate potential is abruptly decreased to almost cathode potential most of the current will then go to the next spade $/n + 1/$ instead of to the plate. This current quickly charges the capacitor connected to this spade and the spade potential decreases. When this potential approaches the cathode potential, the whole beam will switch over to the next box and it is then necessary to restore the plate potential to its normal value in order to avoid that the beam steps further. At this moment the beam is locked to spade $/n + 1/$ and is divided between the plate and one spade in the same manner as before, but it is advanced one step. There it will stay until the next negative pulse is applied to the plate. The spade n now receives no current and its capacitor is consequently discharged by the corresponding resistor.

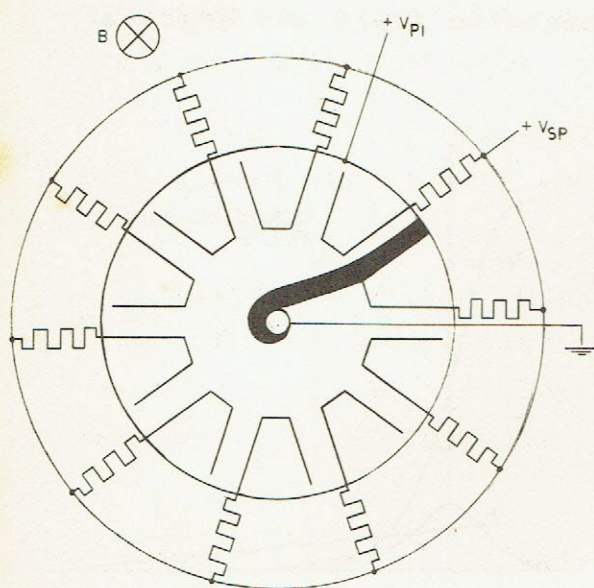


FIG 3 THE BEAM FORMATION WHEN ONE SPADE IS IN WORKING POINT A.

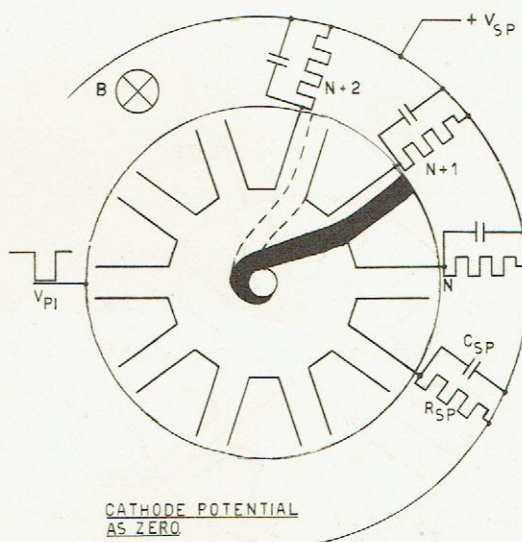


FIG 4 A SIMPLE STEPPING DEVICE USING THE TROCHOTRON RYG 10.

The speed of stepping is increased by decreasing the spade resistors and capacitors. Minimum values are expected to be of the order of 100.000 ohms and 10 pF. A suitable length of the stepping pulse applied to the plate is approximately

$$T_p = 0,8 \frac{C_{sp} \cdot V_{sp}}{I_{pl}}$$

provided that the plate pulse goes down to cathode potential. Because it takes a longer time to discharge the spade capacitor than to charge it with the current available in the trochotron, the time for one complete rotation of the beam /ten steps/ should not be less than $4 \cdot R_{sp} \cdot C_{sp}$.

Increased beam current /increased voltage and magnetic field strength/ contributes to the stability at lower spade resistor values. The use of a cathode resistor is recommended as this minimizes the influence of voltage variations. A variable cathode resistor is also convenient for compensating for possible differences in the circuits or of the magnetic field.

The max. counting speed of the tube itself is of the order of 1.000.000 counts/sec. while reasonable simple driver circuits permit counting speeds up to 400.000 counts per sec.

The position of the beam in the tube can be read electrically from the spade voltage or visually from the fluorescent screen.

Resetting to any of the ten positions may be accomplished by momentarily removing all spade potentials and then reapplying them whilst delaying the voltage rise at the relevant spade. This can easily be achieved by an RC combination or by means of mechanical contacts.

The magnetic field needed can be produced by a cylindrical Alnico magnet 45 mms long and with a wall thickness of more than 5 mms

DESIGNATIONS

V_{sp} = Spade Voltage

R_{sp} = Spade Resistor

V_{pl} = Plate Voltage

B = Magnetic Induction

I_k = Cathode Current

All voltages refer to the cathode potential as 0.

RECOMMENDED WORKING CONDITIONS

Heater Voltage	6.3	volts
Heater Current	0.3	amps
Plate Dissipation maximum	1.0	watt
Spade Dissipation, each spade	0.5	watt

$$\frac{V_{sp}}{B^2} = \text{approx. } 10^5 / \text{volts resp. volt} \cdot \text{sec/m}^2 /$$

$$V_{pl} \text{ approx.} = V_{sp}$$

For sufficient visual indication the plate voltage should not be lower than 80 volts.

Keeping $\frac{V_{sp}}{B^2}$ constant, I_k varies as $V_{sp}^{3/2}$.

NORMAL WORKING POINT

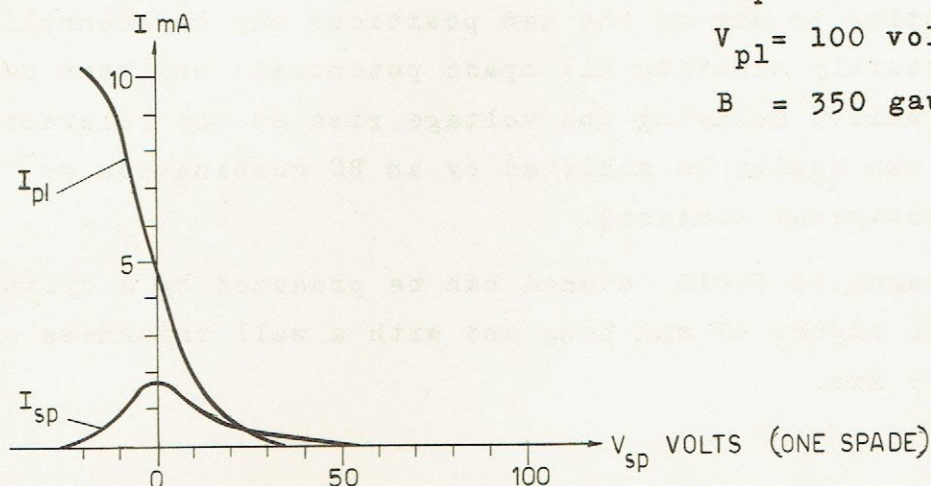
Spade Voltage	100	volts
Plate Voltage	100	volts
Magnetic Induction, approx.	350	gauss
Cathode Current, approx.	10	mA
Spade Resistor	0.2	megohm

