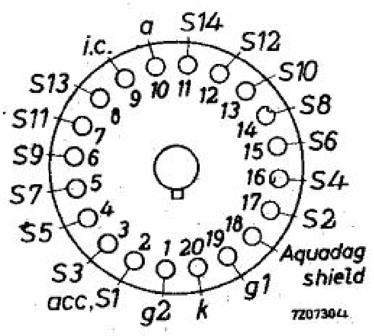
# 14 STAGE PHOTOMULTIPLIER TUBE

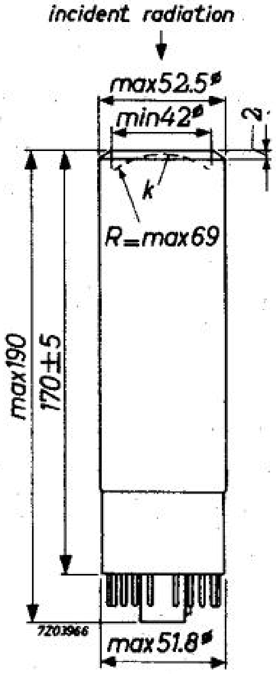
The tube is intended for use in nuclear physics where a high degree of time definition or a high time resolution is required (fast coincidences, life of unstable particles, Cerenkov counters).

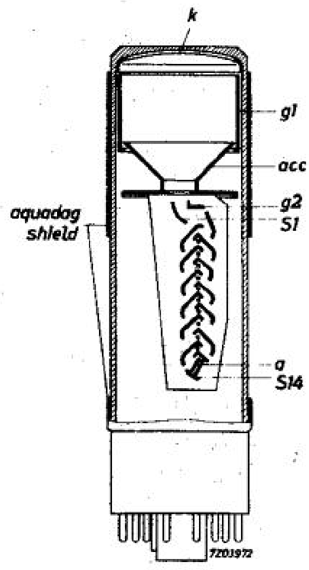
| QUICK REFERENCE DATA | | |
|---|---|---|
| Spectral response | type | A (S11) |
| Useful diameter of the photocathode | 42 | mm |
| Gain (at 2200 V) | $10^8$ | |
| Anode pulse rise time | 2 | ns |
| Linearity | up to 300 | mA |

**DIMENSIONS AND CONNECTIONS** Dimensions in mm

Base: 20-pin (Jedec B20-102)

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## ACCESSORIES

| | | |
|---|---|---|
| Socket | type | FE1003 |
| Mu-metal shields [1] | type | 56130 |
| | type | 56131 |

## GENERAL

Photocathode

| | | | | |
|---|---|---|---|---|
| Description | | semi-transparent, head-on, curved surface | | |
| Cathode material | | | Cs-Sb | |
| Minimum useful diameter | | | 42 | mm |
| Radius of curvature | | max. | 69 | mm |
| Spectral response curve [2] | | type | A (S11) | |
| Wavelength at maximum response | | | 4200 ± 300 | Å |
| Luminous sensitivity [3] | $N_k$ | av. | 65 | μA/lm |
| | | min. | 45 | μA/lm |
| Radiant sensitivity at 4200 Å | | | 55 | mA/W |

Multiplier system

| | |
|---|---|
| Number of stages | 14 |
| Dynode material | Ag-Mg-O-Cs |

Capacitances

| | | | |
|---|---|---|---|
| Grid No.1 to accelerator electrode | $C_{g_1/acc, S_1}$ | 25 | pF |
| Grid No.2 to all other electrodes | $C_{g_2}$ | 7 | pF |
| Anode to final dynode | $C_{a/S_{14}}$ | 7 | pF |
| Anode to all other electrodes | $C_a$ | 9.5 | pF |

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[1]) To avoid electric field distortion in the electron optical system the aquadag shield (pin No.18) must be connected to a voltage near to the cathode voltage. If the cathode is connected to the negative H.T., precautions should be taken to ensure a high-tension insulation between the aquadag shield and the mu-metal shield.

