6p. Radiation Detection

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6p-1. General. Radiation detectors can be classed as either thermal detectors or quantum detectors. In the former the radiation is absorbed and transformed into heat in the detector, producing a temperature rise in the device. Some characteristic of the detector changes as a function of temperature, and this characteristic can be measured to determine the quantity of radiation striking the detector. In this type of receiver, then, the quantity actually measured is the temperature change. In the quantum detector, on the other hand, the incident photons change the detector characteristic directly.

There can be as many thermal detectors as there are material characteristics which change with temperature. Table 6p-1 lists some of the fundamental processes that are used in thermal detectors.

TABLE 6p-1. THERMAL DETECTORS

Device	*Measured characteristic*
Bolometer	Change of electrical resistance with temperature
Thermocouple	Peltier effect or change of contact potential at a junction as a function of temperature
Pneumatic detector	Change of gas pressure in an enclosed chamber as a function of temperature

Various kinds of quantum detectors are mentioned and described briefly in Table 6p-2.

TABLE 6p-2. QUANTUM DETECTORS

Device	*Measured characteristic*
Photoelectric cell	The emission of an electron from a surface when struck by sufficiently energetic photons
Photoconductor cell	The resistance of the cell changes directly as a result of photon absorption
Photovoltaic cell	A voltage is generated directly as a result of the absorption of a photon
Photographic plate	A silver halide is reduced to silver by photon absorption

Both types—thermal and quantum detectors—are manufactured in single elements, multiple elements, and image detectors. The important characteristics of radiation detectors are:

Spectral Response. The reciprocal of the amount of monochromatic incident radiant power that it takes to produce a given detector output response (e.g., electrical signal or photographic density), plotted against radiation wavelength. For thermal detectors, the response is generally independent of wavelength over a range from the ultraviolet to wavelengths which approach the dimensions of the detector. Quantum detectors show a long-wavelength cutoff, related to the energy gap of the

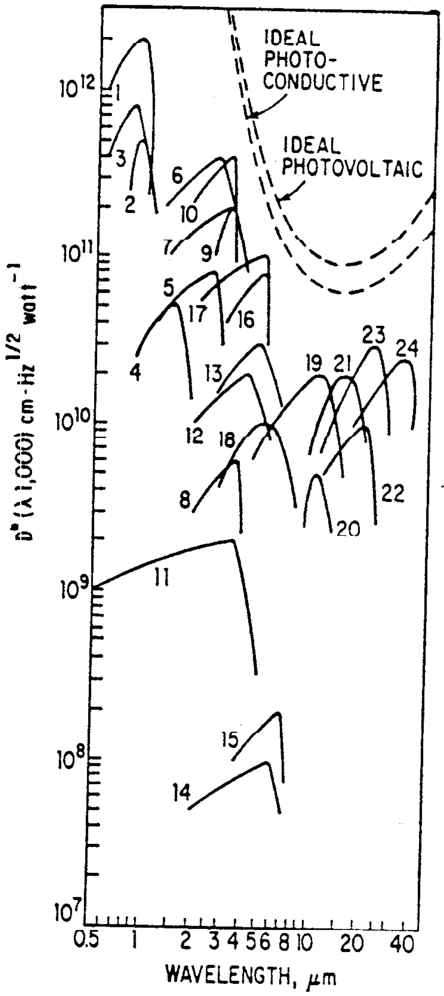


FIG. 6p-1. Characteristics of commercially available semiconductor detectors.

detector material (Fig. 6p-1). Table 6p-3 shows the characteristics of detectors in Fig. 6p-1. The spectral defectivities in Fig. 6p-1 were measured under a 60-deg field of view and with a 295 K background temperature. The theoretical values of peak D^* lie on the dashed curves.

Noise. The fluctuation in the output of the detector when the incident radiation is steady.

JOHNSON NOISE, due to thermal agitation, is present in any electrical circuit, as follows:

$$\text{rms noise voltage} = \sqrt{4kTR(f_2 - f_1)} \qquad \text{(6p-1)}$$

where k = Boltzmann's constant (1.374×10^{-23} joule/K)
T = Kelvin temperature
R = resistive component of circuit element
f_2, f_1 = bandwidth limits

SHOT NOISE, arising from statistical fluctuation in electron tube current, is given by

$$\bar{\imath} = \sqrt{2eI(f_2 - f_1)}$$

where $\bar{\imath}$ = rms noise current
e = electronic charge (1.59×10^{-19} coulomb)
I = direct electron current, amp

Key to Detector Manufacturers in Table 6p-3

a.	Aerojet-General Corp.	Azusa, California
b.	Avco Corporation, Electronics Div.	Cincinnati, Ohio
c.	Barnes Engineering Co.	Stamford, Conn.
d.	Block Engineering, Inc.	Cambridge, Mass.
e.	Catron Electronic Corp.	Geneva, Ill.
f.	E. G. and G.	Boston, Mass.
g.	Electronic Corp. of America	Cambridge, Mass.
h.	Electro-Nuclear Laboratories, Inc.	Menlo Park, Calif.
i.	Honeywell Radiation Center	Boston, Mass.
j.	Infrared Industries, Inc.	Waltham, Mass.
k.	Mithras, Inc.	Cambridge, Mass.
l.	Networks Electronic Corp.	Chatsworth, Calif.
m.	Philco-Ford Corp.	Spring City, Penn.
n.	Raytheon Co.	Waltham, Mass.
o.	Santa Barbara Research Center	Goleta, Calif.
p.	SAT—Paris, France; (U.S. Representative: Elteck Corp.)	Larchmont, N.Y.
q.	Sensor Precision Ind.	Medfield, Mass.
r.	Texas Instruments Inc.	Dallas, Texas
s.	United Detector Technology	Santa Monica, Calif.

TABLE 6p-3. CHARACTERISTICS OF AVAILABLE SEMICONDUCTOR DETECTORS

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Detector material:	Si Silicon		GaAs Gallium arsenide	Ge Germanium	PbS Lead sulfide			InAs Indium arsenide			PbSe Lead selenide	
Operating mode	pv	pc	pv	pv	pc	pc	pc	pv	pv	pv	pc	pc
Typical peak D^* at 1,000-Hz modulation frequency, cm $Hz^{\frac{1}{2}}$ $watt^{-1}$	2×10^{12}	5×10^{11}	8×10^{11}	5×10^{10}	8×10^{10}	4×10^{11}	3×10^{11}	6×10^{9}	2×10^{11}	4×10^{11}	2×10^{9}	2×10^{10}
Wavelength, μm	0.9	0.9	0.85	1.5	2.5	2.7	3.1	3.5	3.2	3.1	3.4	4.1
Field of view, deg	....	....	....	....	....	60	60	....	60	60	....	60
Background temperature, K	....	....	....	....	....	295	295	....	295	295	....	295
Best measured peak D^*, cm $Hz^{\frac{1}{2}}$ $watt^{-1}$ (conditions as above)	1×10^{13}	1×10^{12}	....	....	1.5×10^{11}	7×10^{11}	4×10^{11}	1×10^{10}	3.5×10^{11}	7×10^{11}	2×10^{10}	5×10^{10}
Spectral range exhibiting greater than 50% relative response, μm	0.6–1.0	0.8–1.06	0.6–0.95	0.9–1.7	1.2–2.8	1.3–3.2	1.4–3.8	2.0–3.8	2.5–3.4	1.8–3.3	0.5–4.2	2.0–5.3
Normal operating temperature, K	295	295	295	295	295	195	77	295	195	77	295	195
Operating temperature limits, K (50% peak D^* degradation points)	—, 320	—, 350	....	....	—, 310	130, 250	—, 160	—, 320	—, 210	—, 180	—, 310	—, 230
Typical time constant, seconds	5×10^{-7}	5×10^{-6}	1×10^{-8}	1×10^{-7}	3×10^{-4}	5×10^{-3}	3×10^{-3}	$<1 \times 10^{-6}$	$<1 \times 10^{-6}$	5×10^{-7}	2×10^{-6}	3×10^{-6}
Nominal resistance, ohms	1×10^{6}	1×10^{6}	1×10^{6}	2×10^{5}	1×10	1×10^{4}	2×10^{6}	3×10^{1}	5×10^{4}	5×10^{5}	2×10^{6}	5×10^{6}
Area Configuration												
Single detectors:												
Size range, min. to max., inches	0.004–0.5	0.004–0.7	0.004–0.060	0.004–0.5	0.001–1.0	0.001–1.0	0.001–1.0	0.004–0.1	0.004–0.1	0.004–0.1	0.003–0.5	0.003–0.5
Shape (round, square, or rectangular)	Any	□ ▭	○ ▯	Any	□ ▭	□ ▭	□ ▭	○	○	○	□ ▭	□ ▭
Typical package	TO-5/18	Flat mount	TO 18	TO 5/18, BNC	Flat mount	Glass Dewar	Glass Dewar	TO 5/18	Glass Dewar	Glass Dewar	Flat mount	Glass Dewar
Detector arrays:												
Minimum size per detector, inches	0.004	0.004	....	....	0.001	0.001	0.001	0.003	0.003	0.003	0.003	0.003
Minimum size per space, inches	0.002	0.001	....	....	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002
Dimensions—see code	0.002″	0.020″	....	....	0.001″	0.001″	0.001″	0.002″	0.002″	0.002″	0.001″	0.001″
Manufacturer(s)—see key	*f,h,m,r,s*	*k*	*m*	*h,m,r*	*e,g,j,o,q*	*g,j,o,q*	*g,j,o,q*	*c,h,m,r*	*c,m,r*	*c,o,r*	*j,o*	*j,o*

