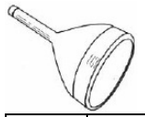
Cathode Ray Tube Phosphors

Of Interest To The Experimenter

RMA/ EIA U.S. Type	Intl E.U. Type	Flourescence			Phosphorescence**	Wavelength Peak(s) nm	Wavelength Range (-10%) nm	Persistence OR (time to decay to 10% of peak)	Composition	Application
?	?	Amber							$InBO_3$:Tb+$InBO_3$:Eu,	
?	?	Blue				450			ZnS:Ag	
?	?	Green				545		Medium	Y_2O_2S:Tb	Display tubes
?	?	Green				545		Medium	Y_2SiO_5:Tb	Projection tubes
?	?	Green				520		Very short	$Y_3(Al,Ga)_5O_{12}$:Ce	Beam index tubes
?	?	White							(Zn,Cd)S:Cu,Cl+(Zn,Cd)S:Ag,Cl	
?	?	White							$InBO_3$:Tb+$InBO_3$:Eu+ZnS:Ag	
?	?	Yellow				588			$InBO_3$:Eu	
?	?	Yellow-Green				550			$InBO_3$:Tb	
?	?	Yellow-Green				544		Medium	$Y_3(Al,Ga)_5O_{12}$:Tb	Projection tubes
P1		Green			Green	525	490-580	20ms		General purpose oscilloscopes And RADAR
P1	GJ GK	Green to Yellowish-Green				525		Medium 1-100 ms	Zn_2SiO_4:Mn (Willemite circa 1948)	General purpose oscilloscopes Display Tubes
P1		Yellowish-Green								Relative luminance 45 Relative writing speed 35 (Tektronix)*
P2		Blue-Green			Green	543	450-640	Long		Special oscilloscopes Radar indicators
P2		Bluish-Green			Green			>1 minute in low ambient ilumination		Relative luminance 60 Relative writing speed 70 (Tektronix)*
P2		Blue-Green			Green			Long	ZnS:Cu(Ag)(B*) (c. 1948)	Special oscilloscopes Radar indicators
P3		Yellow			Yellow	602	504-700	13ms	$Zn_8BeSi_5O_{19}$:Mn (c. 1948)	Early radar (c. 1939)
P3		Greenish-Yellow								Relative luminance 45 Relative writing speed 15 (Tektronix)*
P3		Yellow to Yellow-Green						Medium	zinc beryllium silicate with a manganese activator, written as $ZnBeSiO_4$:Mn	Early radar (c. 1939)
P3		Yellow-Orange						Medium		(J. Whitaker)
P4		White			White	565, 540	390-663	Not over 7% of peak after 33 ms		Black and white TV screens and display tubes
P4		White			Blue	540, 410	326-704	Not over 7% of peak after 33 ms	Silicate	Black and white TV screens and display tubes
P4		White			yellow	540, 435	330-699	Not over 7% of peak after 33 ms	Silicate-sulphide	Black and white TV screens and display tubes
P4		White			White				ZnS:Ag+ZnS:Cu+Y_2O_2S:Eu	Cd-free replacement P4, black and white CRT tubes, display tubes
P4	WW	White			White			Medium Medium short	ZnS:Ag+(Zn,Cd)S:Cu	B&w television receivers, Display tubes
P4		White			White			Medium	a*-ZnS:Ag+$Zn_8BeSi_5O_{19}$:Mn (Replaced circa 1948 with “new” ZnS:CdS:Ag)	Earliest Black and white TV screens and display tubes
P4		White			White					Relative luminance 70 Relative writing speed 25 (Tektronix)*



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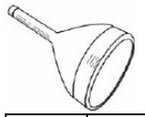
P4		White			White			Medium	ZnS:Ag+(Zn,Cd)S:Ag	Black and white TV screens and display tubes
P5		Blue			Blue	430	348-575	18us		Photographic recording of high speed traces in special oscilloscopes
P5		Blue			Blue					Relative luminance 3 Relative writing speed 15 (Tektronix)*
P5		Blue			Blue			Very short	$CaWO_4$:W (Scheelite) (c. 1948)	Photographic recording of high speed traces in special oscilloscopes
P5	BJ	Blue			Blue			Very short	calcium tungstate with a tungstate activator, written as CaWO.sub.4 :W	Photographic recording of high speed traces in special oscilloscopes