[2]) See spectral response curve in front of this section

[3]) Measured with a tungsten ribbon lamp having a colour temperature of 2850 °K

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## TYPICAL CHARACTERISTICS

With voltage divider A

| | | | | |
|---|---|---|---|---|
| Supply voltage for G = $10^8$ | $V_b$ | av. | 2200 | V |
| | | max. | 2500 | V |
| Anode dark current at G = $10^8$ 1) | $I_{a_o}$ | av. | 0.5 | µA |
| | | max. | 5.0 | µA |
| Linearity between anode pulse amplitude and input light pulse | | up to | 100 | mA |

With voltage divider B

| | | | |
|---|---|---|---|
| Linearity between anode pulse amplitude and input light pulse | up to | 300 | mA |
| Anode pulse rise time at $V_b$ = 2500 V 2) | | $2.10^{-9}$ | s |
| Anode pulse width at half height at $V_b$ = 2500 V 2) | | $4.10^{-9}$ | s |
| Transit time difference between the centre of the photocathode and the edge at $V_b$ = 2500 V | max. | $5.10^{-10}$ | s |
| Total transit time at $V_b$ = 2500 V 2) | | $36.10^{-9}$ | s |
| Maximum peak currents | | 0.5 to 1 | A |

## LIMITING VALUES (Absolute max. rating system)

| | | | | |
|---|---|---|---|---|
| Supply voltage 3) | $V_b$ | max. | 2500 | V |
| Continuous anode current | $I_a$ | max. | 2 | mA |
| Voltage between cathode and first dynode | $V_{k/S_1}$ | max. | 800 | V |
| | | min. | 250 | V |
| Voltage between grid No.1 and cathode | $V_{k/g_1}$ | max. | 100 | V |
| Voltage between grid No.2 and first dynode | $V_{g_2/S_1}$ | max. | 100 | V |
| Voltage between consecutive dynodes | $V_{S_n/S_{n+1}}$ | max. | 500 | V |
| | | min. | 80 | V |
| Voltage between anode and final dynode 4) | $V_{a/S_{14}}$ | max. | 500 | V |
| | | min. | 80 | V |

1) At an ambient temperature of 25 °C.

2) For an infinitely short light pulse, fully illuminating the photocathode.

3) Or the voltage at which the tube circuited in the voltage divider A has a gain of about $10^9$, whichever is lowest.

4) When calculating the anode voltage, the voltage drop in the load resistance should not be overlooked.

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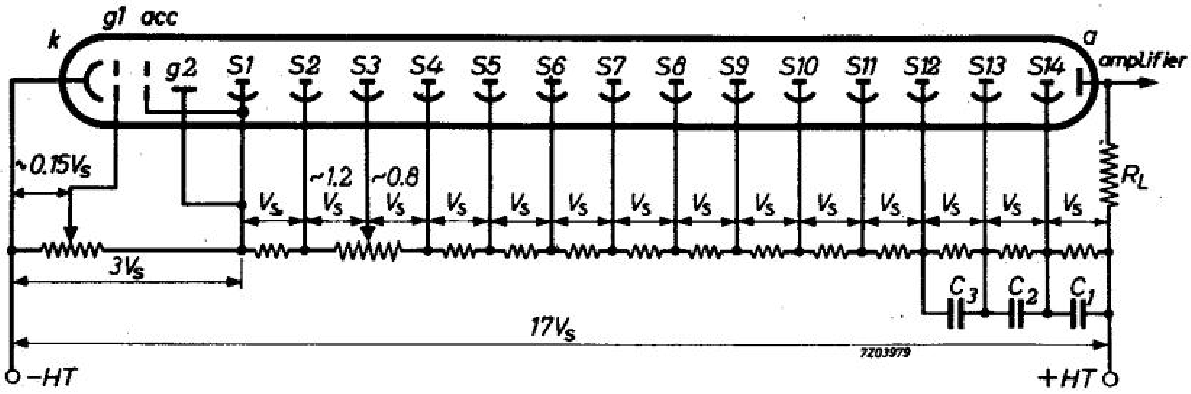
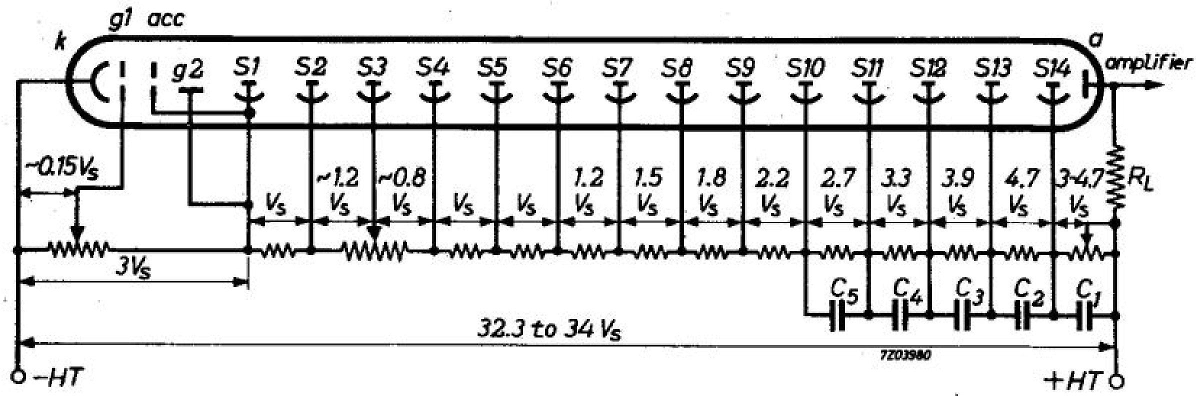
## RECOMMENDED CIRCUITS