TABLE 6p-3. CHARACTERISTICS OF AVAILABLE SEMICONDUCTOR DETECTORS (*Continued*)

	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
Detector material	PbSe Lead selenide	InSb Indium antimonide				Ge:Au Gold-doped germanium	Ge:Hg Mercury-doped germanium	(Hg-Cd)Te Mercury-cadmium telluride	Ge:Cd Cadmium-doped germanium	Si:Sb Antimony-doped silicon	Copper-doped germanium	Zinc-doped germanium
Operating mode	pc	pem	pc	pc	pv	pc	pc	pv	pc	pc	pc	pc
Typical peak D^* at 1,000-Hz modulation frequency, cm $Hz^{\frac{1}{2}}$ $watt^{-1}$	3×10^{10}	1×10^{9}	2×10^{8}	8×10^{10}	1×10^{11}	1×10^{10}	2×10^{10}	5×10^{9}	2×10^{10}	1×10^{10}	3×10^{10}	2.5×10^{10}
Wavelength, μm	4.8	6.0	6.8	5.3	5.1	5.0	10.5	10.6	16	20	23	36
Field of view, deg	60	....	....	60	60	60	60	60	60	60	60	60
Background temperature, K	295	....	....	295	295	295	295	295	295	295	295	295
Best measured peak D^*, cm $Hz^{\frac{1}{2}}$ $watt^{-1}$ (conditions as above)	5×10^{10}	3×10^{9}	....	1×10^{11}	2×10^{11}	2×10^{10}	5×10^{10}	2×10^{10}	4×10^{10}	2×10^{10}	5×10^{10}	5×10^{10}
Spectral range exhibiting greater than 50% relative response, μm	2.7–6.3	2.0–7.0	3.6–7.3	3.0–5.4	2.0–5.4	3.0–7.5	6–14	9–13	11–20	12–23	15–27	20–40
Normal operating temperature, K	77	295	295	77	77	60	27	77	4.2	4.2	4.2	4.2
Operating temperature limits K (50% peak D^* degradation points)	—, 160	....	....	—, 95	—, 105	—, 80	—, 40	—, 100	—, 26	—, 10	—, 20	—, 6
Typical time constant, seconds	4×10^{-6}	2×10^{-7}	1×10^{-6}	6×10^{-6}	$<1 \times 10^{-6}$	1×10^{-7}	2×10^{-7}	$<1 \times 10^{-8}$	1×10^{-7}	1×10^{-7}	5×10^{-7}	2×10^{-8}
Nominal resistance, ohms	5×10^{6}	1×10^{1}	2×10^{1}	1×10^{4}	1×10^{5}	1×10^{5}	1×10^{6}	2.5×10^{1}	1×10^{6}	7×10^{6}	1×10^{6}	2.5×10^{6}
Area Configuration												
Single detectors:												
Size range, min. to max., inches	0.003–0.8	0.015–0.040	0.040–0.1	0.003–0.1	0.003–0.1	0.003–0.1	0.003–0.1	0.020–0.080	0.003–0.1	0.004–0.1	0.003–0 1	0.003–0.1
Shape (round, square, or rectangular)	□ ▭	□	□ ▭	□ ▭	□ ○	□ ▭	□ ▭	□ ▭	□ ▭	□ ▭	□ ▭	□ ▭
Typical package	Glass Dewar	Metal container	Flat mount	Glass Dewar	Glass Dewar	Glass Dewar	Metal Dewar	Glass or metal Dewar	Metal Dewar	Metal Dewar	Metal Dewar	Metal Dewar
Detector arrays:												
Minimum size per detector, inches	0.003	....	....	0.003	0.003	0.003	0.003	Developmental	0.003	0.004	0.003	0.003
Minimum size per space, inches	0.002	....	....	0.002	0.002	0.002	0.002	....	0.002	0.004	0.002	0.002
Dimensions—see code	↔ ✢ ↕ 0.001″	....	....	↔ ⁻₋ ↕ 0.001″	↔ ⁻₋ ↕ 0.002″	↔ ⁻₋ ↕ 0.002″	↔ ⁻₋ ↕ 0.002″	....	↔ ⁻₋ ↕ 0.002″	↔ ⁻₋ ↕ 0.004″	↔ ⁻₋ ↕ 0.002″	↔ ⁻₋ ↕ 0.002″
Manufacturer(s)—see key	j,o.	h,i,j	d,i	h,i,l,m,n,o	b,c,l,m,o,r	c,m,n,o	a,m,n,o,r	p	n,o,r	a	a,m,n,o,r	o

pc Photoconductive mode pv Photovoltaic mode pem Photoelectromagnetic mode Array dimension code: linear ↔; 2-dimensional ✢; linear staggered ⁻₋; space between rows ↕.

Other sources of noise are current noise, photon noise, and flicker noise. Since noise limits the detection of weak signals when unlimited amplification is available, sensitivity of a detector is often expressed as noise equivalent power.

Noise Equivalent Power (NEP). The incident radiation that it takes to produce a detector output signal equal to detector noise in a specified bandwidth (generally 1 Hz). Generally the incident radiation is chopped and expressed in watts as the rms value of the fundamental component of the chopped radiation.

Specific detectivity D^* is the reciprocal of the noise equivalent power of the detector referred to unit area and 1-Hz bandwidth.

$$D^* = \frac{\sqrt{A\,\Delta f}}{\text{NEP}} \qquad \text{watt}^{-1}\,\text{cm sec}^{-\frac{1}{2}} \tag{6p-3}$$

where A = detector area, cm^2

Δf = effective noise bandwidth, Hz

Time Constant. Dynamic response of many detectors to a step function can be approximated by a single exponential of the form $(1 - \epsilon^{-t/\tau})$, in which t is time and τ is the time constant. The frequency response is then approximately

$$\frac{1}{\sqrt{1 + (2\pi f\tau)^2}} \tag{6p-4}$$

where f is the electrical frequency of the signal.

The signal and noise as a function of frequency for a typical lead sulfide detector and a typical lead selenide detector are shown in Figs. 6p-2 and 6p-3.

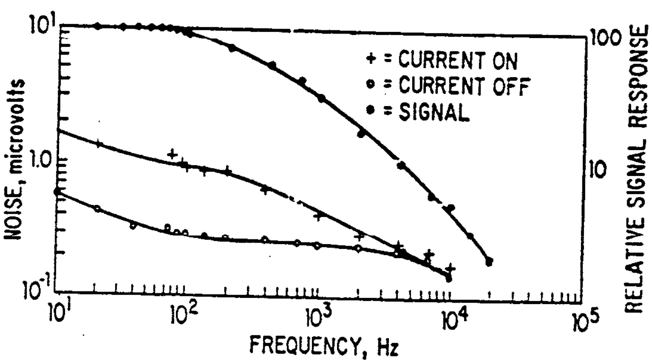


FIG. 6p-2. PbS detector at 25°C. Signal vs. chopping frequency, and noise vs. frequency.