P5		Blue			Blue			Medium short		(J. Whitaker)
P6		White			White	563, 460	416-695	800us		Used in TV receivers for the "Goldmark/CBS color system". P4 is seen as "bluish" compared to P6
P6		White			White					Relative luminance 70 Relative writing speed 25 (Tektronix)*
P6		White			White			Short 800us	ZnS:Ag+ZnS:CdS:Ag	Used in TV receivers for the "Goldmark/CBS color system". P4 is seen as "bluish" compared to P6
P7		Blue-White			Yellow-Green			> 1 minute in low ambient illumination		Relative luminance 45 Relative writing speed 95 (Tektronix)*
P7		Blue-White			Yellow	558, 440	390-650	BluWh-Short Yel-Long		Dual-color, dual-persistence compound phosphor for Radar indicators
P7	YX	Blue-White			Yellow			BluWh-Short Yel-Long	(Zn,Cd)S:Cu	Dual-color, dual-persistence compound phosphor for Radar indicators
P7		Blue-White			Light Yellow			BluWh-Short LtYel-Long	B*-ZnS:Ag on ZnS(86): CdS:Cu Cascade (c. 1948)	Dual-color, dual-persistence compound phosphor for Radar indicators
P8								> 1 minute in low ambient illumination		Obsolete - replaced by P7 Probably similar spectrum to P7
P9										JEDEC registration of this type had been canceled/withdrawn as of 1948. (per "A STUDY OF THE PERSISTENCE CHARACTERISTICS OF VARIOUS CATHODE RAY TUBE PHOSPHORS", W. T. DYALL, TECHNICAL REPORT NO. 56, JANUARY 16, 1948, RESEARCH LABORATORY OF ELECTRONICS, MASSACHUSETTS INSTITUTE OF TECHNOLOGY)
P10		Dark Magenta Trace			Depends on absorption of outside illumination		N/A (peak absorption?)	Approx. 3s to 6,500,000s		Outside light source is used for observation and "erasing". Persistence from several seconds to several months.
P10		Dark Magenta Trace			Depends on absorption of outside illumination		400-500	Very long	KCl (c. 1948)	Outside light source is used for observation and "erasing". Persistence from several seconds to several months.
P11		Blue			Blue	460	400-550	2ms		Oscilloscopes for visual and photographic observation Display Tubes, Vacuum Fluorescent Display



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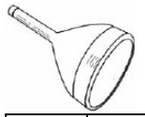
P11	BE	Blue		Blue		460	Short Medium short 0.01-1 ms	ZnS:Ag,Cl or ZnS:(Zn)	Oscilloscopes for visual and photographic observation Display Tubes, Vacuum Fluorescent Display
P11		Purplish-Blue		Purplish-Blue					Relative luminance 25 Relative writing speed 100 (Tektronix)*
P11		Blue		Blue			Short	A*-ZnS:Ag (c. 1948)	Oscilloscopes for visual and photographic observation
P12		Orange		Orange					Relative luminance 18 Relative writing speed 3 (Tektronix)*
P12		Orange		Orange	590	545-680	Medium Long		Radar indicators
P12		Orange		Orange			Long		Radar indicators
P12		Orange		Orange			Medium	$Zn(Mg)F_2$:Mn	Radar indicators
P13		Light Red		Light Red			Medium	$MgO*SiO_2$:Mn (c. 1948)	Storage phosphor
P13								magnesium silicate with a manganese activator	Used for fabricating carbon triode nanotubes
P13		Reddish-Orange							Relative luminance 4 Relative writing speed 1 (Tektronix)*
P14		Violet		Orange	601, 440	390-710	Vio-Short Or-MedLong		Dual-color, dual-persistence compound phosphor for Radar indicators
P14		Purple-White		Light Orange			PW-Medium LO-Long	B*-ZnS:Ag on ZnS(75):CdS:Cu	Dual-color, dual-persistence compound phosphor for Radar indicators
