12-STAGE PHOTOMULTIPLIER TUBE

The XP2020 and XP2020/Q are 44 mm useful diameter head-on photomultiplier tubes with a plano-concave window and a semi-transparent bialkaline photocathode and a high gain 1st dynode from SN14007 onwards. The tubes are intended for use in nuclear physics where the number of photons to be detected is very low. The tubes feature a high cathode sensivity, a good linearity combined with a very low background noise, extremely good time characteristics and good single electron spectrum resolution. They are especially useful in high-energy physics experiments where ultimate time characteristics are needed, such as coincidence measurements, Cerenkov detection, etc. The XP2020/Q has a fused silica window enabling transmission at a wavelength of 160 nm and higher.

QUICK REFERENCE DATA

Radiant sensitivity characteristic	XP2020		bialkaline	
	XP2020/Q		bialkaline on fused silica	
Useful diameter of the photocathode		>	44	mm
Quantum efficiency at 400 nm			25	%
Blue sensitivity of the photocathode			10	μA/lmF
Single electron spectrum resolution			70	%
Supply voltage for a gain of 3×10^7			2200	V
Pulse amplitude resolution for ^{137}Cs		≈	7,2	%
Anode pulse rise time (with voltage divider C)		≈	1,5	ns
Linearity, with voltage divider B	up to	≈	280	mA
Signal transit time distribution	σ	≈	0,25	ns

To be read in conjunction with *General Operational Recommendations Photomultiplier Tubes.*

GENERAL CHARACTERISTICS

Window

Material	
XP2020	borosilicate
XP2020/Q	fused silica
Shape	plano-concave
Refractive index	
XP2020, at 550 nm	1,48
XP2020/Q at 400 nm	1,47
XP2020/Q at 250 nm	1,50

Photocathode (note 1)

Semi-transparent, head-on	
Material	bialkaline
Useful diameter	> 44 mm

GENERAL CHARACTERISTICS (continued)

Radiant sensitivity characteristic		see Figs 6 and 7
Maximum radiant sensitivity at		400 ± 30 nm
Blue sensitivity	typ.	10 μA/lmF
	min.	7.5 μA/lmF
Luminous sensitivity		70 μA/lm
Quantum efficiency at 400 nm		25 %
Radiant sensitivity at 400 nm	≈	80 mA/W

Multiplier system

Number of stages		12
Dynode structure		linear focused
Dynode material		CuBe
Capacitances		
Grid 1 to $k + d_1 + d_5 + g_2$	≈	20 pF
Anode to final dynode	≈	4 pF
Anode to all	≈	7 pF

Magnetic field

See Fig. 13.

It is recommended that the tube be screened against the influence of magnetic fields by a mu-metal shield protruding > 15 mm beyond the photocathode.

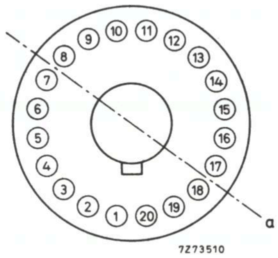

Fig. 1 Axis a with respect to base pins (bottom view).

6 and 7
0 nm
0 μA/lmF
5 μA/lmF
0 μA/lm
5 %
0 mA/W
2
used
pF
pF
pF
metal

RECOMMENDED CIRCUITS

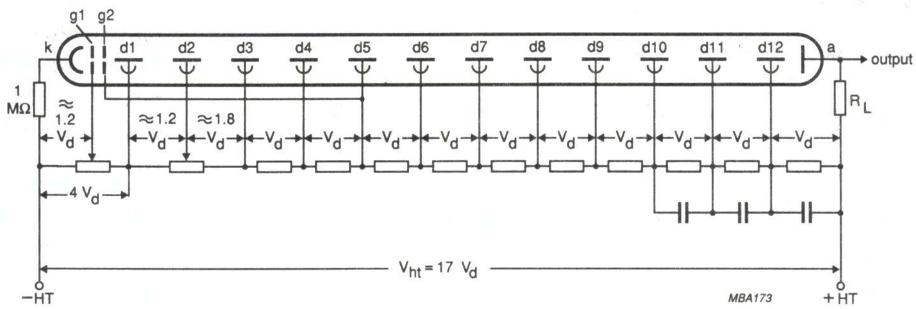

Fig. 2 Voltage divider type A.