EXAMPLE FOR THE CURRENT - VOLTAGE CHARACTERISTICS

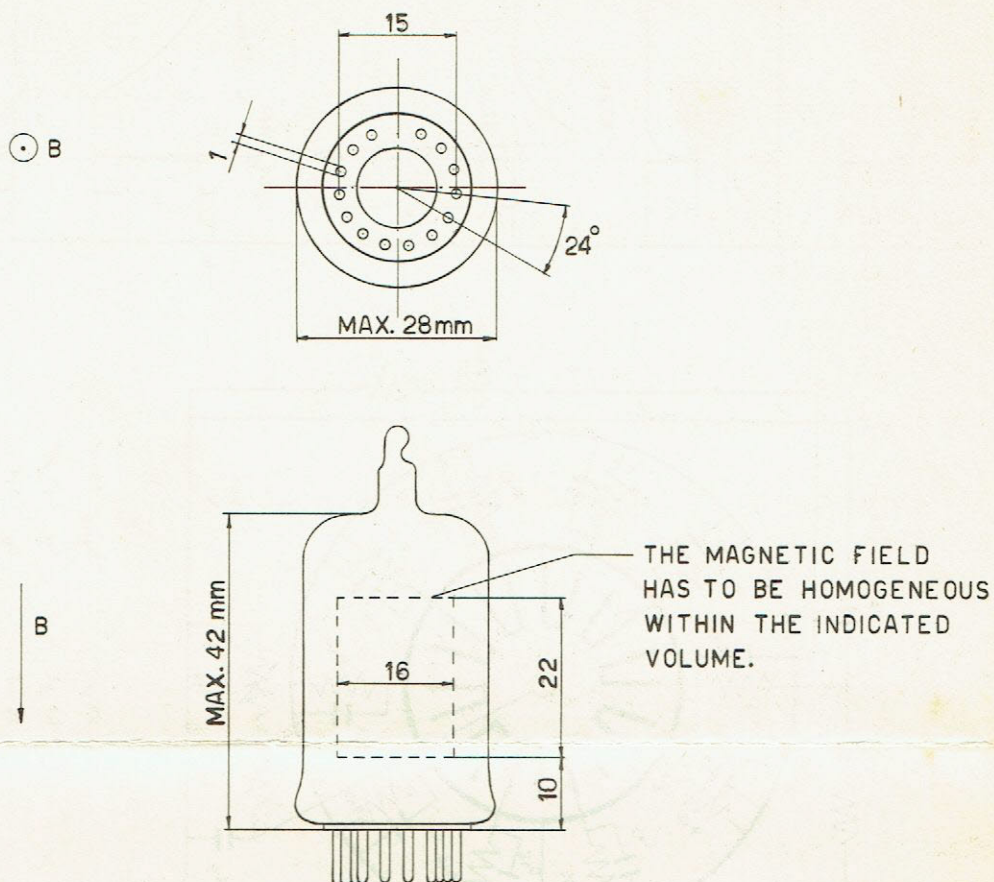
Other spades: $V_{sp} = 100$ volts

$V_{pl} = 100$ volts

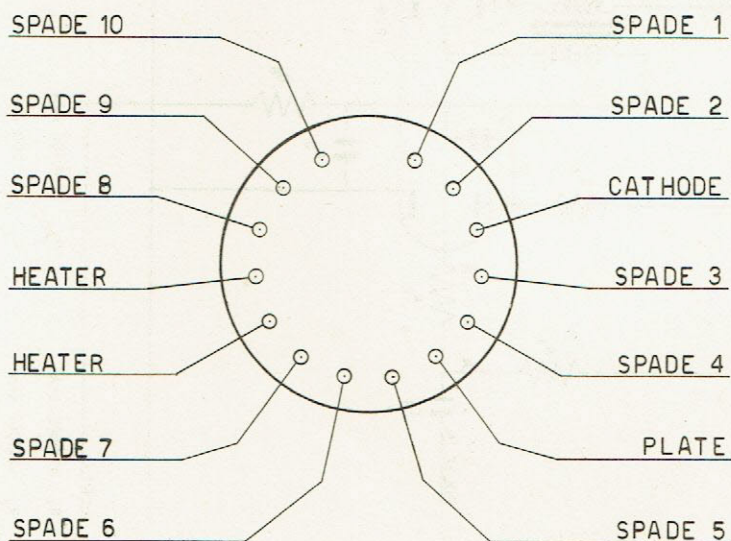
$B = 350$ gauss



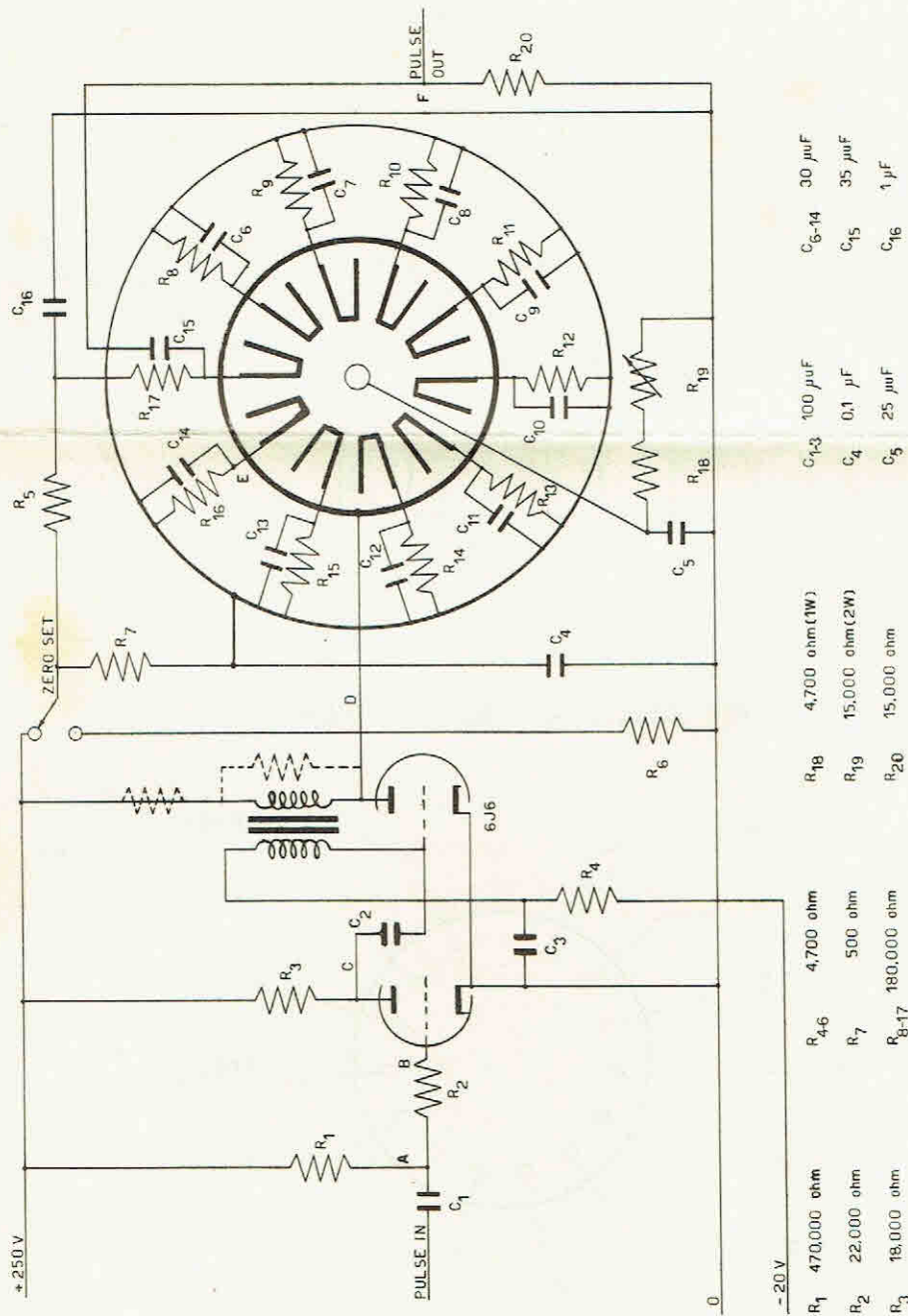
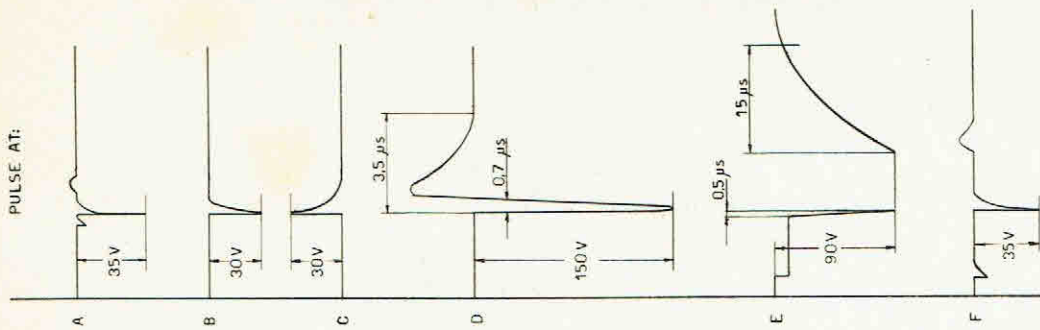
BOTTOM AND SIDE VIEW OF THE TUBE



SOCKET CONNECTION. BOTTOM VIEW.



Counting speed max. 300.000 pulses/sec.