P14		Purplish Blue		Yellowish Orange			Blu -med short ORN - med.		Used where repetition rate is 2-4 seconds after excitation is removed
P14		Purplish-Blue		Orange					Relative luminance 40 Relative writing speed 60 (Tektronix)*
P14		Blue		Red-Orange			BLU-Short RO-Long		Dual-color, dual-persistence compound phosphor for Radar indicators
P14		Blue		Yellow-Orange			BLU-Med. Short YO-Medium		RADAR (J. Whitaker)
P15		Blue-Green Ultraviolet		Blue-Green Ultraviolet	504, 391	370-605	3us		Television pickup of photographs by flying-spot scanning via photomultiplier tube
P15		Bluish-Green							Relative luminance 15 Relative writing speed 25 (Tektronix)*
P15	GG	Blue-Green Ultraviolet		Blue-Green Ultraviolet			Very short Very short	ZnO:Zn	Television pickup of photographs by flying-spot scanning
P15		Ultraviolet		Green			UV -Very short G -short		Flying Spot Scanner (J. Whitaker)
P16		Violet Near-Ultraviolet		Violet Near-Ultraviolet	370	335-437	5us		Television pickup of photographs by flying-spot scanning
P16		Bluish-Purple							Relative luminance 0.1 Relative writing speed 25 (Tektronix)*
P16		Violet Near-Ultraviolet		Violet Near-Ultraviolet			Extremely short	calcium magnesium silicate with an activator of cesium and lithium	Television pickup of photographs by flying-spot scanning
P16		Ultraviolet		Ultraviolet			Very short		Flying Spot Scanner (J. Whitaker)
P17		Greenish-Yellow		Yellow	450, 554	380-635	GrYe-Extremely Short, Ye-Long		Military displays
P17		Yellowish-Green							Relative luminance 30 Relative writing speed 15 (Tektronix)*



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P17		Greenish-Yellow			Yellow			Short and long components		Cascade phosphor combines P7 and P15 characteristics
P17		Blue			Yellow			Blue -Short Yellow -Long		Oscillography, RADAR (J. Whitaker)
P18		White			Blue	540, 410	326-704	13ms		Low frame rate television applications
P18		White								Relative luminance 18 Relative writing speed 35 (Tektronix)*
P18		White						Medium		Low frame rate television applications
P18		White			White			Medium Medium Short		Projection TV (J. Whitaker)
P19		Orange								Relative luminance 25 Relative writing speed 3 (Tektronix)*
P19		Orange						Long		RADAR (J. Whitaker)
P19		Orange			Orange	595	545-665	Very long		Radar screen
P19	LF	Yellow				590		Long Medium long	$(KF,MgF_2):Mn$	Radar screen
P20		Yellow-Green			Yellow-Green	555	460-649	2ms		High visibility displays
P20		Yellowish-Green								Relative luminance 85 Relative writing speed 70 (Tektronix)*
P20	KA	Yellow Yellow-Green						Short Medium 1-100 ms	(Zn,Cd)S:Ag or (Zn,Cd)S:Cu	Display tubes
P20		Yellow-Green			Yellow-Green			Medium Medium Short		Storage Tubes (J. Whitaker)
P21		Yellow			Yellow	606	554-650	Very Long		
P21		Yellow-Orange						Medium long		
P21		Red-Orange			Red-Orange			Medium		RADAR (J. Whitaker)
P22		Red Green Blue			Red Green Blue	643 526 450	390-680	One short Two Medium		Three-color phosphor pixelated pattern used in color displays with shadow mask or aperture grille
P22		Red Green Blue			Red Green Blue			Medium Medium Medium	See P22B, P22G, P22R. P22 is the degignation for the set of phosphors used for color TV CRTs.	Three-color phosphor pixelated pattern used in color displays with shadow mask or aperture grille