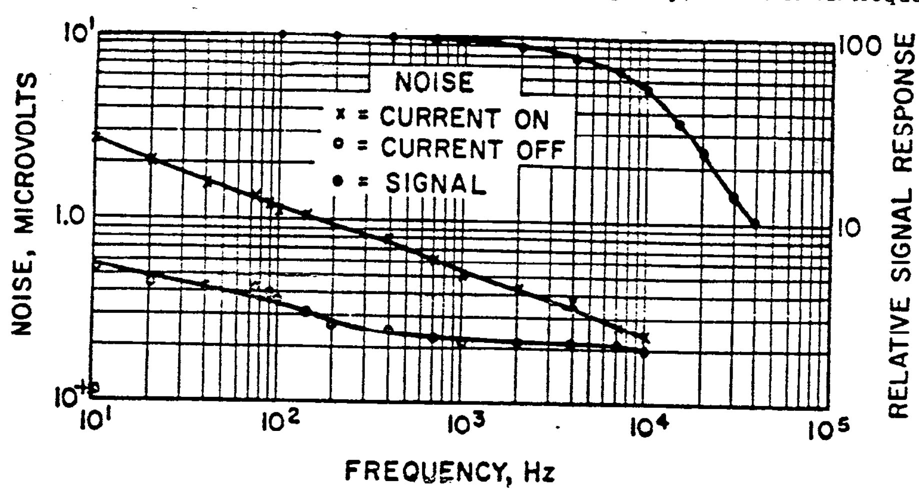


FIG. 6p-3. PbSe detector at −195°C. Signal vs. chopping frequency, and noise vs. frequency.

TABLE 6p-4. PHOTOTUBE TYPES, PHOTOSENSITIVE-DEVICE CLASSIFICATION CHART

Phototubes

Response	Single-unit Vacuum	Single-unit Gas	Twin-unit Vacuum	Twin-unit Gas	Multiplier
S-1	917 919 922 925 6570	1P40 1P41 868 918 921 923 927 928 930 6405/1640 6953	....	920	7120
S-3	926	1P29			
S-4	1P39 929 934 5653 7043	1P37 5581 5582 5583	5652	5584	1P21 931-A 6328 6472 7117
S-5	935	....	....	....	1P28
S-8	....	....	....	....	1P22
S-9	1P42				
S-10	....	....	....	....	6217
S-11	....	....	....	....	2020 5819 6199 6342-A 6655-A 6810-A 7264
Extended S-11	....	....	....	....	7046
S-13	....	....	....	....	6903
S-17	....	....	....	....	7029
S-19	....	....	....	....	7200
S-20	....	....	....	....	7265 7326

TABLE 6p-4. PHOTOTUBE TYPES, PHOTOSENSITIVE-DEVICE CLASSIFICATION CHART (*Continued*)

Camera Tubes

Image orthicons	Vidicons	Iconoscopes
5820 6474 6849 7198 7513	6198 6326 7038 7262 7263	1850-A

Image-converter Tubes

Response	Infrared-sensitive types	Ultraviolet-sensitive types
S-1	6032 6032-A 6914 6914-A 6929	
S-21	......	7404

6p-2. Photoemissive Detectors. A tabulation of photoemissive detector tubes of single, twin, and electron multiplier types is shown in Table 6p-4. The multiplier types have sensitive surfaces ranging in diameter from about 1 to 11 cm with 6, 10, or 14 stages. Table 6p-5 shows dark noise equivalent power data of some of the more sensitive types (ref. 4) with various spectral characteristics. The spectral characteristic curves of various photo surfaces are shown in Fig. 6p-4.

TABLE 6p-5. THE DARK NOISE EQUIVALENT POWER OF VARIOUS PHOTOEMISSIVE DETECTOR TUBES

Type No.	Spectral response	Dark NEP at response pe k		
		At +25°C, watts	At temp. shown, watts at °C	
1P21	S-4	5×10^{-16}	5×10^{-17}	−55
7102†	S-1	1.7×10^{-12}	5×10^{-14}	−60
7200	S-19	5×10^{-16}	3×10^{-17}	−78
7264	S-11	4×10^{-15}	1.2×10^{-15}	−[illegible]0
7265	S-[illegible]0	1.6×10^{-15}	2.3×10^{-16}	−80

† NEP figures are for long-wavelength response peak at 0.8 μm.

The dark NEP data apply only if there is no substantial amount of unchopped effective radiation reaching the photocathode. Otherwise the phototube becomes dominated by shot noise, and the NEP is then given by

$$\mathrm{NEP} = \sqrt{\frac{2eW_f}{C(f_2 - f_1)}}$$

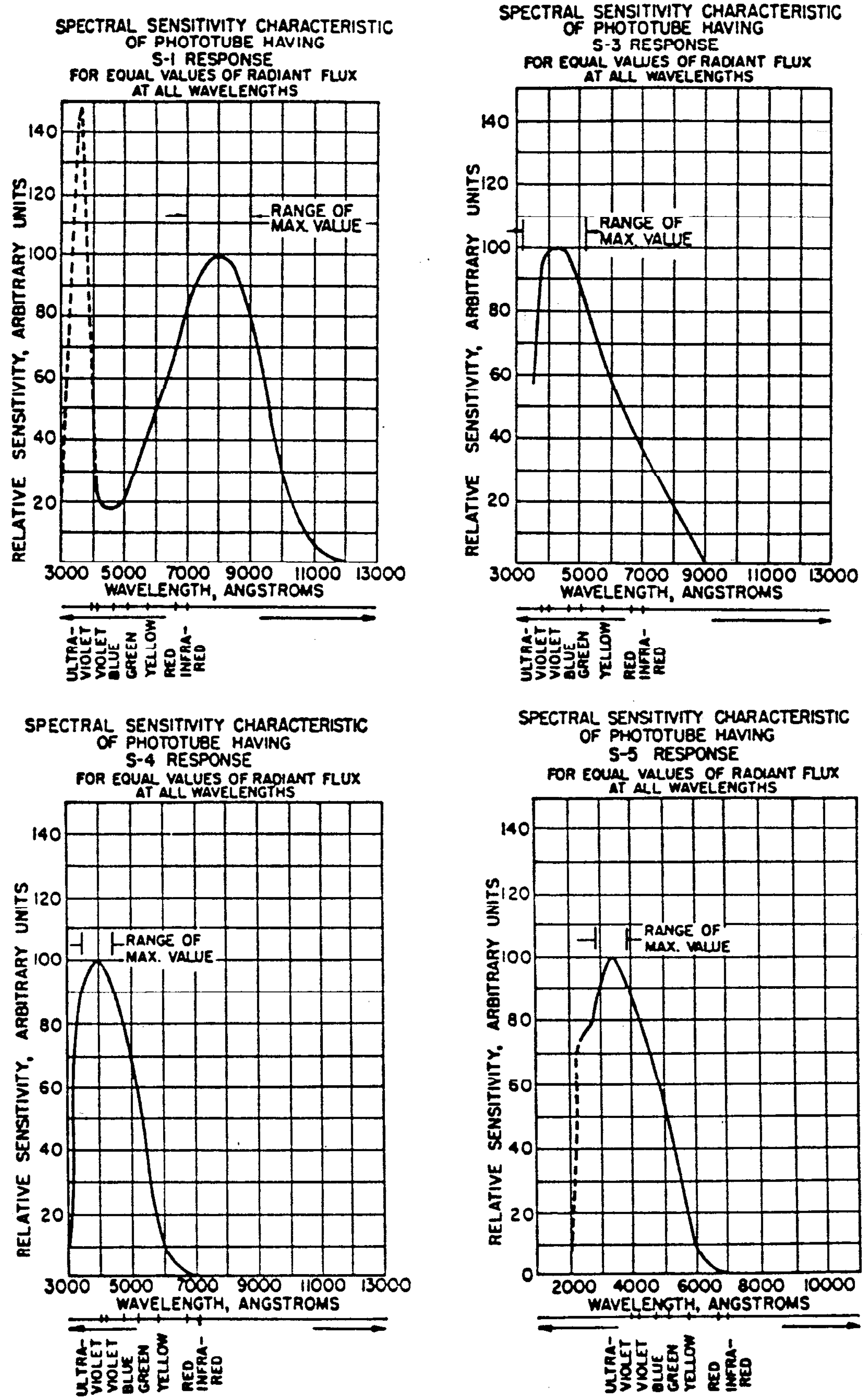
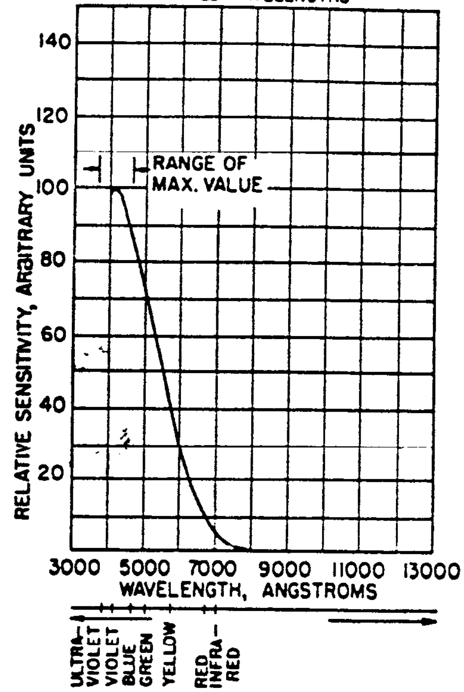
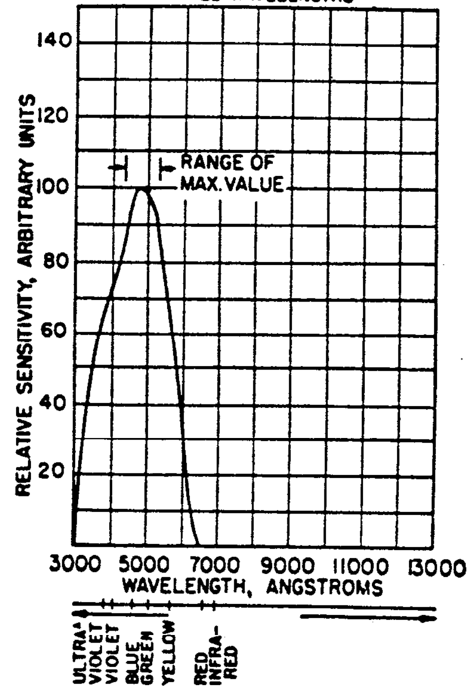