Coaxial Trochotron for Pulse Counting

O STERNBECK, TELEFONAKTIEBOLAGET L M ERICSSON, STOCKHOLM

U.D.C. 621.385.832:621.218.572

The action of the trochotron is based on the characteristics of an electron beam in a magnetic field that is crossed by an electric field. An electron beam, which moves in a trochoidal path perpendicular to the directions both of the magnetic and electric fields, is characterized primarily by its easy deflectability and its capacity to maintain its width even at high currents and low voltages.

The principle of the trochotron originates in an invention of H. Alfvén and H. Romanus.¹ A number of types of electron tubes have been developed by Telefonaktiebolaget L M Ericsson on the trochotron principle. One of them, designated RYG 10, manufactured by AB Svenska Elektronrör, is described below.

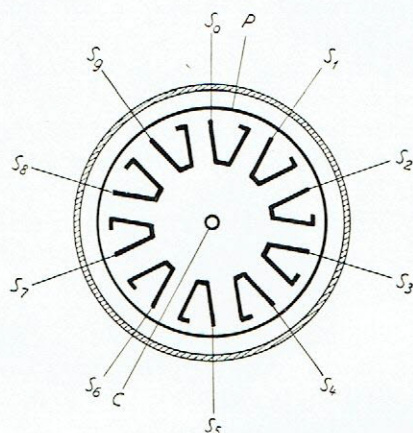


Fig. 1
Schematic cross-section of coaxial trochotron, type RYG 10

S_0-S_9 , control electrodes
P receiving electrode
C cathode

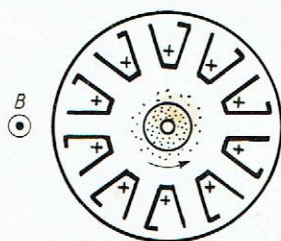


Fig. 2
The coaxial trochotron with all control electrodes positive

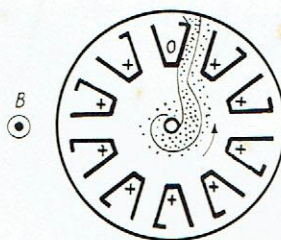


Fig. 3
The coaxial trochotron with 1 control electrode on cathode voltage and the remainder positive

Method of Operation

The coaxial trochotron RYG 10 (previously called AD-3) is a high-vacuum tube, in which the electron beam can be guided into ten different positions or "boxes" and which, when suitably connected, can retain the electron beam in one box until it is moved on to another. A cross-section of the tube is shown in fig. 1. Round an oxide-coated cathode forming the axis are ten V-shaped control electrodes (called spades) so arranged as to form boxes with parallel sides between them. The control electrodes are surrounded by a cylindrical receiving electrode which encloses the control electrodes forming the bottom of the boxes. For the correct functioning of the tube the space enclosed within the receiving electrode must be permeated by a magnetic field with its lines of force parallel to the longitudinal axis of the cathode (perpendicular to the plane of the paper in fig. 1).

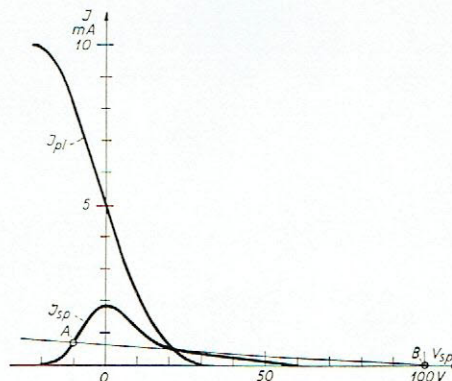
If all control electrodes are made positive in relation to the cathode and the strength of the magnetic field is properly balanced, the magnetic field repels the electrons emitted from the cathode before they reach the control electrodes and compels them to return to the cathode. The returning electrons form a negative space charge around the cathode which further suppresses the emission of electrons, fig. 2. In that condition no current flows in the tube, but around the cathode there circles a swarm of electrons, the direction of movement of which is determined by the direction of the magnetic field. When the potential of one of the control electrodes is now lowered to, for example, that of the cathode, the swarm of electrons can no longer circle around the cathode, but is deflected in the direction of the negative control electrode and into the box between the negative control electrode and the positive control electrode immediately preceding it, finally striking the receiving electrode, fig. 3. An electron current is thus obtained in the tube, the strength of which is determined by the geometry of the tube, the voltage of the control electrodes and the strength of the magnetic field. The transition from dead to live condition due to lowering of the potential of a control electrode is continuous, as will be seen from fig. 4, which shows the current-voltage conditions in the tube. It is observed that the characteristic of the control electrode is negative, i.e. that the current increases if the voltage of the control electrode is decreased. The negative characteristic of the control

¹ ALFVÉN, H. & ROMANUS H.: Valve with trochoidal electronic motion. Nature 160 (1947) p. 614.

Fig. 4

X 4931

Control electrode current (I_{sp}) and receiving electrode current (I_{pl}) as function of the control electrode voltage (V_{sp}). The voltage of the remaining control electrodes is 100 V.



electrodes permits automatic locking of the beam if every control electrode is connected in series with a sufficiently high resistance. In fig. 4 a load line is drawn, and it is manifest that there will be two stable points of operation for the control electrode in series with such a resistance, viz., point A in the neighbourhood of the cathode potential and point B at the feed potential. Thus in a trochotron with control electrodes connected in series with high resistances, if the potential of a control electrode is momentarily lowered to the neighbourhood of the cathode potential, the voltage drop in the series resistance takes over the task of holding the potential of the control electrode at a sufficiently low level, and so-called locking is obtained. To ensure locking with a 100 V control electrode feed voltage, a resistance of about 200,000 Ω will be required.

As is seen from fig. 4, only part of the current in the tube is received by the control electrode, the major portion passing on to the receiving electrode. If the potential of the receiving electrode is reduced below the cathode potential, the electrons are unable to reach the receiving electrode but go to the immediately preceding control electrode. If a resistance of sufficient magnitude is connected in series to the control electrode, the latter undergoes a drop in voltage and takes over the locking of the beam. If the potential of the receiving electrode is still below that of the cathode, the beam continues to the previous control electrode, and so on. Thus the beam itself advances from control electrode to control electrode in the opposite direction to the electrons. On the other hand if the potential of the receiving electrode is again made positive after the beam has moved one step, the beam is retained in the position it last assumed. The normal use of the coaxial trochotron RYG 10 as pulse counter is mainly based on its ability to compel the beam to move one step at a time by means of short negative pulses on the receiving electrode. The condition necessary for stable stepping is that the time during which the receiving electrode is negative coincides with the time required by the beam to lower the voltage of the control electrode from feed voltage to cathode voltage.

Design

The aim has been to make the design of the tube as simple as possible. The number of components has therefore been kept low. The possibility exists of offering an inexpensive product in the event of large scale manufacture.

The tube is in the form of an all-glass bulb with 14-pole button stem with lead-in wires of the same type as in miniature tubes. The tube is 25 mm in diameter and 52 mm long. The electrode-system, which forms a composite unit kept together by the receiving electrode, is spot-welded direct to the lead-in wires. The material used in control and receiving electrodes is a non-magnetic nickel-chromium alloy. The cathode is of the oxide-coated type and is heated by a 6.3 V, 0.3 A coiled filament. The magnetic field required for operation is generated by a separate cylindrical, axially magnetized permanent