Voltage divider type A [1])




Voltage divider type B [1])

k = cathode

$g_1$ = focusing electrode

acc = accelerating electrode

$g_2$ = deflector

$S_n$ = dynode No.n

a = anode

voltage between k and $g_1$ to be adjusted at about 0.15 $V_s$ (see fig.2); voltage between $S_2$ and $S_3$ to be adjusted at about 1.2 $V_s$; decoupling capacitances $C_1$ = 100 q/$V_s$, $C_2$ = 100 q/3$V_s$, $C_3$ = 100 q/9$V_s$, $C_4$ ≈ 100 q/27$V_s$ etc. with q = quantity of electricity transported by the anode.

[1]) To avoid electric field distortion in the electron optical system the aquadag shield (pin No.18) must be connected to a voltage near to the cathode voltage. If the cathode is connected to the negative H.T., precautions should be taken to ensure a high-tension insulation between the aquadag shield and the mu-metal shield.

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## OPERATIONAL CONSIDERATIONS

To achieve a stability of about 1% the ratio of the current through the voltage-divider bridge to that through the heaviest loaded stage of the tube should be approx. 100.

For moderate intensities of radiation a bridge current of about 3 mA will be sufficient.

The last stages must be decoupled by means of capacitances to avoid a serious voltage drop on the dynodes. A practical value for $C_1$ could be $2.10^{-9}$ F. In the case of high countingrates and large peak power output, and to avoid a high-tension supply of large power, it is possible to supply the first stages with a high tension of small output and the end stages with an average voltage of high output.

A. The electron optical input system consists of four elements:

the photocathode k;
the focusing electrode $g_1$;
the accelerating electrode acc;
the deflector $g_2$.

To reduce transit-time fluctuations, geometrical time spread, pulse amplitude spread or dark current, this system has the following advantages:

1. the photocathode is curved, though the outer window surface is flat, thus facilitating optical coupling to a scintillator.
2. a high and homogeneous extraction field at the cathode reduces as much as possible the influence of the initial electron velocities. A cathode-to-accelerator (internally connected to the first dynode) voltage of 350 V ensures a field strength of about 40 V/cm. This field is homogenized at the cathode surface by the focusing electrode $g_1$. Fig.1 shows the electron path in the input system.
3. The potential of electrode $g_1$ to the photocathode can be adjusted in order to obtain one of the following characteristics:
   a. the most satisfactory collection (i.e. for a given luminous flux the largest obtainable anode signal); for this adjustment, see Fig.2 the optimum value of the potential is about 0.15 $V_s$;
   b. the slightest transit-time fluctuations (the most homogeneous extraction field);
   c. the most satisfactory uniformity of collection giving the most constant output pulse amplitude;
   d. the useful cathode area can be controlled by giving the electrode $g_1$ a negative potential with respect to the photocathode, as shown in Fig.3, 4 and 5; obviously this variable electronic iris has the effect of reducing the dark current since the electrons emitted at the edge of the cathode do not reach the first dynode and consequently do not contribute to the anode current.