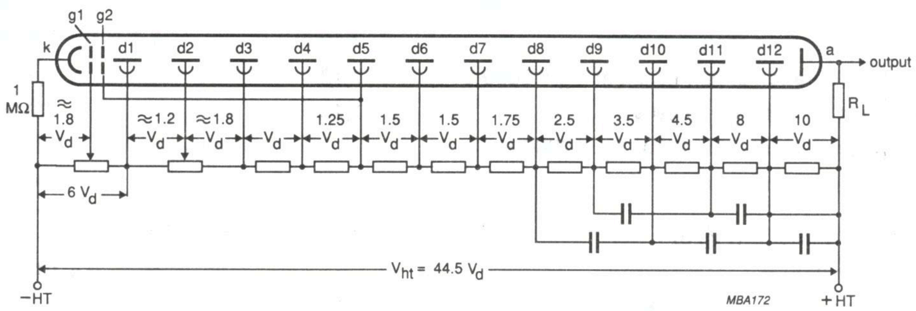

Fig. 3 Voltage divider type B.

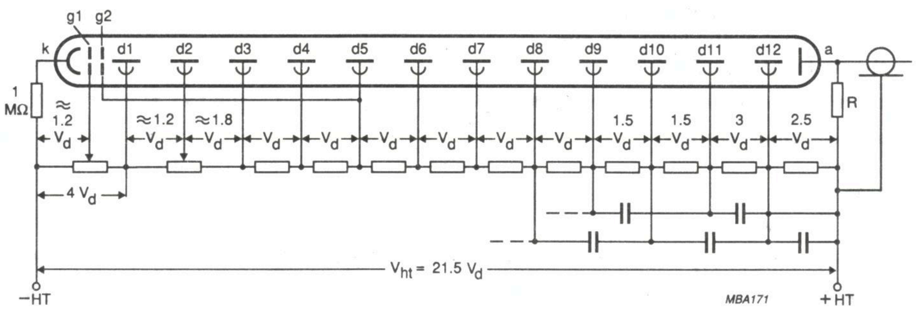

Fig. 4 Voltage divider type C.

k = cathode
g_1, g_2 = focusing and accelerating electrodes
d_n = dynode no.
a = anode
R_L = load resistor

R = This resistor connects the anode when the output cable is not terminated. Recommended value: 10 kΩ.

The cathode resistor of 1 MΩ limits the current in case of unintentional contact between the conductive coating and earth when the anode is earthed.
Typical value of capacitors: 1 nF.

