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PHOTOMULTIPLIERS FOR SCINTILLATION COUNTING

PHILIPS ELECTRON TUBE DIVISION

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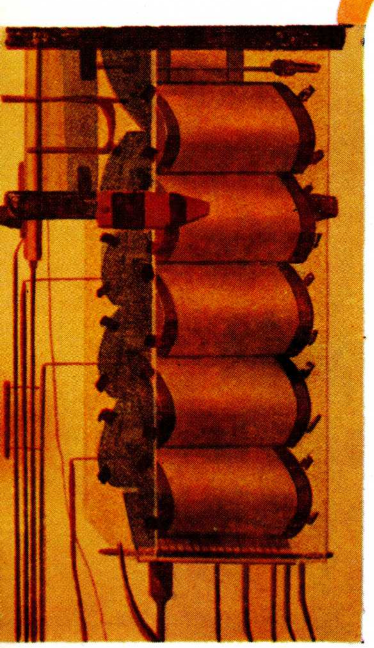
PHOTOMULTIPLIERS

For many years the photomultiplier tube has been employed in several branches of science and industry. The rapidly growing number of applications have promoted the design of a comprehensive range of high-standard photomultiplier tubes, which are the outcome of skilful laboratory research, long experience in tube making, and the continual interaction of user and manufacturer.

The photocathode

Our range of photomultiplier tubes can be subdivided into three categories (see also the relevant spectral response curves):

- *the A-types,* which are equipped with a semi-transparent caesium-antimony photocathode precipitated on the inner side of a polished B40-glass end window; these types are sensitive to light in the visible region, and have their maximum sensitivity in the blue region;
- *the U-types,* which have the same photocathode as the A-types, but are provided with a polished optical quartz window, which gives them a sensitivity that extends into the ultra-violet region;
- *the C-type,* which has a semi-transparent caesium-on-silver oxide photocathode on a polished B40-glass end window; its sensitivity lies mainly in the red and near-infrared region, with a maximum at about 8000 Å.



The electron-optical system

This very significant part of the photomultiplier has been designed with utmost care, which ensures a very good primary-electron collection. The electron-optical system of the fast types is of special design, so that excellent focussing and electron-path synchronisation is obtained.

The multiplier

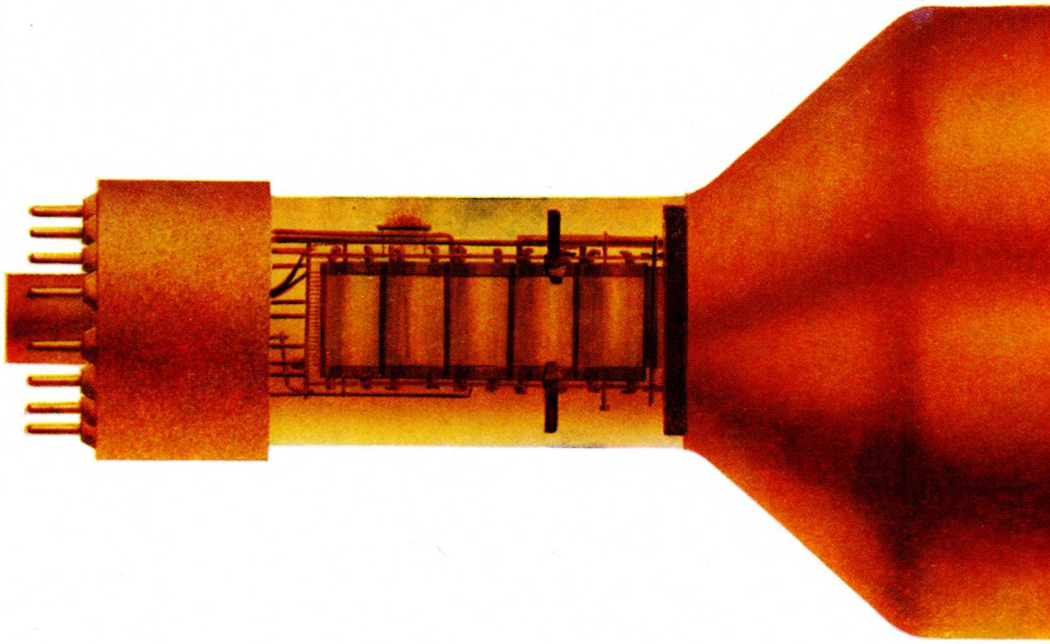
All the tubes mentioned here have a multiplier structure of the linear-focussed type, which is built up from 10, 11 or 14 secondary-emission dynodes of caesium-coated silver magnesium.