Fig. 5

X 4932

Perspective drawing of RYG 10

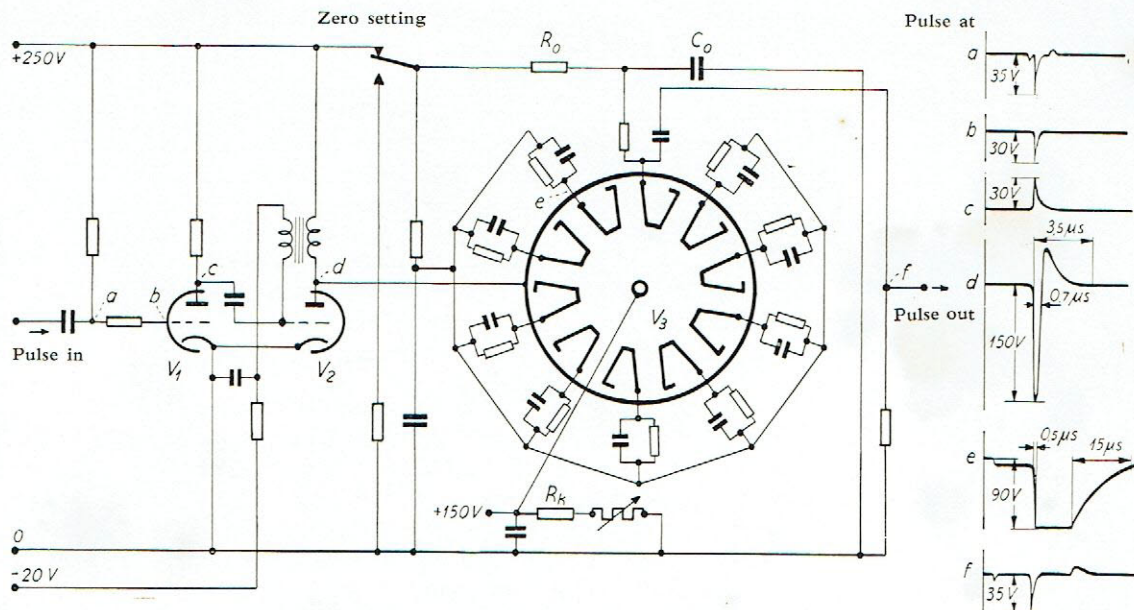


Fig. 6
Wiring diagram for decade counter
using RYG 10

X 7658

magnet surrounding the tube. At a control electrode voltage of 100 V the requisite magnetic field is about 345 gauss.

The position of the beam in the tube is indicated by the voltage drop on the control electrode which locks the beam. A visual indication is often sufficient and, in order to save the roundabout method involved in using separate glow-lamp indicators, the tube has been provided with a fluorescent screen. The fluorescent screen is formed integral with the receiving electrode in such a way that 10 boxes, open at the top, are formed between screen and receiving electrode. Each of these boxes is connected to the corresponding box between the control electrodes by means of holes in the receiving electrode. A voltage of about 100 V is required for clear indication.

Decade Counter

Simultaneously with the tube, a basic circuit suitable for pulse counting has been developed (fig. 6). The stepping principle employed is that described above, involving the movement of the beam one step by means of a short negative pulse on the receiving electrode. To make the required pulsing time comparatively independent of tube and coupling capacitances, all control electrode resistors are coupled in parallel to 25 μF capacitors. A drop in voltage of 100 V for a locked control electrode at a total control electrode capacitance of 40 μF corresponds to a charge of

$$CV = -100 \cdot 40 \cdot 10^{-12} = -4 \cdot 10^{-9} [\text{As}]$$

At a control electrode voltage of 100 V the beam current is about 10 mA and, if the current in the resistance is disregarded, the requisite pulsing time will be

$$t = \frac{CV}{I} = \frac{-4 \cdot 10^{-9}}{-10^{-2}} = 4 \cdot 10^{-7} [\text{s}]$$

The above-mentioned pulsing time will determine the capacity of the counter to distinguish between two successive pulses. For counting longer trains of pulses the speed is limited also by the time constant of the control electrode circuit. The time taken by one revolution (10 steps) must not be less than four times the time constant of the control electrode circuit if the tube is to count irregular trains of pulses.

The pulse is generated by a blocking oscillator V_2 which is started by the phase changer and the amplifier V_1 . The pulses to be counted enter V_1 in

the form of negative voltage pulses. If the counter forms part of a larger counting unit, the pulse arrives from the preceding counter. The grid circuit of V_1 has been made insensitive to negative pulses below a given amplitude, and also to all positive pulses. The blocking oscillator is a stable and simple pulse generator of sufficiently low impedance. Unfortunately it limits the speed of the counter to about 400,000 pulses per second, while RYG 10 with a more complex pulse generator comes up to 10^6 pulses per second.

In order that an outgoing pulse shall be obtained on every tenth incoming pulse, the shunt capacitor of control electrode no. 0 is connected in series with a resistance. Every time the beam enters box 0, a sharp negative outgoing pulse is received.

At zero-setting the feed to all control electrodes is first broken and no current flows in the tube. Thereafter feed voltage is again applied to all control electrodes. Control electrode No. 0 does not reach full voltage until rather later due to the delay in its combined resistance and capacitance R_0C_0 . Since the potential on control electrode 0 is at first lower than on the remaining control electrodes, the beam to control electrode 0 is locked.

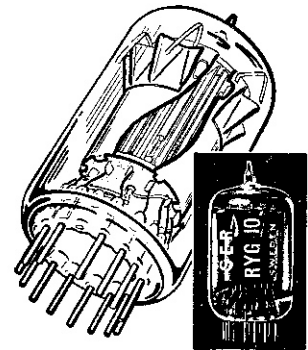
Thanks to the complete symmetry of the tube, zeroing can be performed in any of the ten positions. Reading and zeroing arrangements may be considerably varied to meet different requirements of speed and amplitude.

The counter is extremely reliable in operation. Despite the absence of precision components it functions at variations in feed voltage of from 200 to 300 V. No adjustment is necessary on replacement of tubes, nor trimming of individual units. On the other hand the magnet must from the start be magnetized to the proper field strength and the magnetic field must be parallel to the axis of the tube.

Summary

RYG 10 is up to this time the only commercial decade pulse counter tube which permits direct setting to a desired position, indication of the beam position in the form of an electric potential from all positions, and a high counting speed. Its simplicity, small dimensions and clear indication, and its applicability in simple coupling arrangements, give promise of its finding wide use within the fields of mathematical machines and other instruments.

The RYG 10 is a pulse counting tube in which a beam is formed with the help of a magnetic field. The beam position is indicated on a fluorescent screen in the tube, and also as a voltage on each of the ten control electrodes. Switching rates up to 1 mc can be obtained. The tube is used as a decade counter in Geiger-Müller apparatus, in industrial counting equipment, electronic computers, frequency dividers and the like.



MECHANICAL DATA

Basing designation

Pin No	Connected to
1	Spade 1
2	Spade 2
3	Cathode
4	Spade 3
5	Spade 4
6	Plate
7	Spade 5
8	Spade 6
9	Spade 7
10	Heater
11	Heater
12	Spade 8
13	Spade 9
14	Spade 10

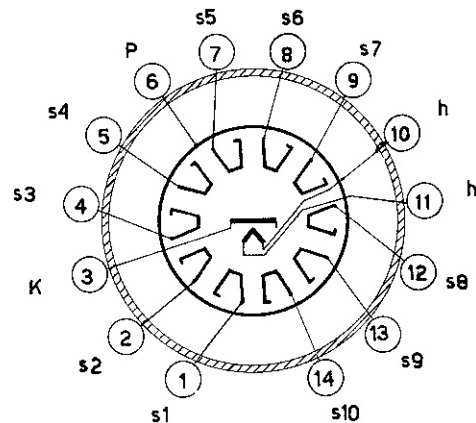


FIG. 1
BOTTOM VIEW

Dimensions

Overall Length, max.	55 mms
Diameter, max.	28 mms
Diameter of pin circle	15 mms
Diameter of pins	1 mm

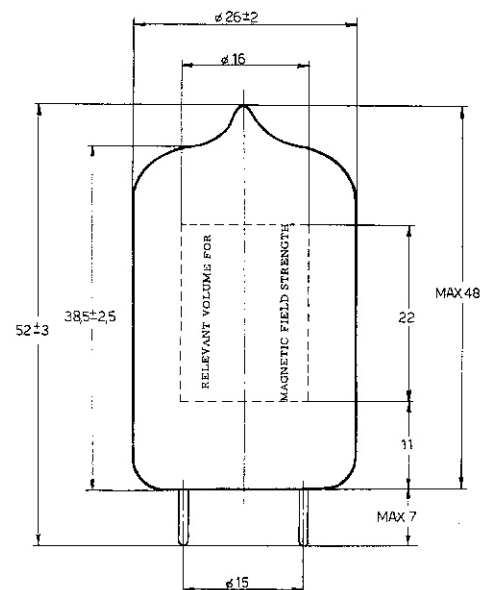


FIG. 2

Magnetic Field

A cylindrical magnet (see fig. 3) is recommended to provide the magnetic field. The magnet should be made of homogeneous material, and should give a field in the direction of the axis of the cathode with maximum variation of the order of a few percent within the relevant volume in fig. 2.

The field strength is defined as the mean value over the relevant volume, measured with a fluxmeter and a coil of the same size as the electrode structure of the tube.