TYPICAL CHARACTERISTICS

	note			
With voltage divider A (Fig. 2)	2			
Supply voltage for a gain of 3×10^7 (Fig. 8)			typ.	2200 V
			<	2600 V
Anode dark current at a gain of 3×10^7 (Fig. 8)	3,4		typ.	7 nA
			<	100 nA
Background noise at a gain of 3×10^7 (Fig. 11-14)	5		typ.	900 c/s
			<	2500 c/s
Single electron spectrum at a gain of 3×10^7 (Fig. 15)				
resolution	15		≈	70 %
peak to valley ratio	16		≈	2,5
Pulse amplitude resolution for ^{55}Fe at a gain of 3×10^7	6		≈	41 %
Peak to valley ratio for ^{55}Fe at a gain of 3×10^7			≈	34
Pulse amplitude resolution for ^{137}Cs at V_b = 1500 V	6		≈	7,2 %
Anode pulse rise time at V_b = 2000 V	7,13		≈	1,6 ns
Anode pulse duration at half height at V_b = 2000 V	7,13		≈	3,7 ns
Signal transit time at V_b = 2000 V	7,13		≈	28 ns
Anode current linear within 2% at V_b = 2000 V		up to	≈	25 mA
Obtainable peak anode current			≈	100 mA
With voltage divider B (Fig. 3)	2			
Gain at V_b = 2800 V			≈	2×10^6
Anode pulse rise time at V_b = 2800 V	7,13		≈	1,7 ns
Anode pulse duration at half height at V_b = 2800 V	7,13		≈	2,7 ns
Signal transit time at V_b = 2800 V	7,13		≈	31 ns
Signal transit time difference between the centre of the photocathode and 18 mm from the centre at V_b = 2800 V			≈	0,25 ns
Anode current linear within 2% at V_b = 2800 V		up to	≈	280 mA
Obtainable peak anode current			≈	0,5 to 1 A
With voltage divider C (Fig. 4)	2			
Gain at V_b = 2500 V			≈	2×10^7
Anode pulse rise time at V_b = 2500 V	7,13		≈	1,5 ns
Anode pulse duration at half height at V_b = 2500 V	7,13		≈	2,4 ns
Signal transit time at V_b = 2500 V	7,13		≈	30 ns
Signal transit time distribution at V_b = 2500 V	12,13	σ	≈	0,25 ns
Signal transit time difference between the centre of the photocathode and 18 mm from the centre at V_b = 2500 V			≈	0,25 ns
Anode current linear within 2% at V_b = 2500 V		up to	≈	70 mA
Obtainable peak anode current			≈	250 mA

LIMITING VALUES (Absolute maximum rating system)

	note			
Supply voltage	8	max.	3000	V
Continuous anode current	14	max.	0,2	mA
Voltage between focusing electrode (g_1) and photocathode		max.	300	V
Voltage between first dynode and photocathode	9	max.	800	V
		min.	300	V
Voltage between consecutive dynodes (except d_{11} and d_{12})		max.	400	V
Voltage between dynodes d_{11} and d_{12}	13	max.	600	V
Voltage between anode and final dynode	10	max.	700	V
		min.	80	V
Ambient temperature range	11			
operational (for short periods of time)		max.	+ 80	°C
		min.	−30	°C
continuous operation and storage		max.	+ 50	°C
		min.	−30	°C