The voltage supply

An effectively stabilised supply voltage is necessary, since the relative gain variation of e.g. an 11-stage tube is roughly ten times the relative overall voltage variation. Depending on the application, the total voltage applied to the tube may be either:

- the maximum permissible voltage to obtain maximum gain;
- a reduced voltage (1100 - 1400 V) to obtain the optimum signal-to-noise performance.

The supply to the dynodes may be derived from a potential divider, as



shown in the figures in this folder. It is recommended to use a bleeder current of at least 100 times the average anode current of the photomultiplier. In pulse techniques, such as scintillation counting, a bleeder current of about 1 mA is usually sufficient, provided that the last two or three stages are decoupled by means of capacitors of 100 pF and 200 pF.
For the high-current types 56 AVP, 56 UVP and 58 AVP a bleeder current of at least 3 to 5 mA is required for consistent results.
It may be useful in certain circumstances to have a high-voltage, high-impedance supply for the greater part of the dynodes, and a separate low-voltage, low-impedance supply for the remaining, heavier loaded stages.
In the recommended potential divider circuits the negative high tension is connected to the photocathode, and the anode is earthed. This will mostly be the case in spectrometry where direct measurement of the anode current is required. In pulse techniques, however, the cathode will usually be earthed, the pulse being taken from the anode via a blocking capacitor.

Time resolution

The types 56 AVP, 56 UVP and 58 AVP have been designed specially for fast-coincidence techniques in nuclear physics, and have an extremely low spread in transit time (approx. 10^{-9} s for the 58 AVP and $<5 \times 10^{-10}$ s for the 56 AVP). They are capable of delivering anode pulses with a rise time of 2×10^{-9} s. To take full advantage of this characteristic they are moreover designed as high-gain, high-current types, thus permitting very high and steep pulses to be extracted from the anode with a 100 Ω matched coaxial cable as a load.
For the general-purpose types 150 AVP and 53 AVP the difference in transit time between electrons emitted from the centre of the photocathode and those emitted from the edge is about 4×10^{-9} s; both tubes deliver pulses with a rise time of about 6×10^{-9} s.

Energy resolution

The tubes intended specially for use in γ-ray spectrometry (153 AVP and XP 1031) have a guaranteed energy resolution for the Cs^{137} photopeak of less than 9%.
Type XP 1010, designed for X-ray spectrometry, has a good energy resolution for this low energy region (about 50% for the Cu, K_α photopeak of 8 keV) and a background of less than 50 c/s for 3 keV.

REMARKS

(1) To ensure a long life of the photocathode it is strongly recommended:

- **not to expose the tube to excessive light, even when the power is switched off;**
- **to keep the tube in darkness when it is not in operation.**

(2) Before carrying out a measurement for which optimum accuracy is required, it is recommended to switch the power supply on about half an hour beforehand, so that the dark current has the opportunity to reach a stabilised normal value.

(3) To eliminate the influence of magnetic fields it is advisable to use a mu-metal screening. Further information on these mu-metal cylinders with suitable dimensions for the various types of tubes can be found on the back of this folder.