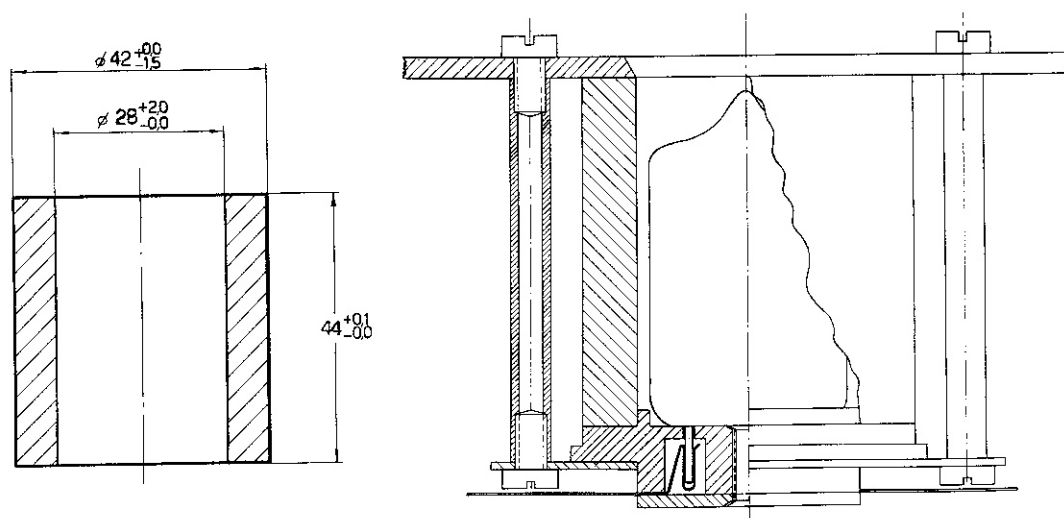


FIG. 3

ELECTRICAL CHARACTERISTICS

Heater Voltage	6.3	volts
Heater Current	0.3	amp
Plate Dissipation, max.	2.0	watts
Spade Dissipation, each spade, max.	0.5	watt
Heater-Cathode Voltage, max.	100	volts

Interelectrode Capacitances

Spade to other electrodes, approx.	2	uuF
Plate to other electrodes, approx. *	22	uuF

* Measured with the tube inside a magnet, connected to the spades and cathode, having an inside diameter of 29 mms.

Typical operation I (for max. recurrence frequencies 400 kc/s)

Supply Voltage (ref. to ground)	250	volts
Magnetic Field Strength	325	gauss
Spade Capacitance (incl. internal cap.)	33.5	uuF
Spade Resistance	180,000	ohms
Cathode Resistance (adjust to specified cathode current)	20,000	ohms
Cathode Current **	7.5	milliamps
Rise & Faltime of Drive-pulse, approx.	0.05	microsec.
Width of pulse at cathode potential	0.5	microsec.

Typical operation II (for max. recurrence frequencies 1 mc/s)

Supply Voltage (ref. to ground)	350	volts
Magnetic Field Strength	375	gauss
Spade Capacitance (incl. internal cap.)	13	uuF
Spade Resistance	150,000	ohms
Cathode Resistance (adjust to specified cathode current)	20,000	ohms
Cathode current **	11.5	milliamps
Rise & Falltime of Drive-pulse, approx.	0.05	microsec.
Width of pulse at cathode potential	0.3	microsec.

** At pulse recurrence frequencies above 100 kc/s, the cathode current decreases somewhat.

Note. If visual indication of the beam position is desired, the plate should be operated at not less than 80 volts.

TECHNICAL INFORMATION

CONSTRUCTION AND OPERATION

The RYG 10 is a high-vacuum tube in which the electron beam can be guided to 10 positions, or boxes, arranged around the cathode, and can be set direct to any position desired.

External circuit components hold the beam in a given position until it is required in another.

Ten V-shaped electrodes, called spades, form a circle of ten boxes with parallell sides around the oxide-coated cathode. The plate is a cylinder outside the spades (see fig. 4).

CLEAR CONDITION

If all the spades are positive with respect to the cathode, the magnetic field will deflect the emitted electrons before they reach the spades, and they will be driven back towards the cathode. This establishes a negative space charge around the cathode, which suppresses further emission. Under these conditions, the tube passes no current. A cloud of electrons circle around the cathode, their direction of rotation being determined by the polarity of the magnetic field (see fig. 5).

ONE SPADE AT CATHODE POTENTIAL

If one of the spades is at cathode potential, the electrons can no longer circle around the cathode, but are deflected towards the spade. They pass into the box formed by the negative spade and its preceding neighbour, and then strike the plate (see fig. 6).

The strength of the electron flow thus established depends on the geometry of the tube, the spade voltage, and the intensity of the magnetic field. The variation of the plate and spade currents with the spade voltage appears in fig. 7, which also shows that a part of the spade characteristic has a negative slope. It is this property upon which the locking operation of the tube is based.

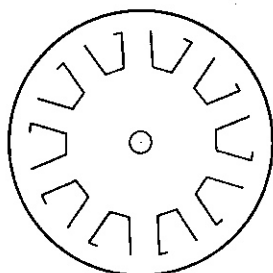


FIG. 4

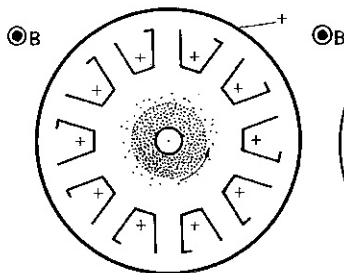


FIG. 5

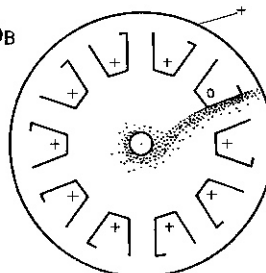


FIG. 6

LOCKING THE BEAM

If a sufficiently high resistance is placed in series with each spade, the negative spade characteristic allows automatic locking of the beam; when the voltage on a spade falls momentarily to cathode level, the voltage drop across the resistance holds the spade voltage low enough to lock the beam in position.

A spade with such a series resistance has two stable operating points (see fig. 7):

- Near the cathode voltage, where the beam is automatically locked and current flows in the spade circuit.
- At the supply voltage, where no spade current flows.

ADVANCING THE BEAM

Fig. 8 shows how the beam can be advanced in the RYG 10.

There is an RC circuit in series with each spade. Assume that the beam is locked by spade N, a larger part of the electron flow going to the plate. If the plate voltage is now lowered to the cathode level or below it, the electrons will flow to spade N + 1, following the path indicated by the dashed lines in the drawing. The resultant current charges the capacitor in the spade circuit, and the spade voltage drops. When the voltage has dropped to a certain value, the beam is locked to spade N + 1 and the entire beam advances to the next box. The plate voltage must now resume its positive value, as otherwise the beam will continue to rotate.

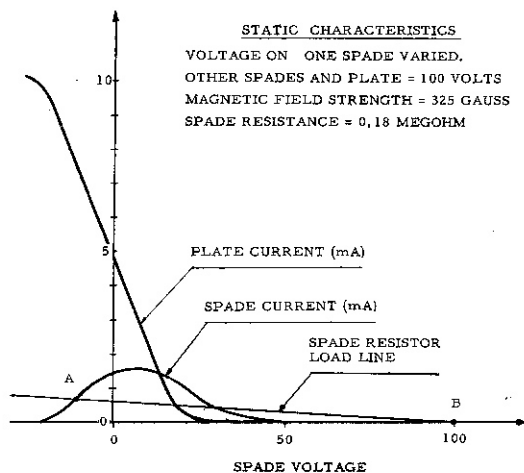


FIG. 7

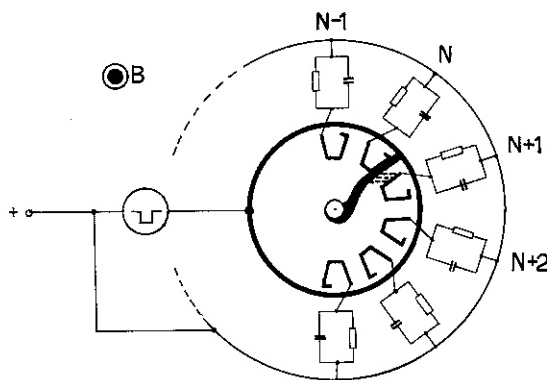


FIG. 8

CONDITIONS FOR OPERATION

Two conditions must be met for the tube to function as a counter:

1. The values of the spade voltage, the magnetic field strength and the spade circuit resistance must be such that the beam can be held in every box.
2. The duration of the drive pulse must be such that the beam advances one position only, for each pulse.