Fig. 6p-4. Spectral sensitivities of commercially available phototubes.

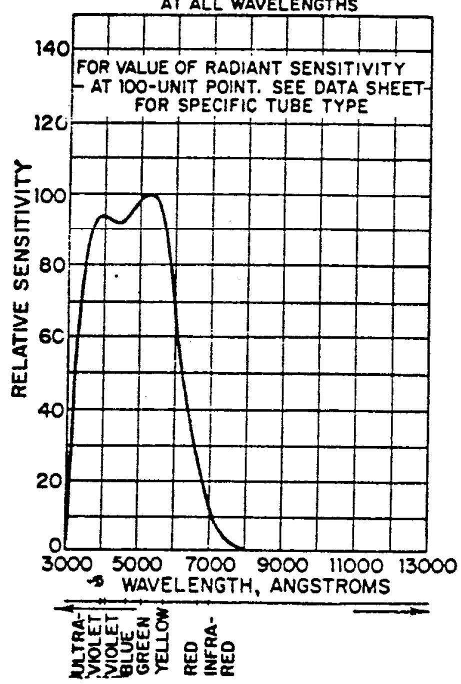
SPECTRAL SENSITIVITY CHARACTERISTIC OF PHOTOTUBE HAVING S-8 RESPONSE
FOR EQUAL VALUES OF RADIANT FLUX AT ALL WAVELENGTHS



SPECTRAL SENSITIVITY CHARACTERISTIC OF PHOTOTUBE HAVING S-9 RESPONSE
FOR EQUAL VALUES OF RADIANT FLUX AT ALL WAVELENGTHS



SPECTRAL SENSITIVITY CHARACTERISTIC OF PHOTOTUBE HAVING S-10 RESPONSE
FOR EQUAL VALUES OF RADIANT FLUX AT ALL WAVELENGTHS



SPECTRAL SENSITIVITY CHARACTERISTIC OF PHOTOTUBE HAVING S-11 RESPONSE
FOR EQUAL VALUES OF RADIANT FLUX AT ALL WAVELENGTHS

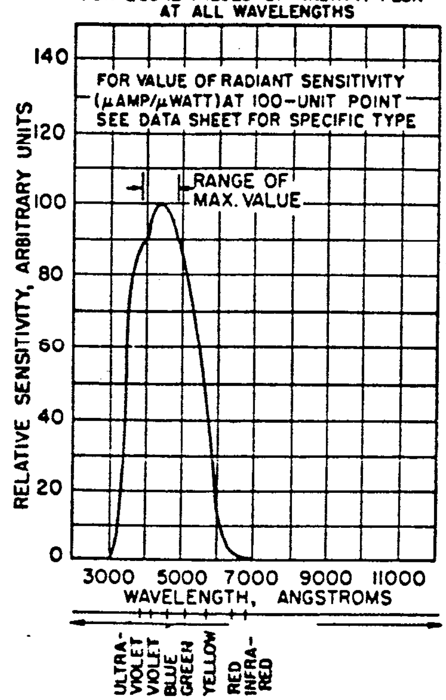


FIG. 6p-4 (*Continued*)