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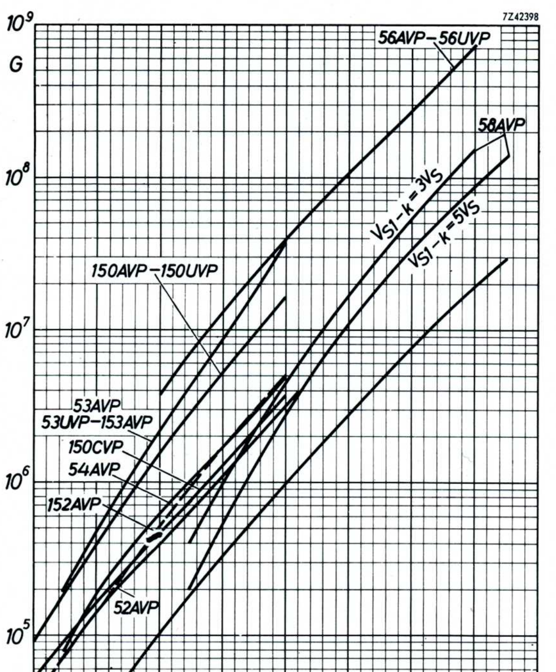
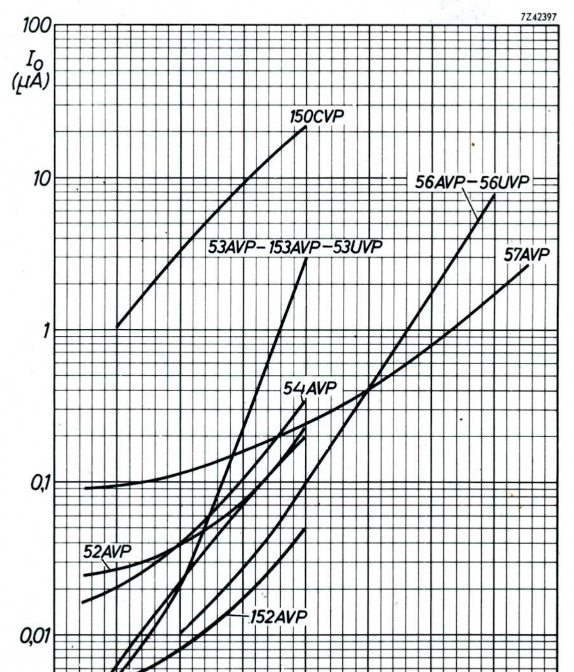
μ-METAL SCREENING CYLINDERS

type number	diameter (mm)	length (mm)	for photomultiplier type
56127	$42 ^{+1}_{-0}$	90 ± 1	150 AVP, 150 UVP
56128	$57 ^{+1}_{-0}$	90 ± 1	53 AVP, 53 UVP, 153 AVP, 150 CVP
56129	$132 ^{+1}_{-0}$	150 ± 1	54 AVP, 58 AVP, XP 1040
56131	$75 ^{+1}_{-0}$	110 ± 1	56 AVP, 56 UVP
56132	$240 ^{+1}_{-0}$	300 ± 1	57 AVP, 58 AVP with envelope

GAIN AND DARK-CURRENT CHARACTERISTICS



Gain as a function of the total voltage



Dark current as a function of the total voltage

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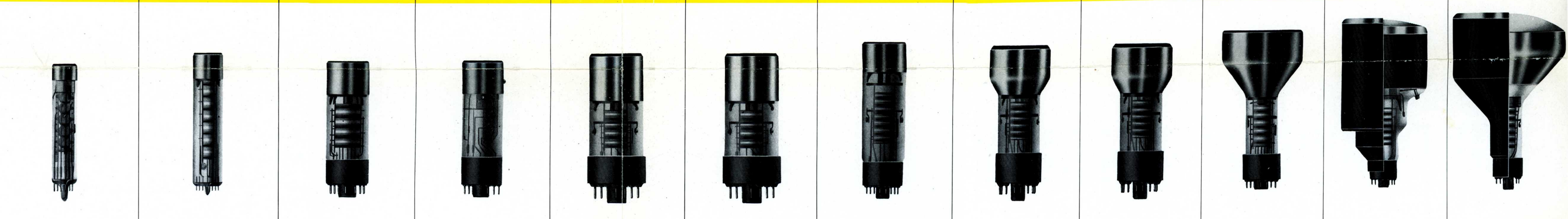
PHOTOMULTIPLIERS