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## OPERATIONAL CONSIDERATIONS (continued)

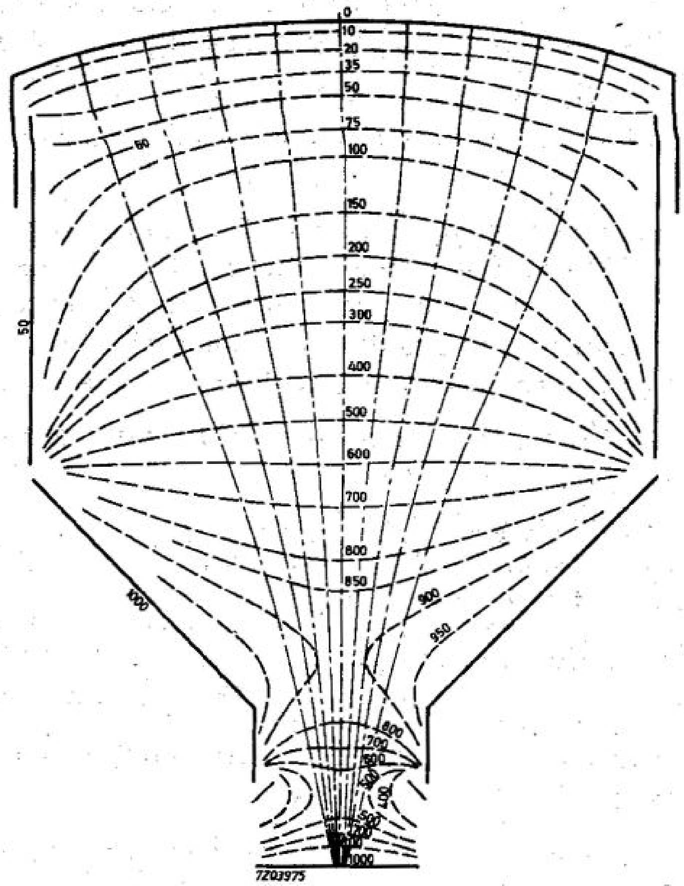


Fig.1 Electron optical input system

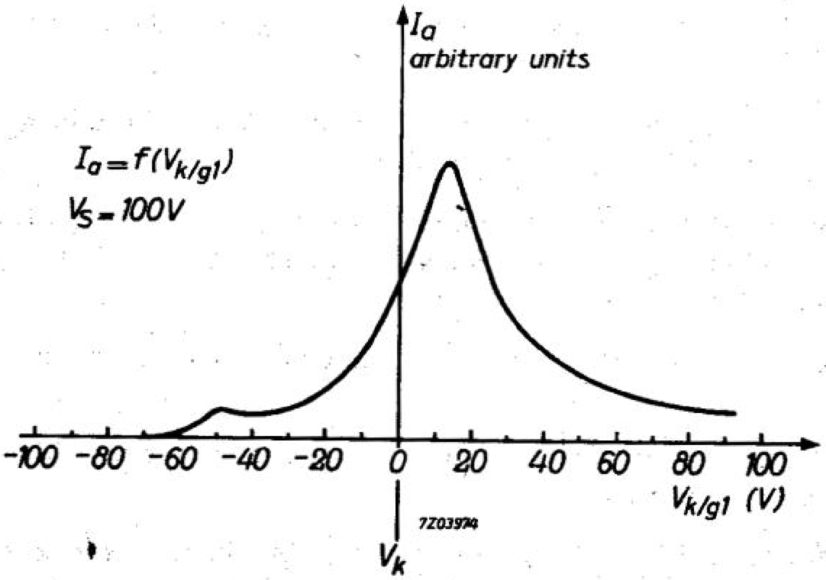


Fig.2 Anode current variation with the adjustment of $g_1$

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## OPERATIONAL CONSIDERATIONS (continued)