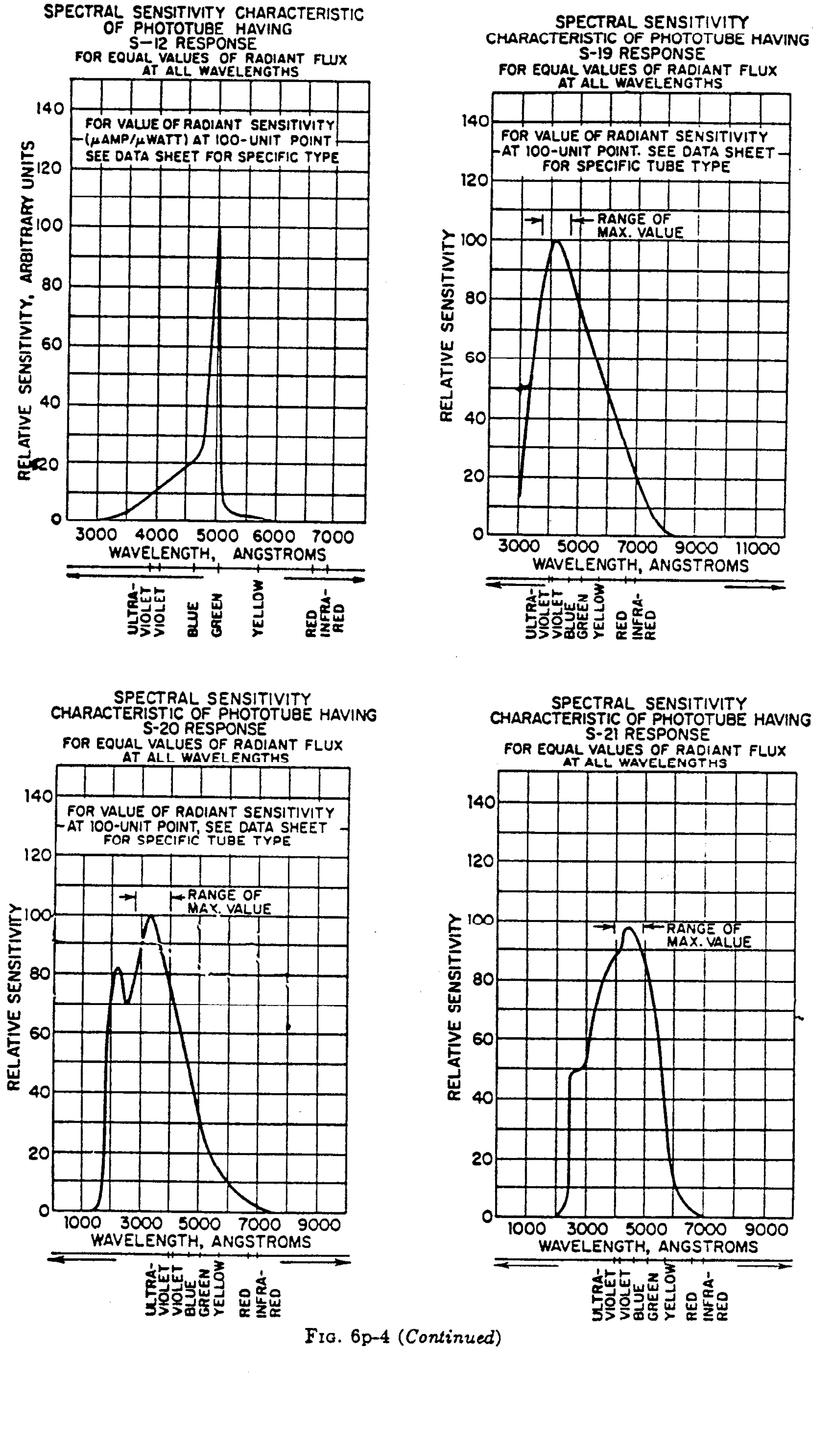
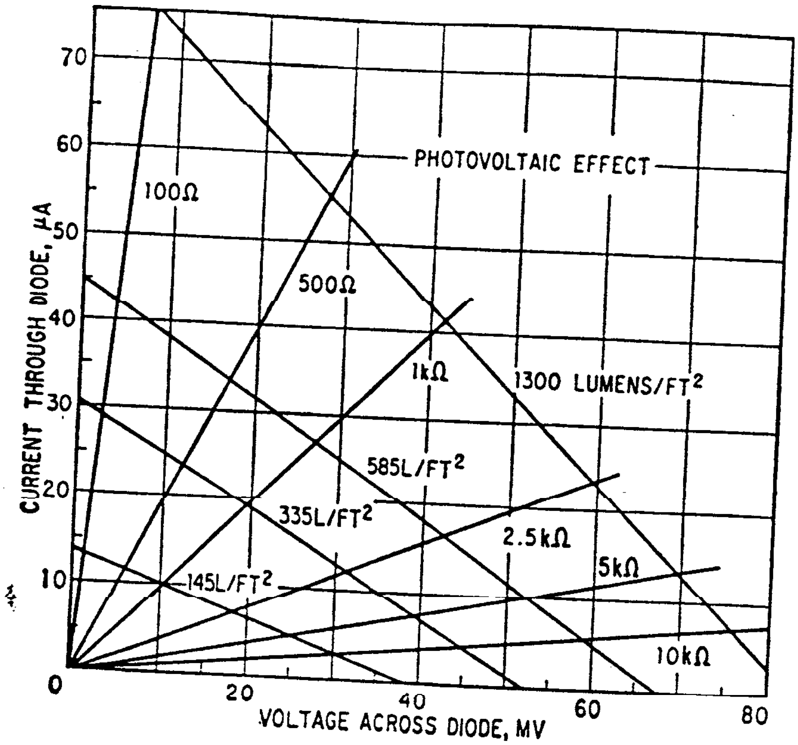


Fig. 6p-4 (*Continued*)



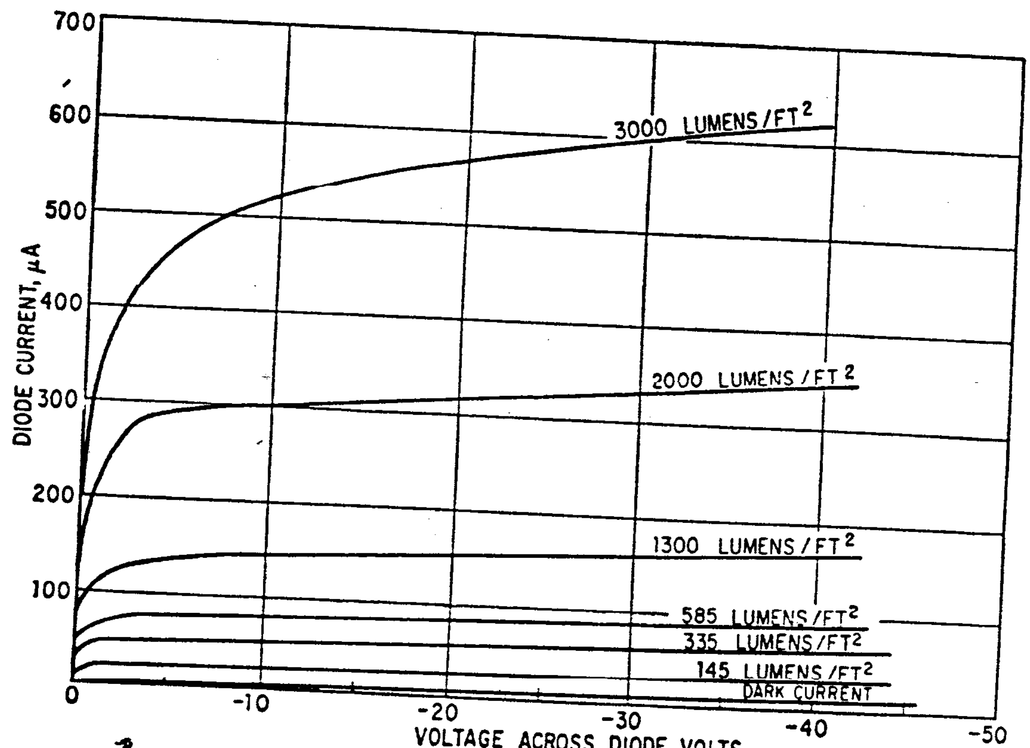


FIG. 6p-5. Germanium photodiode curves showing biased and unbiased photovoltaic characteristics.

where e, f_2, f_1 = quantities defined under shot noise

W_f = unchopped background radiation reaching the photocathode, effective watts

C = cathode sensitivity, amp per effective watt

6p-3. Germanium Photodiodes and Silicon Cells. The characteristics of germanium photodiodes are shown in Fig. 6p-5. Silicon photovoltaic cells (ref. 2) are used largely for the conversion of solar energy into electrical energy. Typical data are shown in Fig. 6p-6.

6p-4. Cadmium Sulfide, Cadium Selenide, and Selenium Detectors. CdS and CdSe cells (ref. 3), listed in Table 6p-6, are available in photoconductive surfaces, areas 1 to 100 mm^2, potted in transparent resin or sealed in glass envelope. Some CdSe cells have very low dark conductance: $<10^{-4}$ μmho per square surface. Low dark resistance equivalent illumination $<10^{-5}$ ft-c makes CdS and CdSe suitable for detecting low light levels without light chopping. Both have long time constants at low light levels. Comb-type electrodes (series 500 and 500L) provide greater conductance values. Series 400, 400L, and 600L have a rectangular sensitive surface of approximately $\frac{1}{16}$ by $\frac{3}{16}$ in. Spectral performance curves are given in Fig. 6p-7. Conductances at various illumination levels are given in Fig. 6p-8. The spectral response of a typical selenium cell is shown in Fig. 6p-9.

6p-5. Image Converters or Image Intensifiers. Available types (ref. 4), shown in Table 6p-7, have a semitransparent photoemissive cathode at the input end of an evacuated glass envelope (ref. 5). Electrons emitted in a pattern corresponding to the image falling on the surface are accelerated and focused onto an output surface of electroluminescent phosphor at high potential to produce a bright picture. Types 6914 and 6929, having a silver-oxygen-cesium photocathode, can be used to convert an image formed in near-infrared radiation to a visible image. If a fast optical system is used to image a visible scene on the photosurface, the output phosphor image can be made brighter than the scene. For 2870 K tungsten illumination of noncolor selective objects, the screen brightness/scene brightness ratio is given by

$$\frac{\text{Conversion index}}{4f^2M^2}$$

where f = f/ratio of optical system

M = magnification (output/input image)

For all three types listed: Magnification (output/input image size) = 0.8; screen phosphor = P20.

6p-6. Vidicons. Available types (ref. 6) have a photoconducting layer on the inside of a window at the input end of an evacuated glass envelope (ref. 7). The charge pattern developed when an image falls on this surface is scanned by an electron beam to produce a video signal. Vidicons are used in compact television pickup equipment.