		152 AVP	52 AVP	XP 1010	150 CVP 1)	53 AVP/53 UVP 1)
application		optical and scintillation applications under limited dimensional conditions; space research; computers	scintillation counting; small probes; oil prospecting	X-ray spectrometry; at 5.9 keV: plateau > 70 V, slope <8% per 100 V background < 50 c/s	red and infra-red sensitive optical instruments	scintillation counting; α detection; flying-spot equipment; optical instruments
max. tube diameter	(mm)	19	25.5	39.5	39.5 14)	57
seated tube height	(mm)	88	130	110	110	129
number of stages		10	10	10	10	11
number of pins		12	13	12	12	14
dynode type		linear	linear	linear	linear	linear
dynode material		AgMgOCs	AgMgOCs	AgMgOCs	AgMgOCs	AgMgOCs
cathode diameter	(mm)	14	20	32	32	44
cathode material		SbCs	SbCs	SbCs	AgOCs	SbCs
cathode sensitivity						
luminous 2)	(μA/lm)	40 (>25)	60 (>35)	60 (>35)	30 (> 15)	60 (>35)
radiant 3)	(mA/W)	30	50	50	3	50
cathode dark current	(A/cm²)	10^{-15}	10^{-15}	10^{-15}	0.5×10^{-12}	10^{-15}
overall sensitivity	(A/lm)	150 (>30) 4)	250 (>30) 4)	1250 (>100) 4)	100 (>20) 4)	4000 (>100) 4)
dark current	(μA)	<0.1 6)	<0.1 6)	<0.05 7)	<10 8)	<0.05 7)
max. linear output	(mA)					
high gain		5	5	30	5	30
high current		10	10	100	10	100
rise time	(ns)					
high current		—	—	4	—	4
time spread	(ns)	—	—	6	—	6
energy resolution for Cs^{137}	(%)	—	—	<11	—	<11
max. total voltage	(V)	2000	1800	1800	1800	1800
max. anode current	(mA)	1	1	1	1	1
max. anode dissipation	(W)	0.5	0.5	0.5	0.5	0.5
cathode-to-dynode voltage	(V)					
minimum		120	120	120	120	120
maximum		300	500	500	500	500
inter-dynode voltage	(V)					
minimum		80	80	80	80	80
maximum		200	300	300	300	300