Notes

1. The bialkaline photocathode has a significant resistance which increases rapidly with reducing temperature. It is thus recommended that it should not be subjected to light of too great an intensity; the cathode current should be limited to, for example, 1 nA at room temperature or 0,1 nA at −30 °C. If too high a photocurrent is passed, the cathode can no longer be considered to be an equipotential surface, and the focusing of electrons onto the first dynode will be affected, resulting in departure of linearity.
2. To obtain a peak pulse current greater than that obtainable with divider A, it is necessary to increase the inter-dynode voltage progressively. Divider circuit B and C are examples of progressive dividers, each giving a compromise between gain, speed and linearity. Other dividers can be conceived to achieve other compromises. It is generally recommended that the voltage ratio between two successive stages is less than 2.
3. Wherever possible, the power supply should be arranged so that the cathode is earthed and the anode is at + HT, however, it is sometimes necessary to supply the tube with the anode earthed and the cathode at −HT. Under these circumstances, erratic noise and dark current are generally increased and unstable, particularly immediately after application of voltage. The tube is provided with a conductive coating connected to the cathode. It is recommended that, if a metal shield is used, this should be kept at cathode potential. This implies safety precautions to protect the user. The envelope of the tube should be supported only by insulators with an insulation resistance of $> 10^{15}\ \Omega$.
4. Dark current is measured at ambient temperature, after the tube has been in darkness for approx. 1 min. Lower value can be obtained after a longer stabilization period in darkness (approx. 30 min.).
5. After having been stored with its protective hood, the tube is placed in darkness with V_b set to a value to give a gain of 3×10^7. After a 30 min. stabilization period noise pulses with a threshold of $4{,}25 \times 10^{-13}$ C (corresponding to 0,1 photoelectron) are recorded (Fig. 9).
6. Pulse amplitude resolution for ^{55}Fe is measured with a NaI (TI) cylindrical scintillator with a diameter of 25 mm and a height of 1 mm provided with a beryllium window. The count rate is $\approx 10^3$ c/s. Pulse amplitude resolution for ^{137} Cs is measured with a NaI (TI) cylindrical scintillator with a diameter of 44 mm and a height of 50 mm. The count rate is $\approx 10^4$ c/s.
7. Measured with a pulsed light source, with a pulse duration (FWHM) of < 1 ns, the cathode being completely illuminated. The rise time is determined between 10% and 90% of the amplitude of the anode pulse. The signal transit time is measured between the instant at which the illuminating pulse at the cathode becomes maximum, and the instant at which the anode pulse attains its maximum. Rise time, pulse duration and transit time vary as a function of high tension supply voltage V_b, approximately as $V_b^{-1/2}$.
8. Total HT supply voltage, or the voltage at which the tube has a gain of 2×10^8, whichever is lower.
9. Minimum value to obtain good collection in the input optics.
10. When calculating the anode voltage the voltage drop across the load resistor should be taken into account.
11. This range of temperatures is limited principally by stresses in the sealing layer of the base to the glass bulb. Where low temperature operation is contemplated, the supplier should be consulted.
12. Transit time fluctuations of single electrons leaving the photocathode result in a transit time distribution at the anode. This distribution is characterized by its standard deviation σ.
13. Non-inductive resistors of 51 Ω are incorporated in the base connected to d_{11} and d_{12}. See also *General Operational Recommendations Photomultiplier Tubes.*
14. A value of $< 10\ \mu A$ is recommended for applications requiring good stability.
15. The single electron spectrum resolution to be optimized by adjusting the dynode 2 voltage.
16. Peak to valley ratio is defined as the single electron peak value divided by the minimum value to the left of the peak.

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MECHANICAL DATA

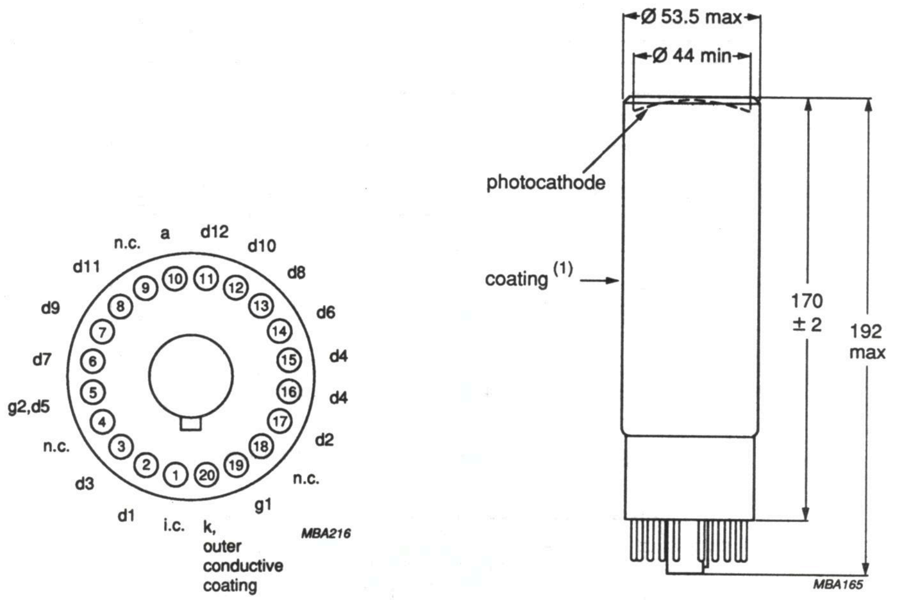

Fig.5.