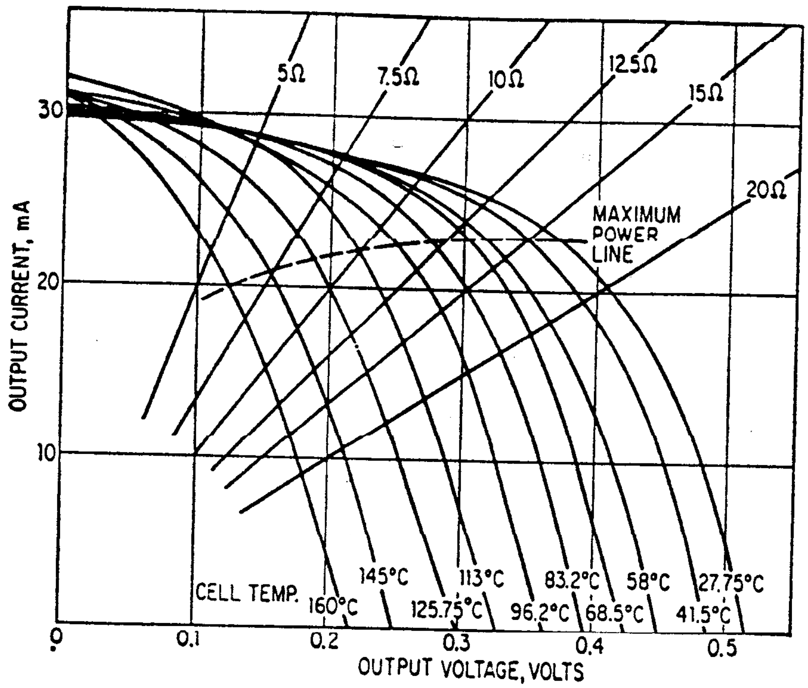
Other types 6326, 7038, 7263, 7290, 7325 have similar resolution, sensitive area, relative spectral response, and generally similar characteristics. Vidicons have also been made with infrared sensitive PbS photocathodes (ref. 13). Figures 6p-10 and 6p-11 and Table 6p-8 show characteristics of Vidicon Type 7262.

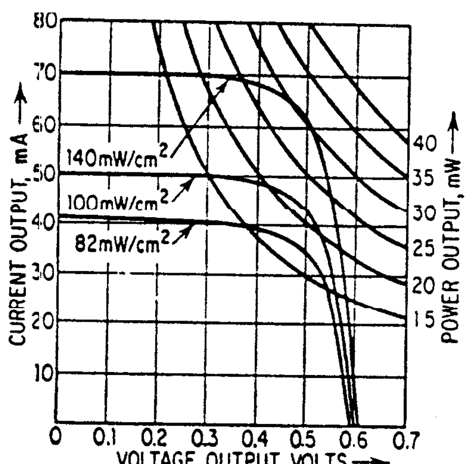
6p-7. Image Orthicon. The image orthicon (ref. 8) is a television pickup tube that has a semitransparent photocathode, a mesh screen, and a thin dielectric target of high resistivity. Electrons emitted by the cathode are focused on the target, causing secondary emission which leaves the rear face of the target with a positive charge pattern. This is scanned by an electron beam whose signal currents are amplified by electron multiplier stages to provide a high-level output current.

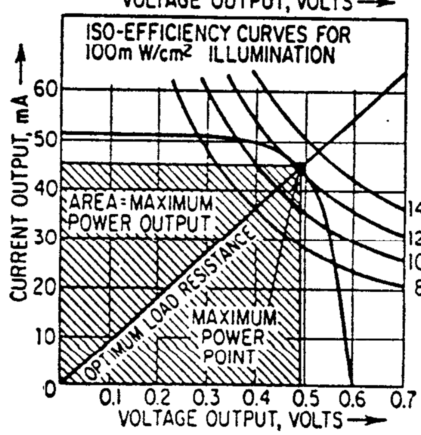
Table 6p-6. Characteristics of CdS and CdSe Cells
Refer to Fig. 6p-8

Material†	2 (CdS)					3/3A (CdSe)					4 (CdSe)					5 (CdS)					7 (CdS)				
Light level, ft-c	0.01	0.1	1	10	100	0.01	0.1	1	10	100	0.01	0.1	1	10	100	0.01	0.1	1	10	100	0.01	0.1	1	10	100
Time constant (to 1 − 1/e of final reading):																									
Rise, sec	2.5	0.59	0.14	0.037	0.008	0.29	0.069	0.017	0.004	0.001	1.1	0.25	0.047	0.010	0.002	2.8	0.30	0.074	0.021	0.007	1.1	0.25	0.047	0.010	0.002
Decay, sec	0.57	0.17	0.053	0.016	0.005	0.030	0.014	0.007	0.003	0.002	0.120	0.053	0.023	0.010	0.005	1.3	0.22	0.058	0.021	0.014	0.12	0.053	0.23	0.010	0.005
Temp. characteristic $100 \times \frac{G_t}{G_{25}°C}$:																									
−25°C	46	110	116	110	92	600	340	200	130	120	220	130	99	99	98	77	80	95	95	100	110	94	88	86	86
0°C	52	100	110	104	95	250	240	160	120	110	170	110	100	100	101	78	82	96	99	100	110	98	94	93	93
25°C	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
50°C	250	103	97	98	99	78	28	51	69	79	73	84	89	95	96	160	120	110	110	100	89	94	99	102	107
75°C	370	120	93	94	94	95	48	31	44	48	53	60	65	80	88	230	120	120	110	100	50	69	87	97	120

† Last digit of CL cell number.







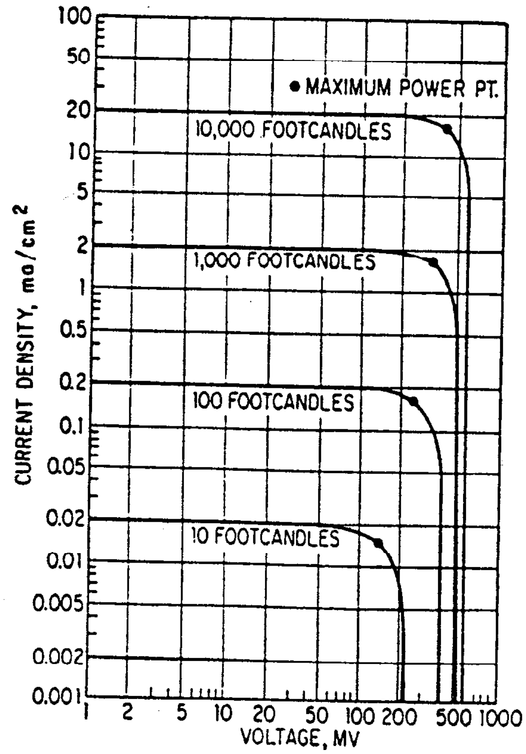


Fig. 6p-6. Characteristics of silicon solar cells.