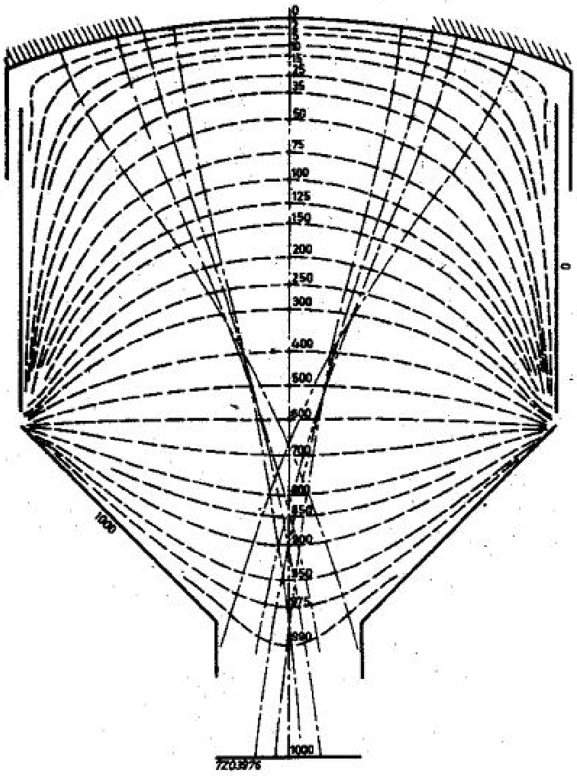


Fig.3

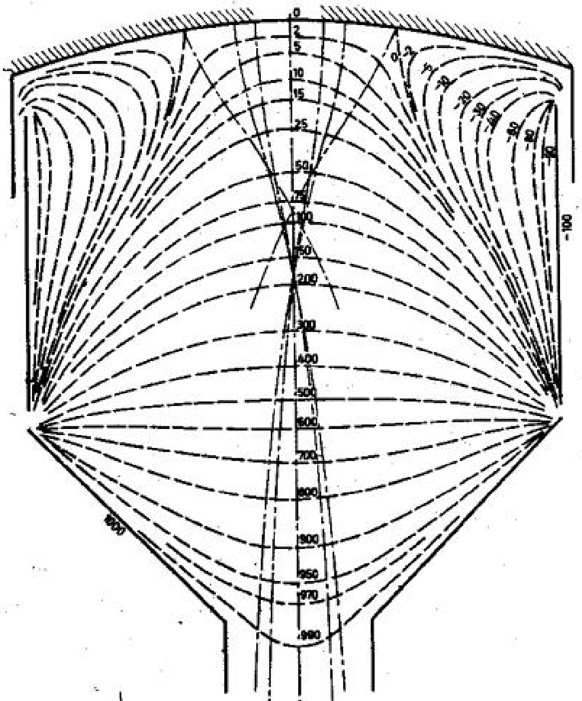


Fig.4

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**OPERATIONAL CONSIDERATIONS** (continued)

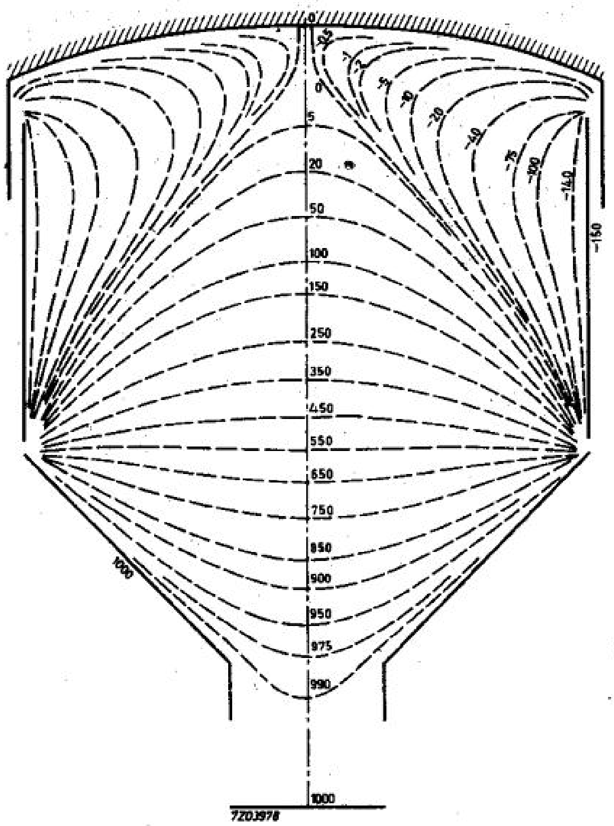


Fig.5

4. Because the first dynode cannot be placed parallel to the photocathode, the beam of primary electrons is deflected by the electrode $g_2$ to make it impinge at right angles to the first dynode surface. Collection on the first dynode is controlled by the potential of the third dynode (see recommended circuits).

5. The multiplier system consists of 14 stages, providing a total current amplification of $10^8$ at about 2200 V (see Fig.6).