SUPPLY VOLTAGE LIMITS

For most applications, the two characteristics shown in fig. 9 are of importance.

Characteristic I is obtained by varying the voltage on spade N, with the other spades and the plate at the supply voltage. (Compare fig. 7, where the same curve is shown).

Characteristic II is obtained by varying the voltage on spade N with the spade N - 1 at locking voltage E_L , and the plate and other spades at the supply voltage.

The lowest supply voltage which can be used is that at which the loadline just cuts the peak of characteristic curve I (see fig. 10). At lower supply voltages, the spade current characteristic drops so that the loadline does not cut the curve, and the spades do not lock the beam.

The highest supply voltage which can be used is that at which the tail of curve II just touches the loadline (see fig. 11). At higher voltages, selfrotation occurs.

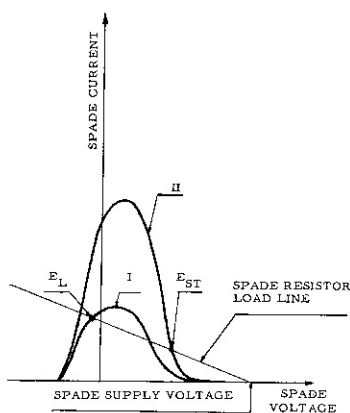


FIG. 9

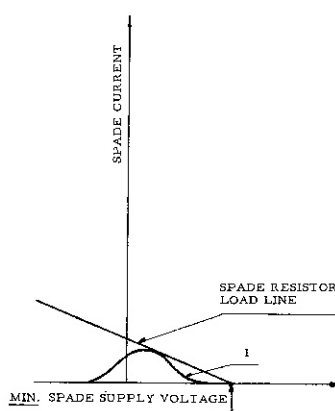


FIG. 10

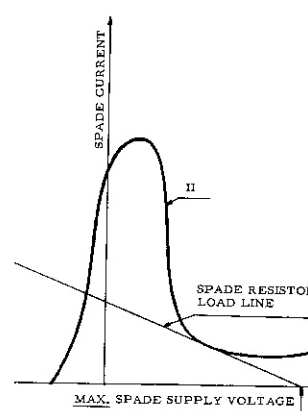


FIG. 11

SHAPE OF DRIVE PULSE

The pulse duration must be sufficient to allow the voltage on spade $N + 1$ to drop below the beam advance value (E_{ST} in fig. 9); otherwise, the beam will not advance.

The pulse must not last long enough, however, to allow the voltage on spade $N + 2$ to drop below E_{ST} , as the beam will then advance more than one position.

The amplitude of the pulse must be great enough to hold the plate voltage down to the cathode level or below it during the stepping interval.

For the following discussion the effective pulse width is defined as the time the plate voltage is equal to or below cathode level.

To prevent the tube capacitances and stray capacitances from seriously affecting the stepping we recommend a value of not less than 10 μF for the spade capacitor.

STEPPING SPEED

As the spade voltage has to obtain its initial value before the beam returns, the time for a complete rotation (10 positions) is determined by the time required for the spade capacitor to discharge.

The time that should be allowed for one rotation is:

$$4 \cdot R_{sp} \cdot C_{sp} \quad (1)$$

R_{sp} should be at least 100,000 ohms. At values lower than 170,000 ohms, it is necessary to use high voltages and strong magnetic fields so as to increase the cathode current. Reference is made to "Selecting operating conditions" on page 7.

CATHODE RESISTOR

To counteract variations in cathode current caused by variations in the supply voltage or input pulse rate or by aging of the magnet, it is advisable to use a resistor in series with the tube, usually a cathode resistor.

INDICATION OF BEAM POSITION

The fluorescent screen in the tube provides visual indication of the beam position. Since the potential of the spade to which the beam is locked is at cathode level, electrical indication can also be obtained. Load resistors down to 3 megohms may be used in the spade circuits without endangering beam advance.

ZEROING

Since the tube is symmetrical in construction, it can be zeroed to any of its ten positions. The simplest procedure is to open the voltage supply to all spades, which clears the tube; then the supply voltage is applied again, but the voltage rise at the "0" spade is delayed by an RC circuit or by means of manual switching.

SELECTING OPERATING CONDITIONS

Notation:

E_{sp}	spade supply voltage with respect to cathode
E_p	plate voltage with respect to cathode
B	magnetic field strength, defined as in fig. 2
I_k	cathode current
R_{sp}	spade circuit resistance
C_{sp}	spade capacitance, including external capacitances
t	duration of drive pulse

A suitable operating point can be determined with the equations below.

To find the relationship between the spade supply voltage and the magnetic field strength:

$$\frac{E_{sp}}{B^2} = 0.96 \cdot 10^{-3} \quad \text{volt/}(\text{gauss})^2 \quad (2)$$

To find the spade circuit resistance:

$$R_{sp} \cdot \sqrt{E_{sp}} = 1.80 \cdot 10^3 \quad \text{kohm} \cdot (\text{volt})^{1/2} \quad (3)$$

To find the pulse duration:

$$\frac{t}{C_{sp}} \cdot \frac{I_k}{E_{sp}} = 1.10 \cdot 10^{-3} \quad \frac{\mu\text{s} \cdot \text{mA}}{\mu\text{uF} \cdot \text{V}} \quad (4)$$

Normally, E_p should be equal to E_{sp}

An operating point chosen from the above equations gives a favourable operation range. A view of permitted variations is given in fig. 12 to 14, where:

Fig. 12 shows the static characteristics for cathode current as a function of the supply voltage at different magnetic fields and with one spade locked by a resistor of 180,000 ohms.

Fig. 13 shows permitted voltage changes when all other parameters are kept at the values indicated on the diagrams. The working ranges should be considered as average values.

Fig. 14 shows that the working range decreases at higher counting speeds.

Figs. 15 and 16, finally, show the construction of driving circuits for different counting speeds.