Base	20-pin (JEDEC B20-102)
Net mass	240 g

ACCESSORIES

Socket	type FE 1120
Mu-metal shield	type 56619
Base assembly	S563

(1) The envelope of the tube is covered with a conductive coating, connected to the cathode. On top of this a black paint is applied which is neither guaranteed to be light tight nor isolating. Care should be taken to avoid electric shock.

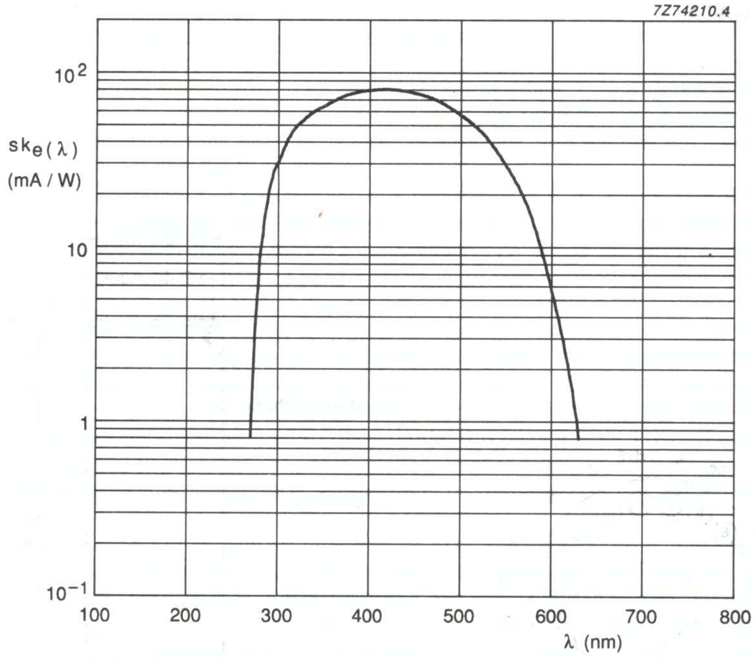

Fig. 6 Spectral sensitivity characteristic XP2020.

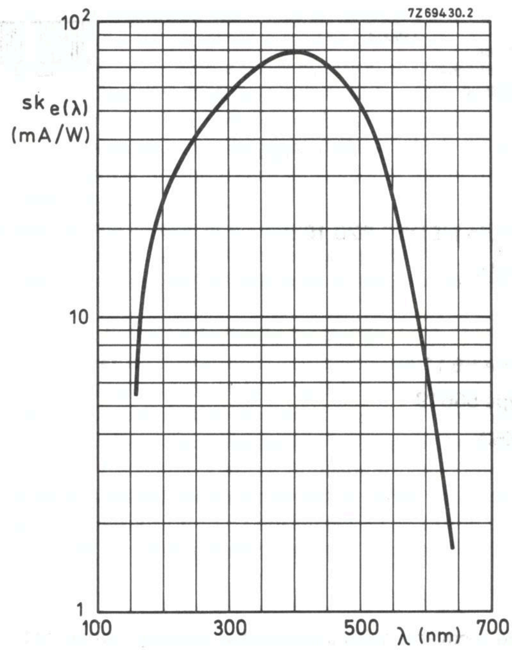

Fig. 7 Spectral sensitivity characteristic XP2020/Q.