The tube is capable of producing very strong peak currents (up to 1 A). Actually, the time constant at the output of the multiplier must be very small. Therefore it is necessary, taking into account the parasitic capacitances, to use a low-load resistance. It is advisable to use a resistance-matched coaxial cable (e.g. 75 or 100 Ω). With this load the tube easily delivers pulses of tens of volts, so that an amplifier is rendered superfluous.

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**OPERATIONAL CONSIDERATIONS** (continued)

It should be noted that in a number of applications it is not necessary for the current to be proportional to the incident luminous flux. As a matter of fact such short pulses are needed for time measurements only, so not for spectrography purposes. If at the same time it is required, however, to determine the energy of the incident radiation, it is possible to select from one of the dynodes a signal proportional to the incident flux. In fact, when ascending the dynodes progressively, starting from the anode, the current is divided at each stage by d-1, d representing the secondary-emission coefficient of each stage ($d \approx 3.5$). It is therefore possible to locate a dynode, the current of which is lower than, or equal to, the saturation limit of the dynodes.

Fig.7 illustrates the variation of the anode current as a function of the incident flux, the voltage divider being of type B. The anode current is then linear up to 300 mA.

Care should be taken that the anode voltage is adjusted to its optimum value. In fig.8 the anode current variation is plotted against anode-to-final-dynode voltage.

It should be noted that for equal high tension the gain of the tube is smaller for voltage divider type B than for one according to type A. In practice, therefore, it will be preferable to use the type A distribution, or a distribution between A and B (e.g. starting with 1.2 $V_s$ between $S_8$ and $S_9$ 1.5 $V_s$ between $S_9$ and $S_{10}$ and so on, maintaining the same progression.

It is advisable to screen the tube with a mu-metal cylinder against magnetic-field influences.

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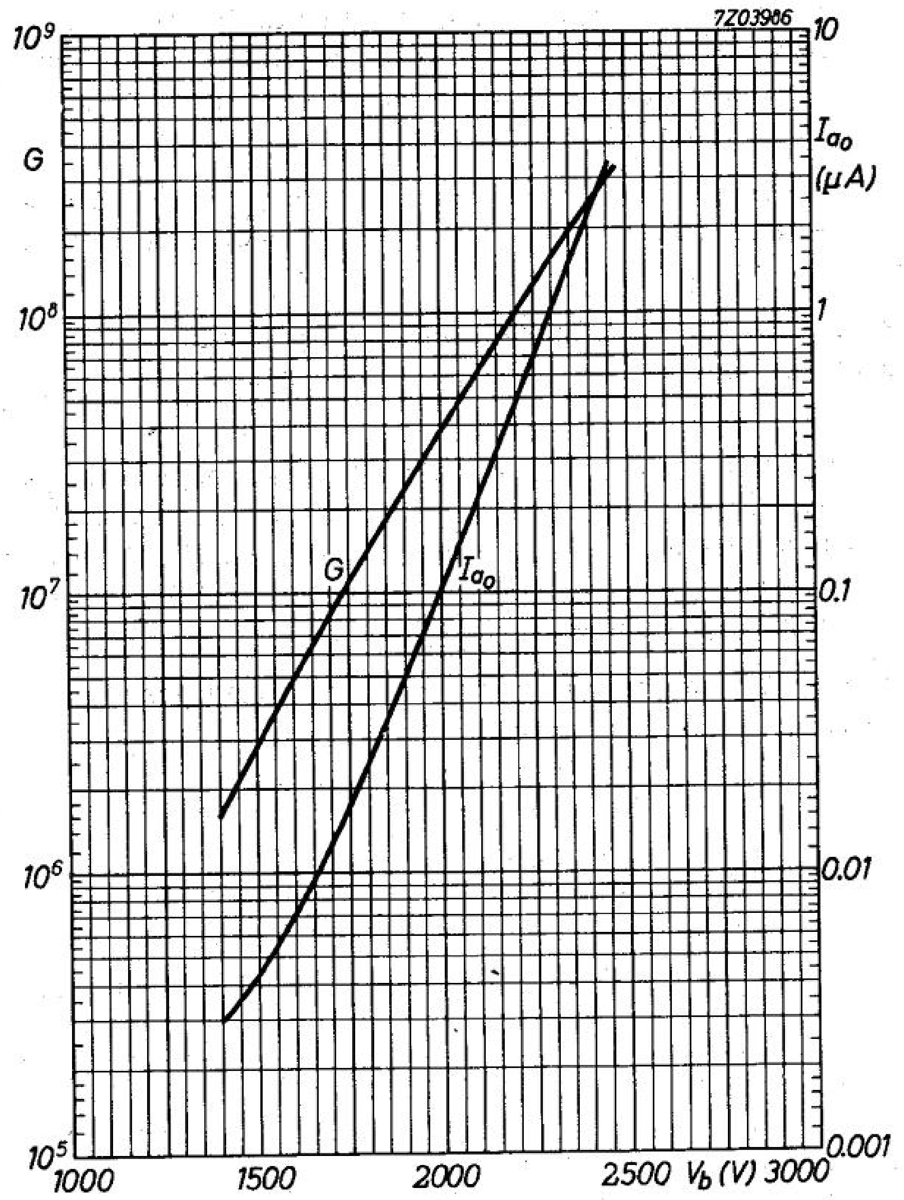
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$10^9$
$10^8$
$10^7$
$10^6$
$10^5$
G
10
1
0.1
0.01
0.001
$I_{a_0}$
($\mu$A)
G
$I_{a_0}$
1000
1500
2000
2500
$V_b$ (V)
3000