AVERAGE CHARACTERISTICS

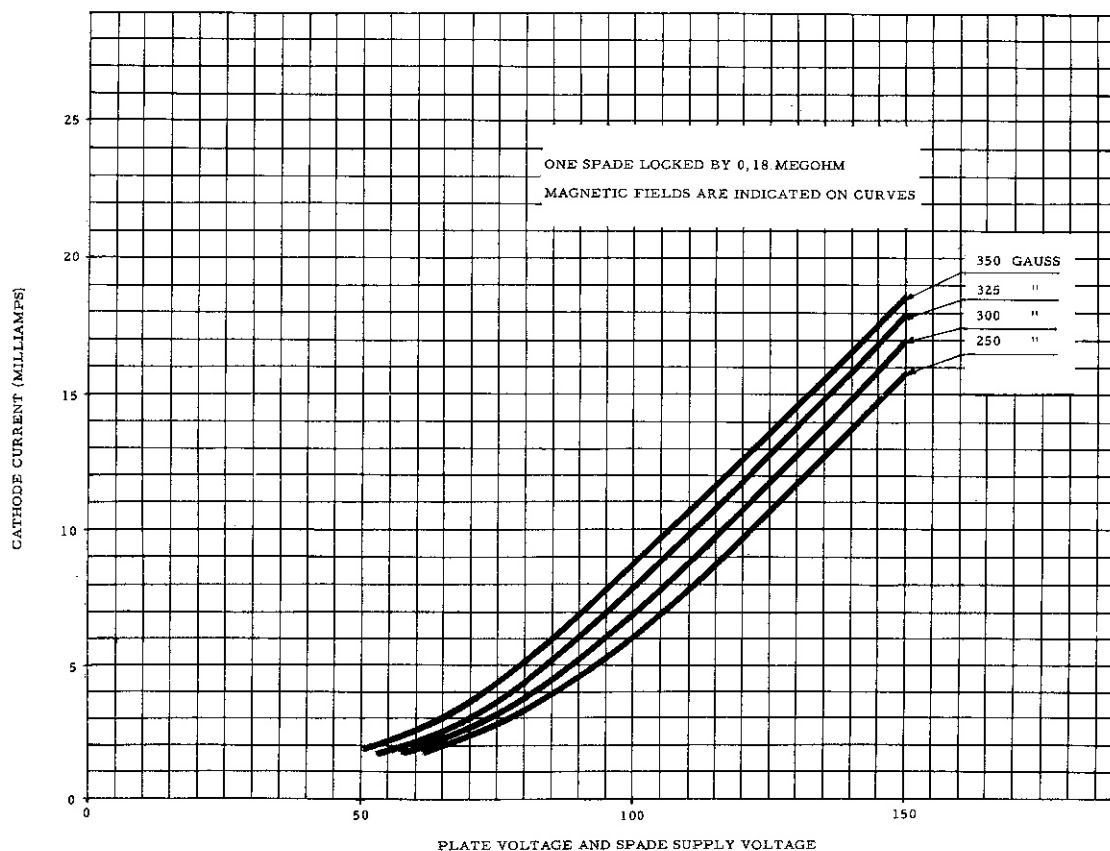
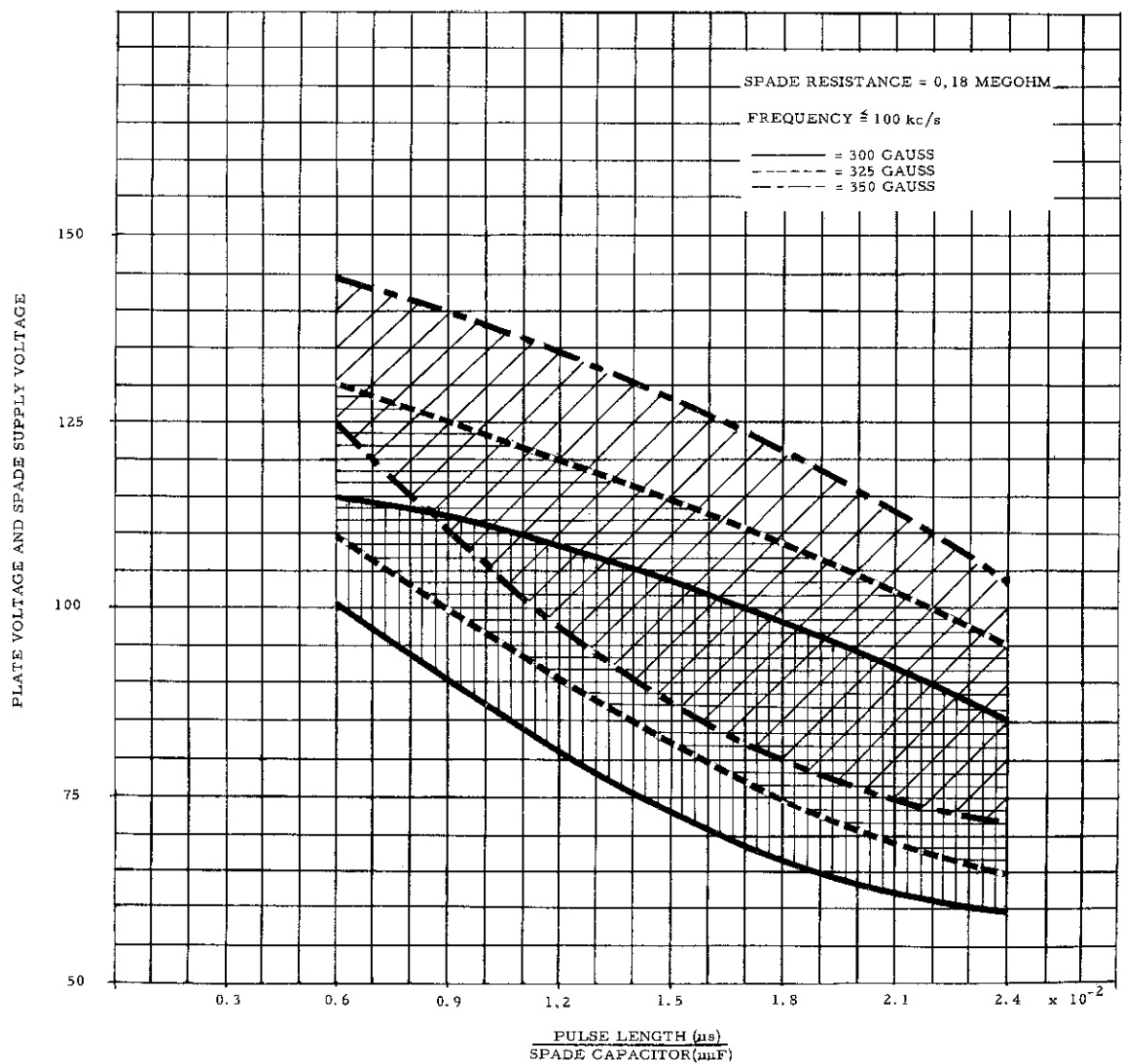