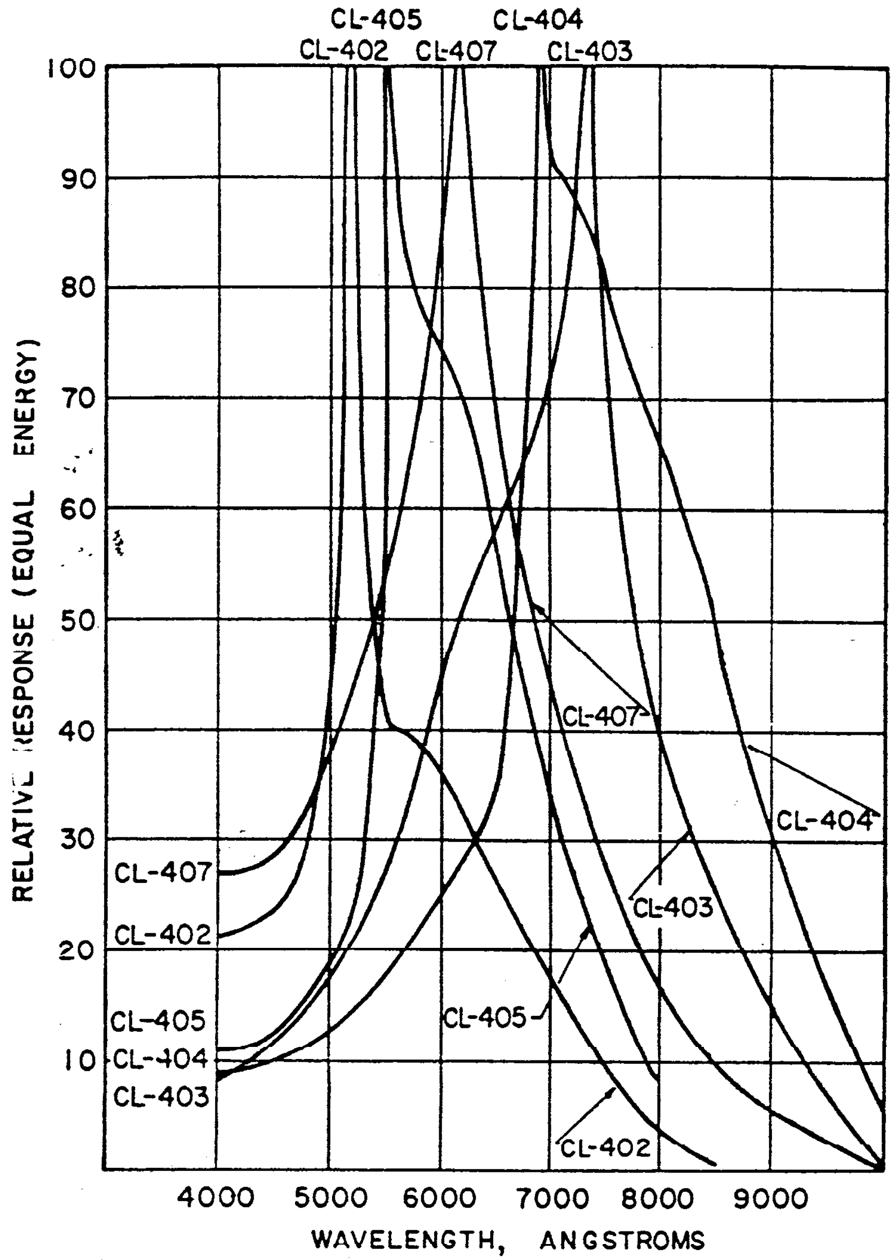


FIG. 6p-7. Spectral response of CdS and CdSe photoconductive cells.

IMAGE ORTHICON TYPE 7198 DATA†

Sensitive area..............	Approximately 1.1 × 1.4 in.
Spectral response..........	S-10
Resolution.................	Limited at high light level to approximately 600 lines; diminishes to approximately 75 lines at 2×10^{-5} ft-c

† See ref. 6,

The light-transfer characteristics of this tube are shown in Fig. 6p-12; the effect of photocathode illumination on the signal-to-noise ratio is given in Fig. 6p-13. Other types (ref. 10)(5820, 6849, 7389A, 7513, 7611, and 4401) have similar sensitive area,

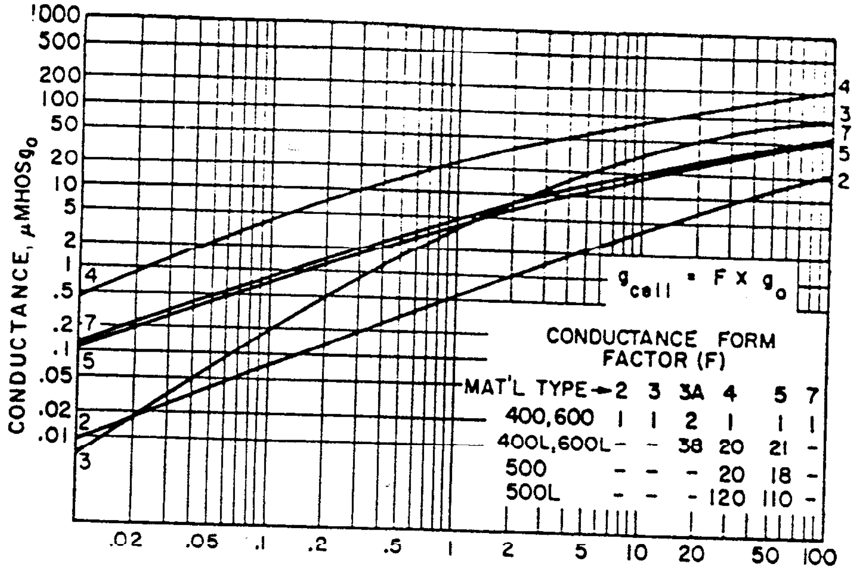


Fig. 6p-8. Characteristics of CdS and CdSe cells.

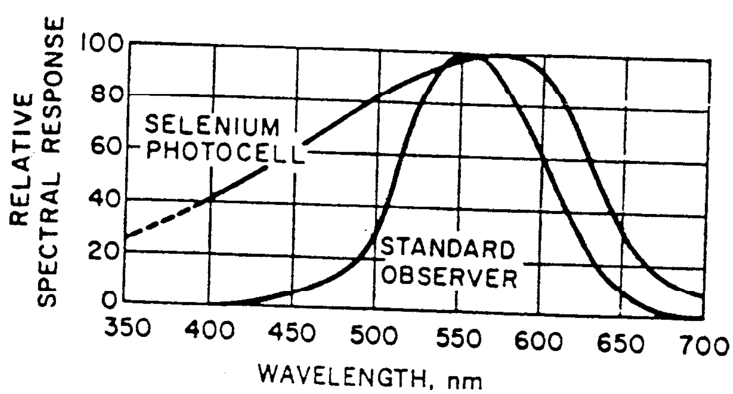


Fig. 6p-9. Spectral response of selenium photocell.

Table 6p-7. Image Converters

Type no.	Spectral response	Screen volts	Cathode diameter, in.	Conversion index	Resolution (Note 3)		Screen background
					At center	At 0.3 in. from center	
6914	S-1	16,000	1.00	15 (Note 1)	28	13	0.16 (Note 4)
6929	S-1	12,000	0.75	10 (Note 1)	33	9	0.21 (Note 4)
7404	S-21	12,000	0.75	6,000 (Note 2)	33	9	10^{-10} (Note 5)

Notes:

1. Ratio of output lumens to incident lumens at photocathode (2870 K).
2. Number of output lumens produced by one incident watt at 2,537 Å.
3. Resolution in line pairs per millimeter at photocathode.
4. Equivalent screen background input in incident microlumens/cm².
5. Equivalent screen background input in incident watts/cm².

TABLE 6p-8. VIDICON TYPE 7262 DATA
(Sensitive area, $\frac{3}{8}$ by $\frac{1}{2}$ in.; limiting resolution, 600 to 750 lines)

	Max sensitivity operation	Avg sensitivity operation	Min lag operation
Highlight illumination, ft-c	2	15	100
Target voltage	60–100	30–50	15–25
Dark current, μa	0.2	0.02	0.004
Highlight target current, μa	0.4–0.5	0.3–0.4	0.3–0.4
Signal current, peak μa	0.2–0.3	0.3–0.4	0.3–0.4
Signal current, avg μa	0.08–0.1	0.1–0.2	0.1–0.2

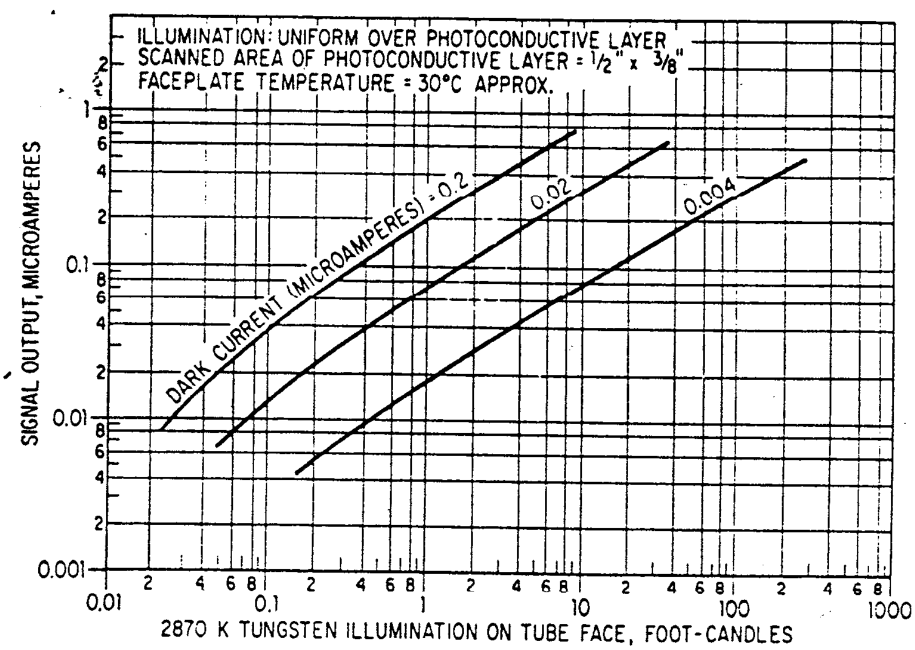


FIG. 6p-10. Typical light-transfer characteristics of Vidicon Type 7262.