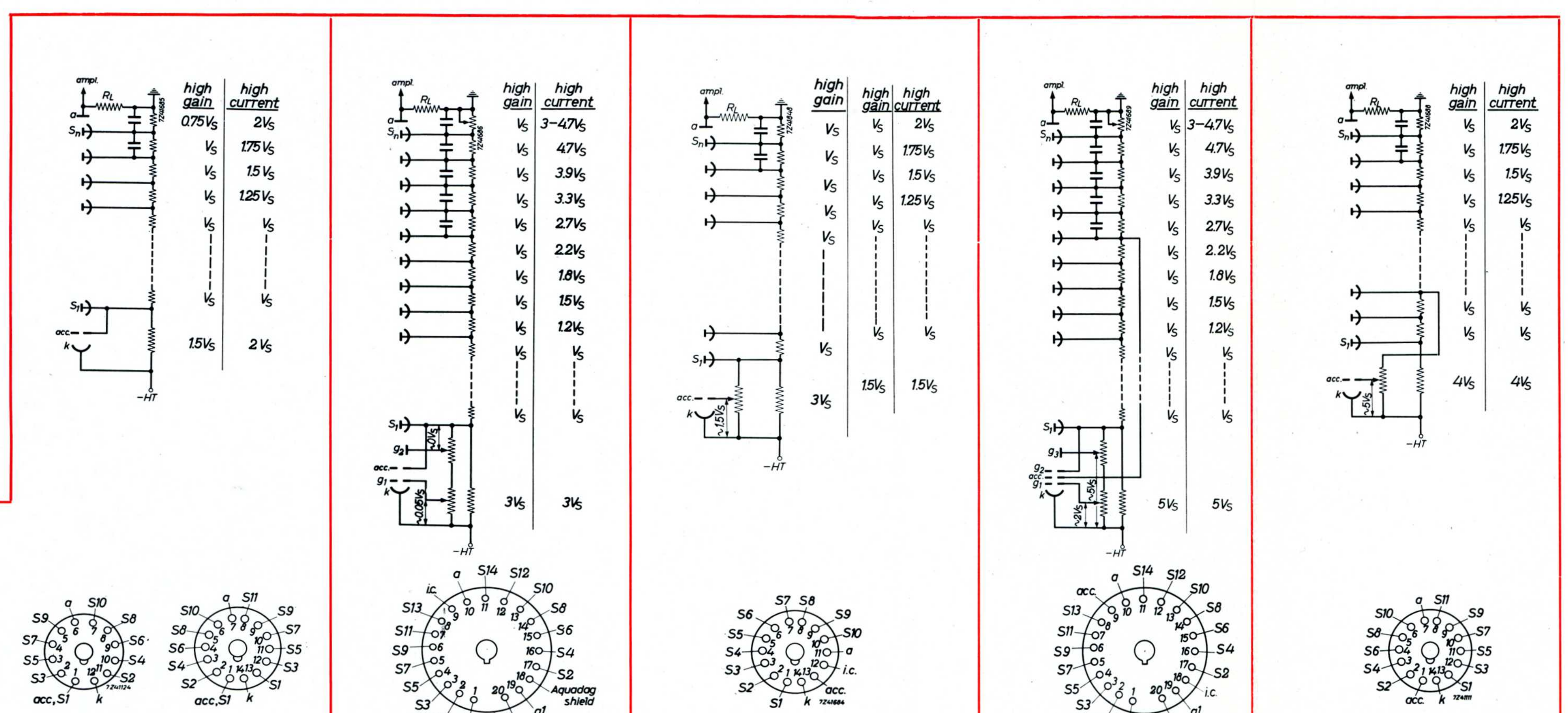
		153 AVP	56 AVP/56 UVP 1)	XP 1030	XP 1031	54 AVP	58 AVP/XP 1040 13)	57 AVP
application		γ-ray spectrometry	fast coincidence (high gain, high resolution) Cerenkov counters	nuclear physics; α detection	γ-ray spectrometry	scintillation counting; α detection; γ-ray spectrometry	fast coincidence high gain, high resolution) Cerenkov counters	uranium prospecting; total body measurements; photographic printing; flying-spot: live and transparent
max. tube diameter	(mm)	57	53.5	75.5	75.5	130	136.3 (130)	235 (231)
seated tube height	(mm)	120	170	136	136	210	264	305
number of stages		11	14	10	10	11	14	11
number of pins		14	20	14	14	14	20	14
dynode type		linear	linear	linear	linear	linear	linear	linear
dynode material		AgMgOCs	AgMgOCs	AgMgOCs	AgMgOCs	AgMgOCs	AgMgOCs	AgMgOCs
cathode diameter	(mm)	44	42	63.5	63.5	111	110	200
cathode material		SbCs	SbCs	SbCs	SbCs	SbCs	SbCs	SbCs
cathode sensitivity								
luminous 2)	(μA/lm)	70 (>50)	60 (>45)	60 (>40)	70 (>40)	60 (>35)	60 (>45)	50 (>35)
radiant 3)	(mA/W)	55	50	50	55	50	50	45
cathode dark current	(A/cm²)	10^{-15}	10^{-15}	10^{-15}	10^{-15}	10^{-15}	10^{-15}	10^{-15}
overall sensitivity	(A/lm)	4500 (>100) 4)	>6000 5)	250 (>100) 4)	300 (>100) 4)	500 (>100) 4)	>6000 5)	250 (>60) 5)
dark current	(μA)	<0.05 7)	<5 9)	<0.2 12)	<0.2 12)	<0.5 10)	<15 9)	<1 7)
max. linear output	(mA)							
high gain		30	100	50	50	30	100	30
high current		100	300	100	100	100	300	100
rise time	(ns)							
high current		4	2	7	7	—	2	—
time spread	(ns)	6	0.5	7	7	—	1	—
energy resolution for Cs^{137}	(%)	<9	—	—	<9	—	—	—
max. total voltage	(V)	1800	2500 11)	2000	2000	2000	3000 11)	2500
max. anode current	(mA)	1	2	1	1	1	2	1
max. anode dissipation	(W)	0.5	1	0.5	0.5	0.5	1	0.5
cathode-to-dynode voltage	(V)							
minimum		200	250	100	100	120	250	200
maximum		500	800	500	500	500	800	1000
inter-dynode voltage	(V)							
minimum		80	80	80	80	80	80	80
maximum		300	500	300	300	300	500	300