FIG. 12

AVERAGE CHARACTERISTICS



AVERAGE CHARACTERISTICS

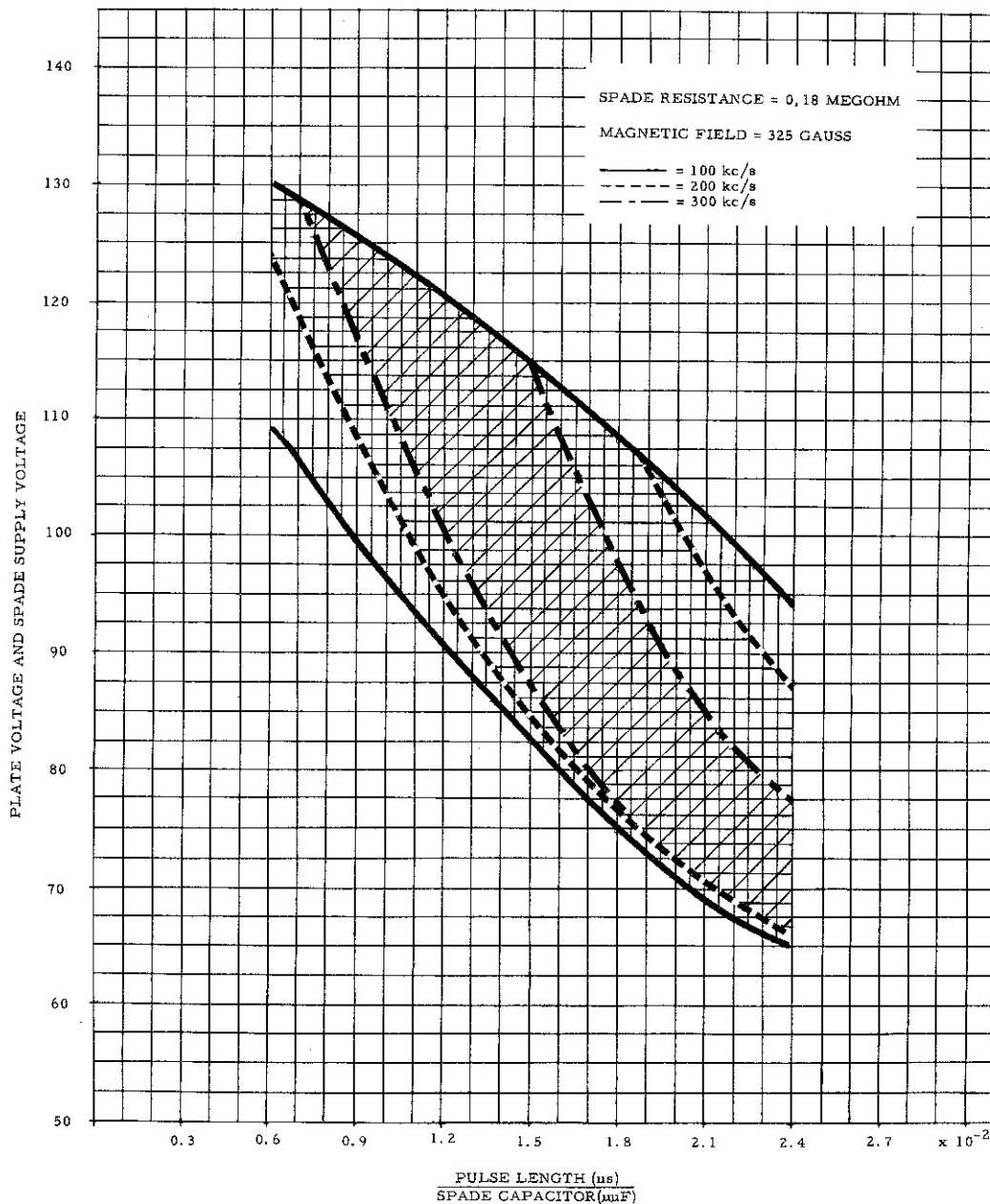


FIG. 14

TROCHOTRON DRIVING CIRCUIT FOR FREQUENCIES UP TO 1 Mc/s

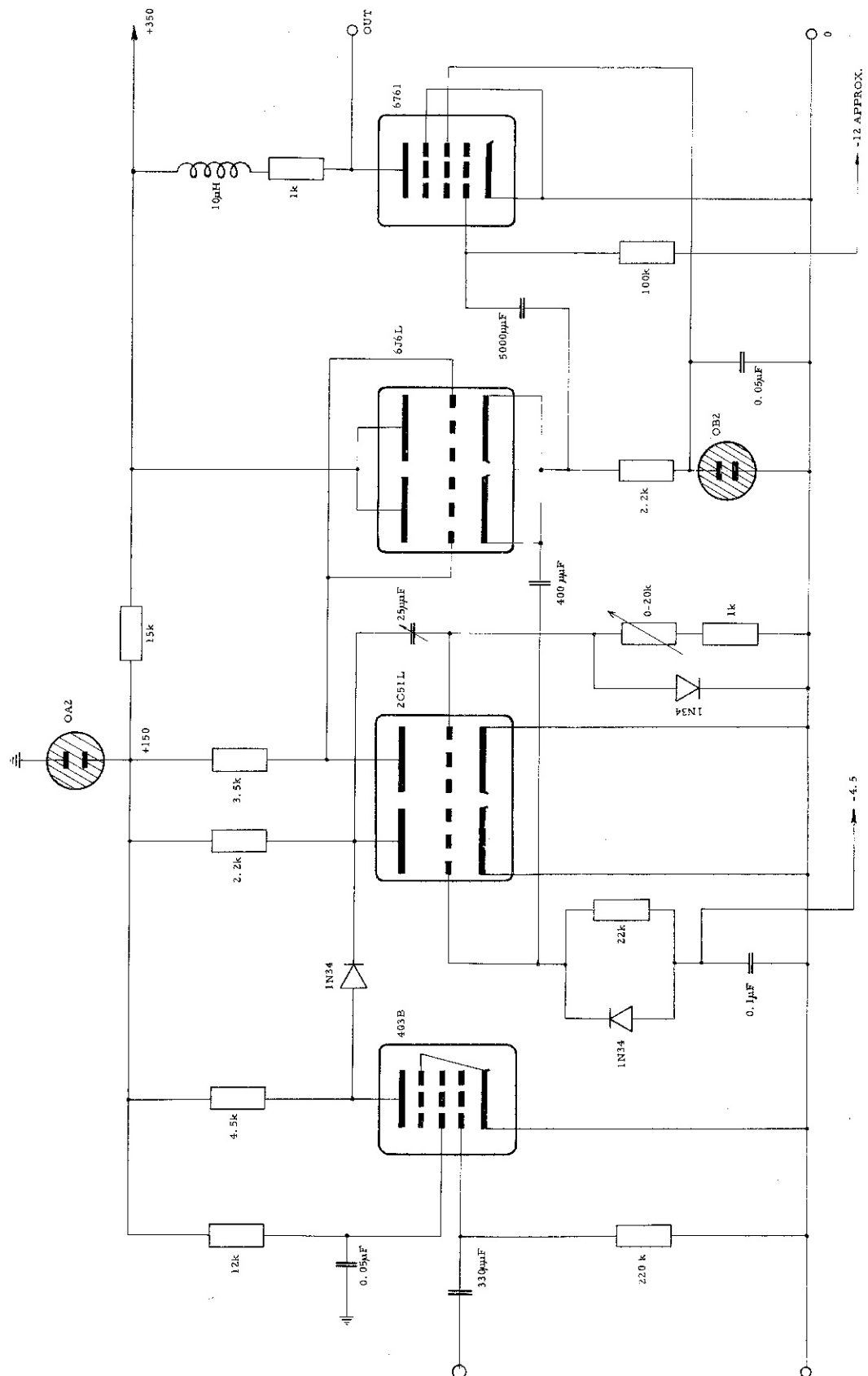


FIG. 15

RYG 10

BEAM SWITCHING TUBE TROCHOTRON

Ericsson
LM

DECADE COUNTER, USING THE TROCHOTRON RYG 10
Counting speed max. 300.000 pulses/sec.

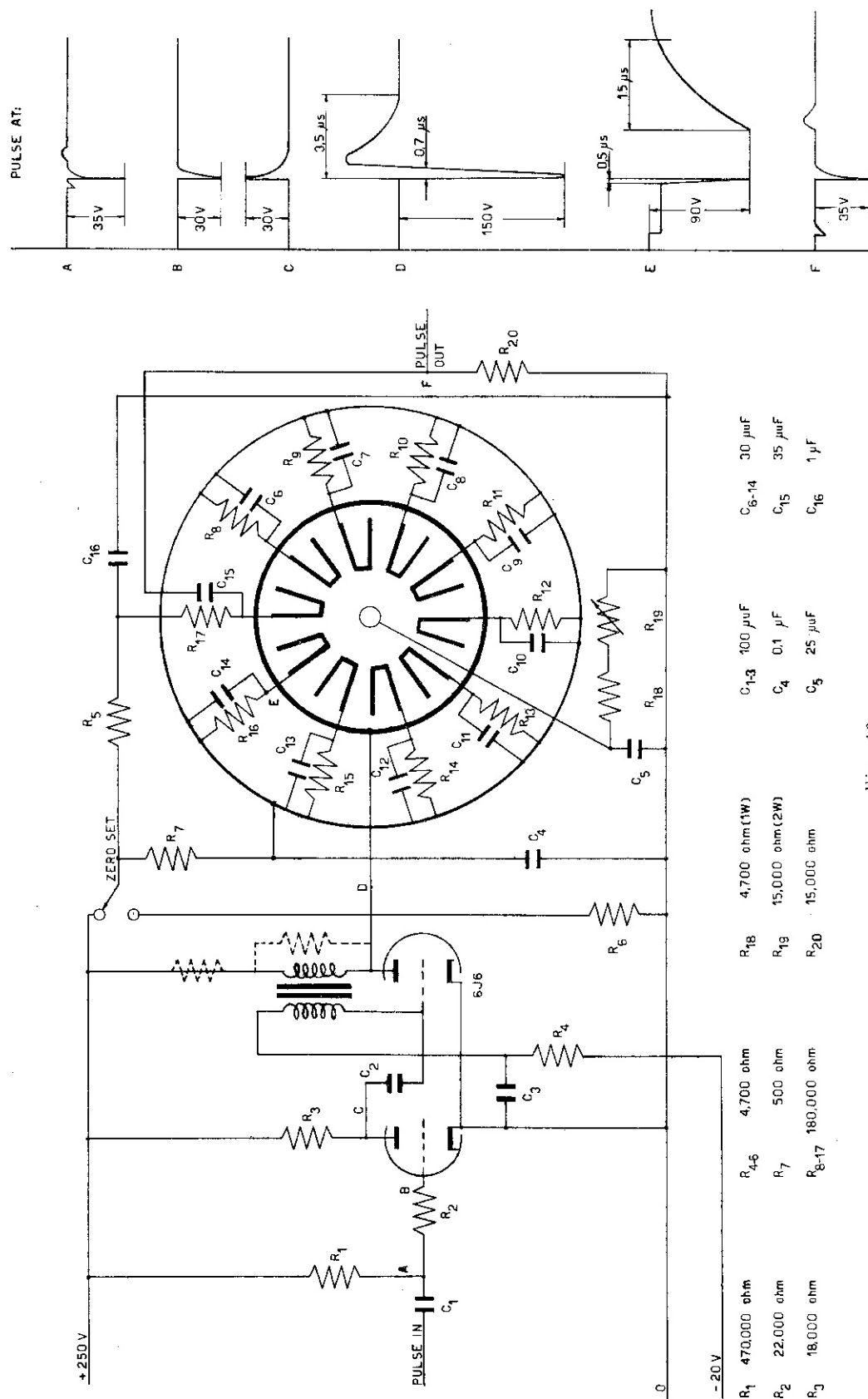


Fig. 16