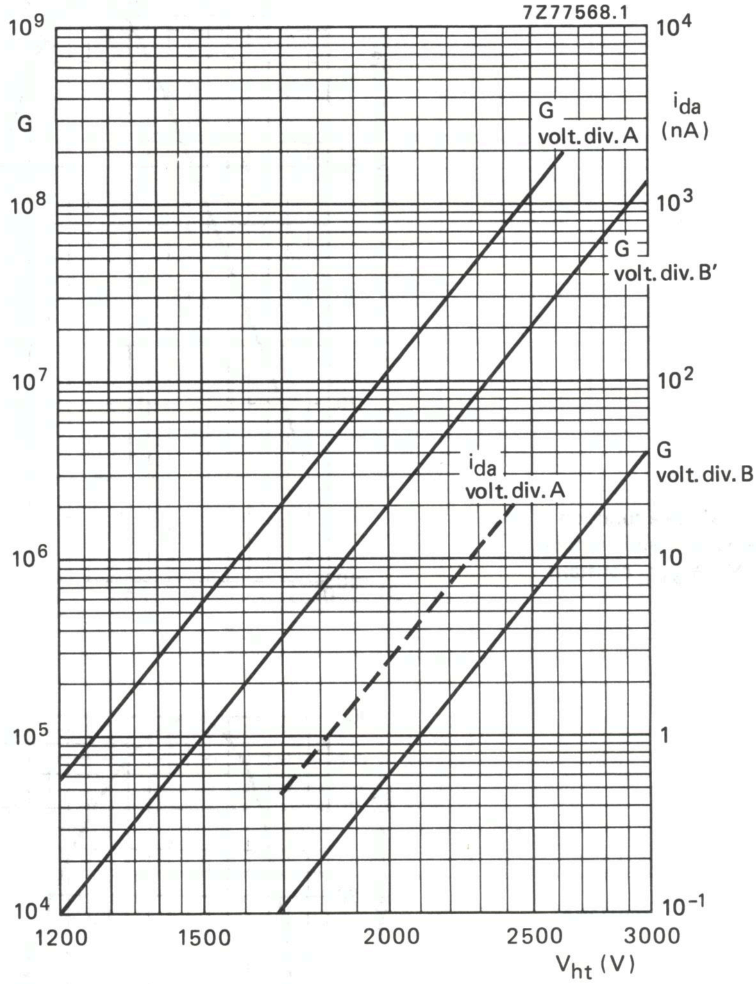

Fig. 8 Gain, G, and anode dark current, i_{da}, as a function of supply voltage V_b.

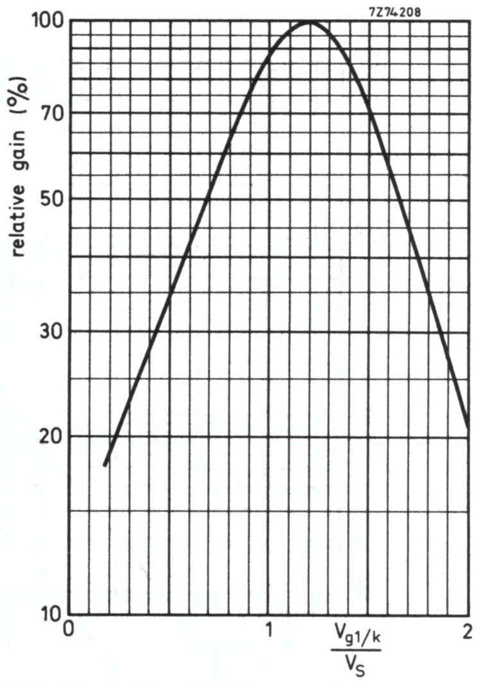

Fig. 9 Relative gain as a function of the voltage between grid 1 and cathode, normalized to V_S. $V_{S1/k}$ constant.