Fig. 6

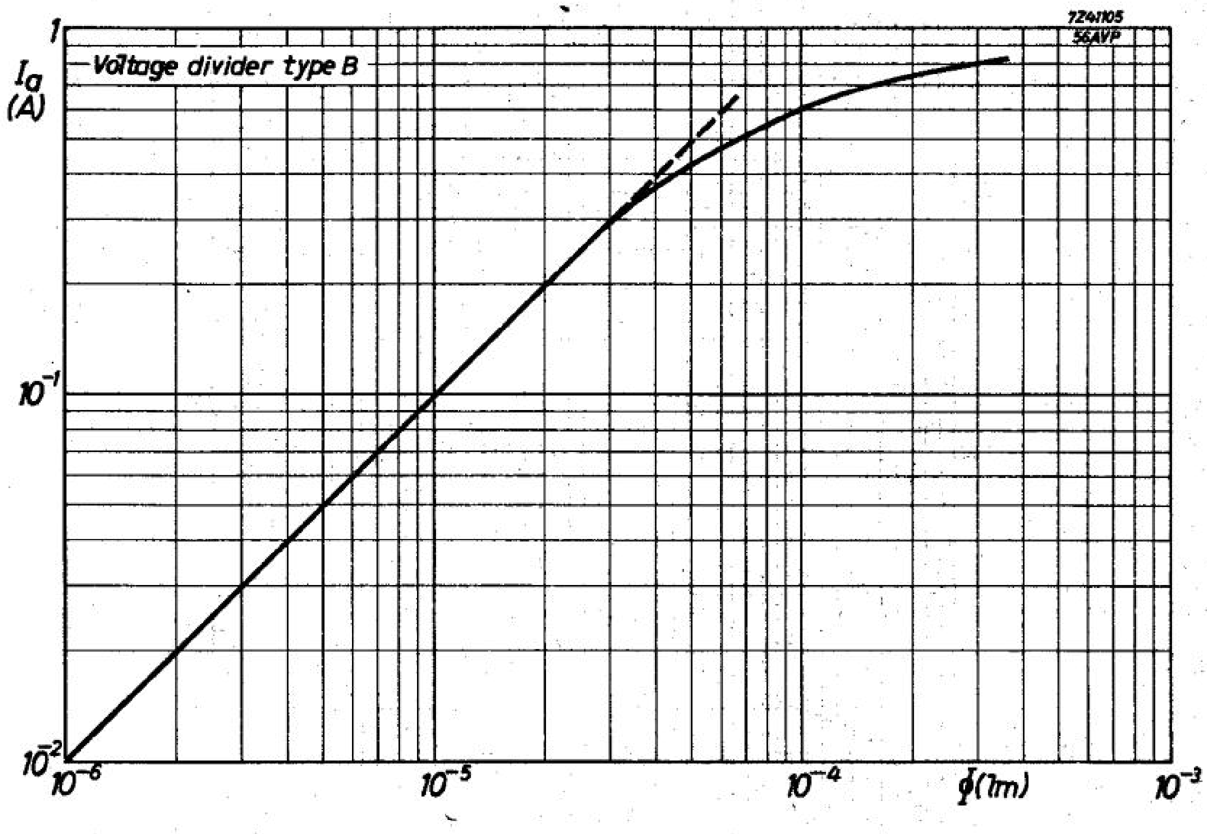
7Z41105
56AVP
Voltage divider type B
$I_a$
(A)
1
$10^{-1}$
$10^{-2}$
$10^{-6}$
$10^{-5}$
$10^{-4}$
$\Phi$ (lm)
$10^{-3}$