NOTES

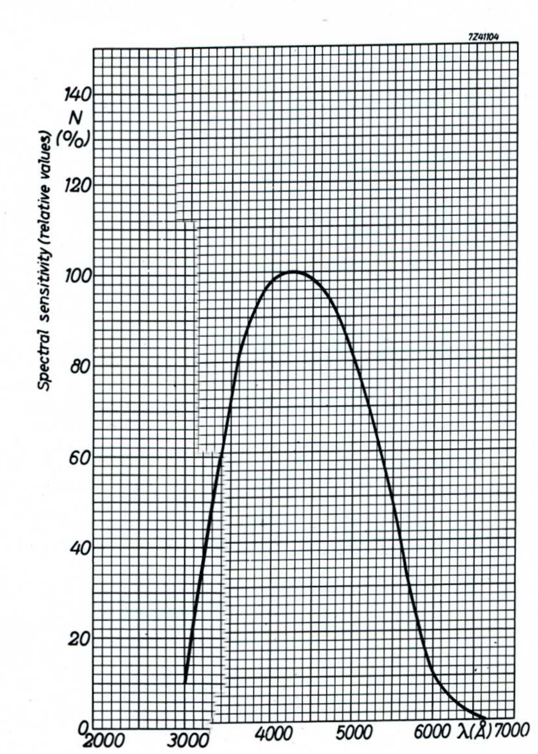
1) The spectral response of the A-types corresponds with S_{11}, that of the U-types with S_{13}, and that of the C-type with S_1.
2) Measured with a tungsten ribbon lamp with a colour temperature of 2850 °K.
3) Measured at 4200 Å (for the 150 CVP at 8000 Å).
4) Measured at a total voltage of 1800 V.
5) Measured at a total voltage of 2500 V (58 AVP: 3000 V).
6) At an overall sensitivity of 30 A/lm.
7) At an overall sensitivity of 60 A/lm.
8) At an overall sensitivity of 20 A/lm.
9) At a gain of 10^8.
10) At an overall sensitivity of 250 A/lm.
11) Or the voltage at which the tube circuited in the voltage divider A has a gain of about 10^9, whichever occurs first.
12) At an overall sensitivity of 100 A/lm.
13) The 58 AVP has a curved window surface; a plane-concave acrylic-resin adaptor is delivered with the tube. Type XP 1040 has a plane outer window surface.
14) Plus max. 10 mm side exhaust stem.



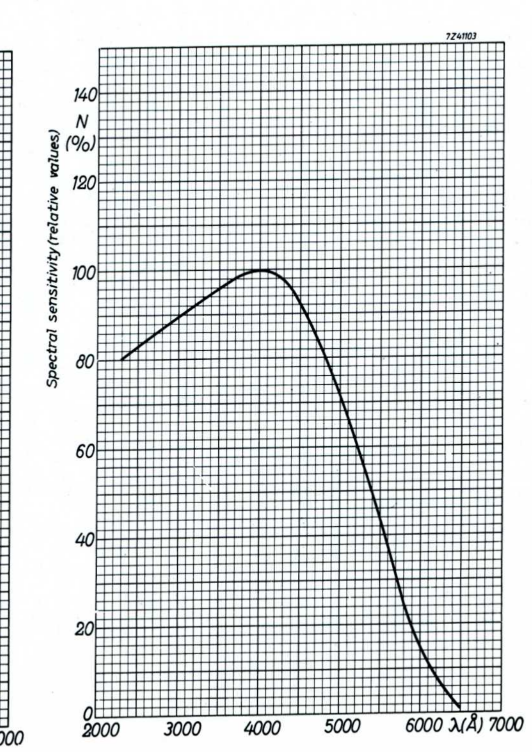
OPERATING CHARACTERISTICS



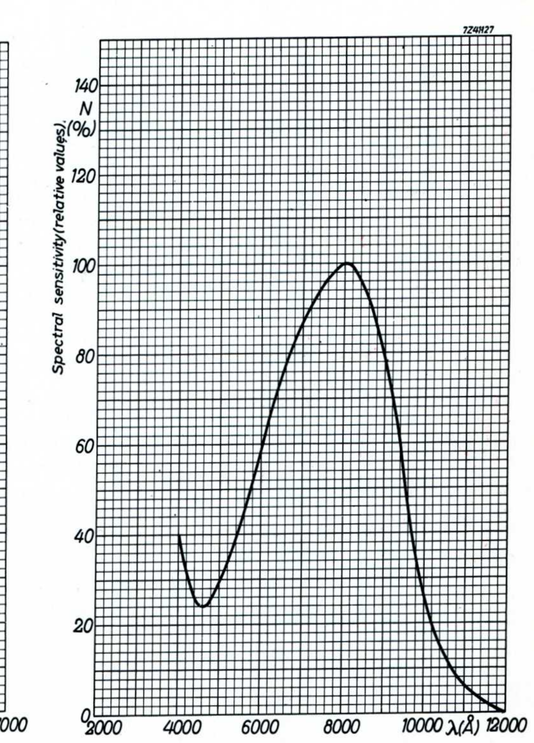
152 AVP — 52 AVP — 150 AVP, 150 UVP, 150 CVP, XP 1010 — 53 AVP, 53 UVP, 153 AVP — 56 AVP, 56 UVP — XP 1030, XP 1031 — 58 AVP, XP 1040 — 57 AVP



Spectral response curve of the A-types



Spectral response curve of the U-types



Spectral response curve of the C-type