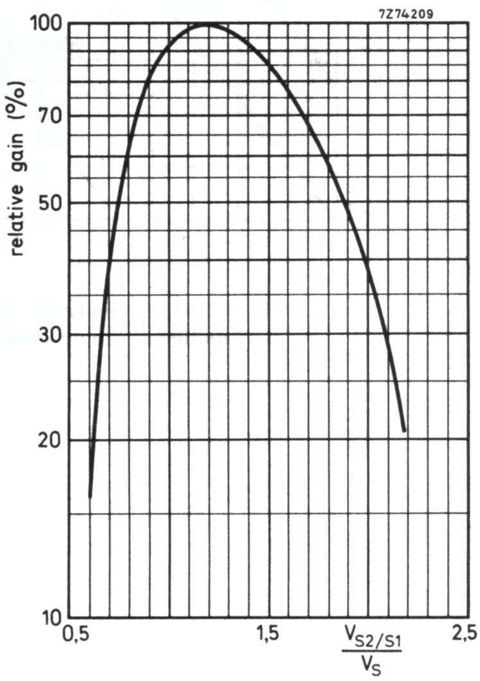

Fig. 10 Relative gain as a function of the voltage between S_2 and S_1, normalized to V_S. $V_{S3/S1}$ constant.

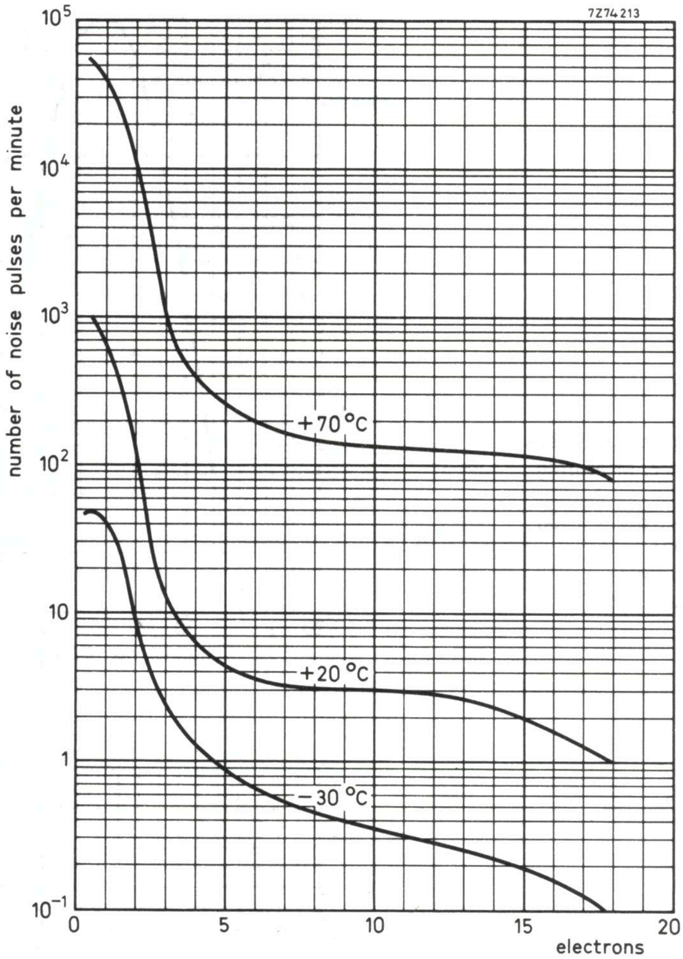

Fig. 11 Typical background spectrum from 0,1 to 18 equivalent photoelectrons, at a gain of 3×10^7 with voltage divider A.

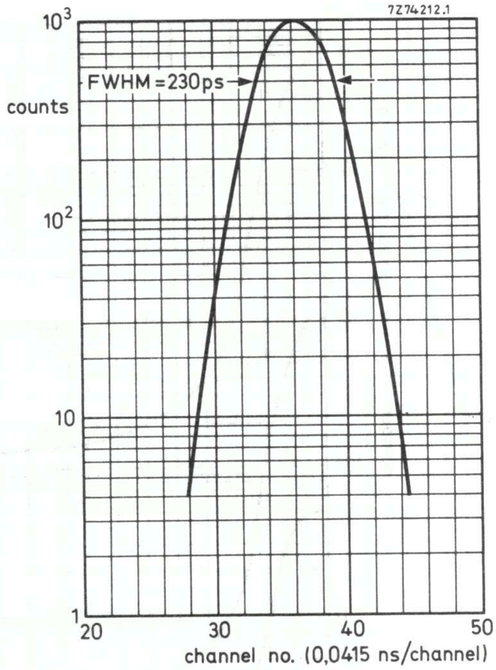

Fig. 12 Time resolution for 2 tubes XP2020 in coincidence. Measuring conditions:
Number of photoelectrons ≈ 1500
Supply voltage 2500 V
Constant fraction operation
Dynamic energy region 20%.