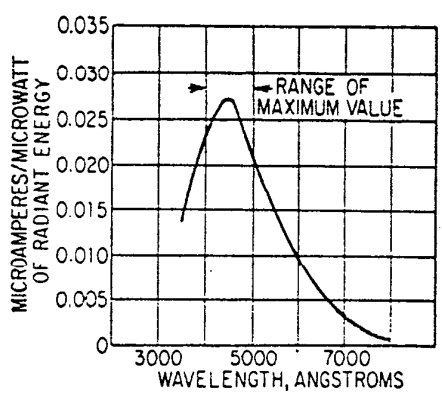


FIG. 6p-11. For Vidicon Type 7262, curve for equal values of signal-output current at all wavelengths. Signal-output microamperes from scanned area of $\frac{1}{2}$ by $\frac{3}{8}$ in. = 0.02, dark current (μa) = 0.02.

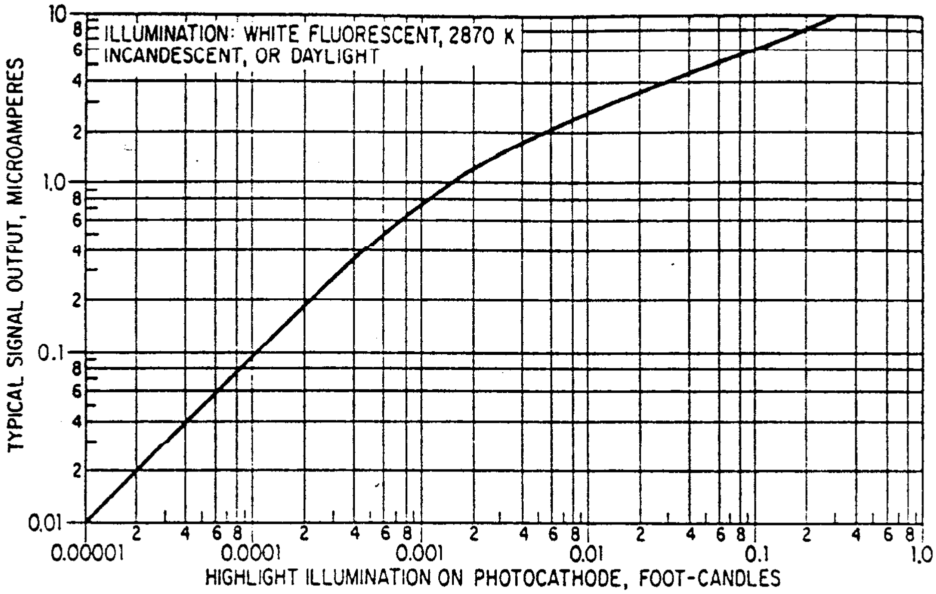


FIG. 6p-12. Basic light-transfer characteristics of Type 7198.

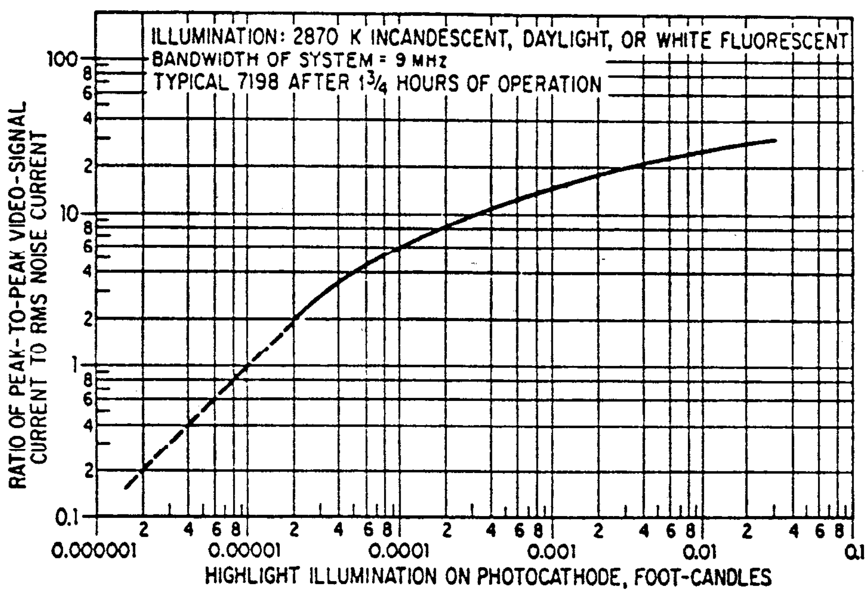


FIG. 6p-13. Effect of photocathode illumination on signal-to-noise ratio of typical 7198.

resolution, and relative spectral response. Some later types (Z5294 and C74037) have a thin film target, giving better than 300-line resolution at 10^{-5} ft-c. Type Z5395 has an S-1 photocathode. The developmental Type C73477 has an image-intensifier stage.

6p-8. Photographic Emulsions. Characteristics of various photographic materials manufactured by Eastman Kodak Company are shown in ref. 11.

6p-9. Commercially Available Thermal Detectors. Characteristics of some available thermal detectors are shown in Table 6p-9. Another thermal detector is the evaporograph (ref. 12). The sensitive element here is a transparent membrane

TABLE 6p-9. CHARACTERISTICS OF COMMERCIALLY AVAILABLE THERMAL DETECTORS†

Detectors	Material	Time const, sec	Area	Frequency of measurement, Hz	Resistance, ohms	V/W	Equivalent noise input for 1-Hz bandwidth
Bolometer‡	Platinum	0.016	6.5×0.25 mm	10	40	10 rms volt/avg watt	1.7×10^{-10} avg watt equal rms noise
Bolometer§	Mixture manganese, nickel, and cobalt oxide	0.20 0.40	2.5×0.2 mm	15	3×10^6	1,210 rms volt/avg watt	1.8×10^{-10} avg watt equal rms noise
Golay pneumatic cell¶	Gas-filled cavity	0.015	3-mm circle	10	....	....	6×10^{-11} avg watt equal rms noise

† See ref. 13.
‡ Made by Baird-Atomic, Inc.
§ Made by Servo Corporation of America and Barnes Engineering Company.
¶ Made by Eppley Laboratory, Inc.

about 2 cm in diameter on which is formed an oil film. When infrared radiation falls on this film, the oil evaporates. The difference in thickness of the film can then be seen with white-light interference colors. The room-temperature device can detect temperature differences of the order of 1°C.

References

1. "RCA Tube Handbook," HB-3, General Electric Data Sheet.
2. Hoffman Electronic Corp., Data Sheets T1B 32-58, HSD5-1-60; International Rectifier Corp., "Engineering Handbook."
3. Clairex Corp. Data Sheet 400, 500, 600; "RCA Tube Handbook," HB-3; NAVORD Report 4649, U.S. Naval Ordnance Laboratory, Corona, Calif.
4. "RCA Tube Handbook," HB-3.
5. *Proc. IRE* **47**, 1467, 1605, 1618 (1959).
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7. *Proc. IRE* **47**, 1607 (1959).
8. The Image Orthicon, *Proc. IRE*, July, 1946.
9. "Smithsonian Physical Tables," 9th ed.
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11. "Kodak Photographic Plates for Scientific and Technical Use," 7th ed., Eastman Kodak Company, Rochester, N.Y.
12. Baird-Atomic, Inc., Data Sheet.
13. *Proc. IRE* **47**, 1503 (1959).