Fig. 7

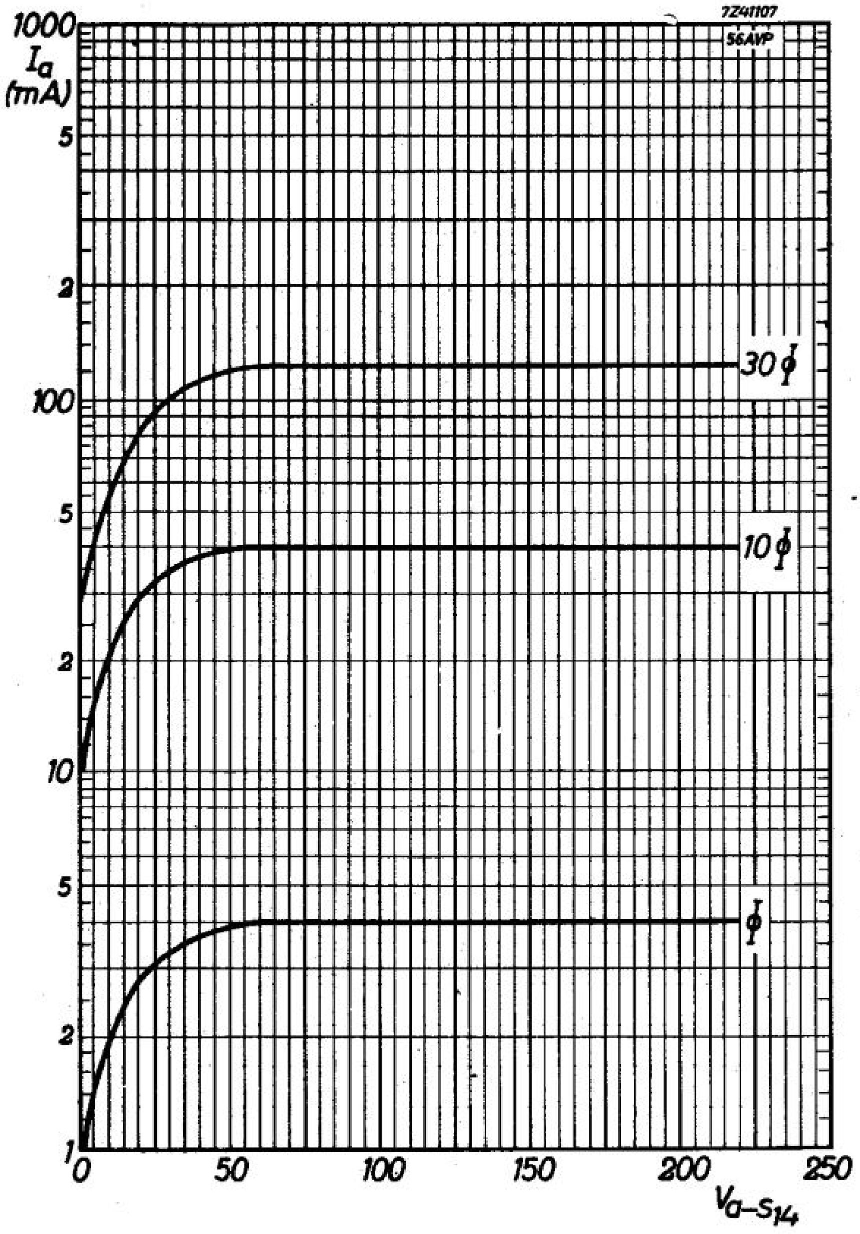
7Z41107
56AVP
1000
$I_a$
(mA)
5
2
100
5
2
10
5
2
1
0
50
100
150
200
250
$V_{a-S_{14}}$
30 Φ
10 Φ
Φ

Fig. 8