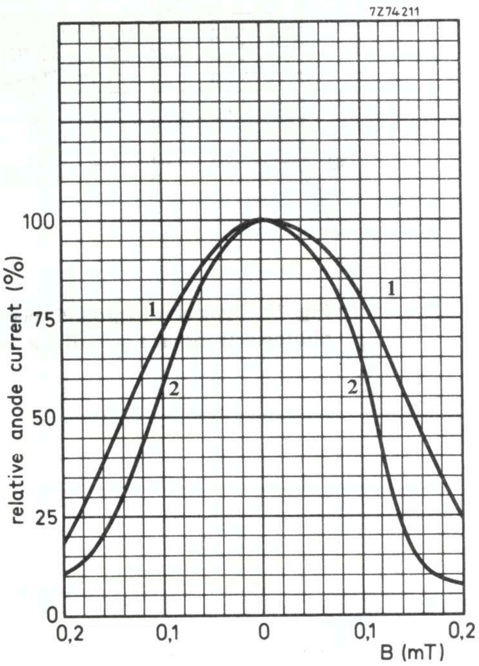

Fig. 13 Relative anode current as a function of the magnetic flux density B.
1. ⊥ axis a
2. // axis a

Fig. 1

Fig.
Resc

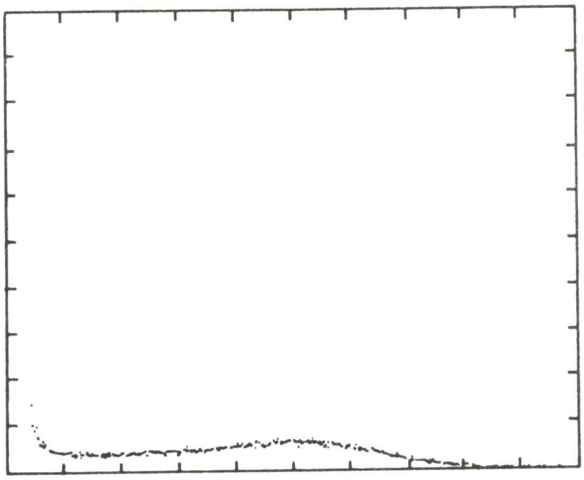

Fig. 14 Background noise spectrum, obtained with an XP2020 tube, series no. 13246. Gain: 3×10^7.

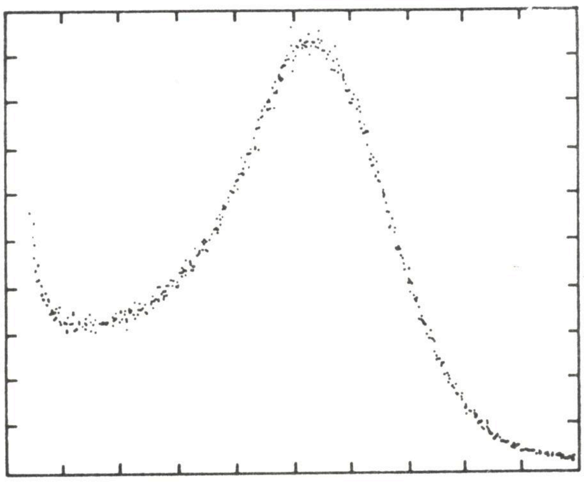

Fig. 15 Single electron spectrum obtained with an XP2020 tube, series no. 13246. Gain: 3×10^7. Resolution 67%. Peak to valley ratio: 2,8 (see Note 16).