P22B		Blue						Medium	$ZnS:Ag+Co\text{-}on\text{-}Al_2O_3$ or ZnS:Ag+Pigment	Phosphor for color TV screens
P22G		Green				530		Medium	ZnS:Cu,Al or ZnS:Cu,Au,Al	Phosphor for color TV screens
P22R		Red				611		Medium	$Y_2O_2S:Eu+Fe_2O_3$ or $Y_2O_2S:Eu$+Pigment	Phosphor for color TV screens
P23		White			White	575, 460	400-720	Short		Low temperature Sepia color similar to P4 used in television
P23		White						Medium		Persistence similar to P4 used in television
P23		White								Relative luminance 80 Relative writing speed 35 (Tektronix)*
P23		White			White			Medium Short		Direct-view Television (J. Whitaker)
P24		Blue-Green			Blue-Green	507	426-640	1.5us		
P24		Greenish-Blue								Relative luminance 8 Relative writing speed 6 (Tektronix)*
P24	GE	Green			Green	505		Short 1-10 µs	ZnO:Zn	Flying spot scanner Vacuum fluorescent display
P24		White						Short		Color flying spot scanner

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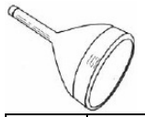
P25		Orange		Orange	610	530-710	Very Long		Military displays with 2-10 second refresh interval
P25		Yellowish-Orange							Relative luminance 12 Relative writing speed 5 (Tektronix)*
P25	LJ	Orange					Long	$CaSiO_3$:Mn,Pb	Storage phosphor
P25		Orange		Orange			Medium		RADAR (J. Whitaker)
P26		Orange		Orange			Very Long		RADAR (J. Whitaker)
P26		Orange							Relative luminance 17 Relative writing speed 3 (Tektronix)*
P26	LC	Yellow-Orange			595		Very long >1000ms	(KF,MgF_2):Mn	Radar screen
P27		Orange-Red					Medium	zinc phosphate with a manganese activator	Storage phosphor, Color TV monitor service
P27		Reddish-Orange					Medium		Relative luminance 20 Relative writing speed 7 (Tektronix)*
P27		Reddish-Orange		Reddish-Orange			Medium		Color TV monitor (J. Whitaker)
P28	KE	Yellow					Medium	(Zn,Cd)S:Cu,Cl	RADAR
P28		Yellow-Green					Long		Display tubes
P28		Yellowish-Green							Relative luminance 50 Relative writing speed 50 (Tektronix)*
P29							medium		Two Color stripe pattern, aircraft instruments
P29		P2 and P25 stripes		P2 and P25 stripes			medium		RADAR (J. Whitaker)
P30		?		?					Not Registered with JEDEC
P31	GH	Yellowish-Green					Medium short 0.01-1 ms	ZnS:Cu or ZnS:Cu,Ag	Oscilloscopes Oscilloscopes for printing
P31		Green							Relative luminance 100 Relative writing speed 75 (Tektronix)*
P32		Blue-Green		Yellowish-Green					Relative luminance 25 Relative writing speed 15 (Tektronix)*
P32		Purple-Blue		Yellowish-Green			Long		RADAR (J. Whitaker)
P33	LD	Orange		Orange	590		Very long >1000ms	MgF_2:Mn	Radar screen
P33		Orange							Relative luminance 20 Relative writing speed 7 (Tektronix)*
P34		Blue-Green		Green					Relative luminance 17 Relative writing speed 15 (Tektronix)*
P34		Bluish Green		Yellow Green			Very long		Oscilloscope, RADAR, visual information storage
P35		Blue-White							Relative luminance 55 Relative writing speed 45 (Tektronix)*
P35		Green		Blue			Medium Short		Oscillography (J. Whitaker)
P36		Yellow-Green		Yellow-Green			Very short		Flying spot scanner (J. Whitaker)
P37		Blue		Blue			Very short		Flying spot scanner (J. Whitaker)
P38	LK	Orange			590		Very long	$(Zn,Mg)F_2$:Mn	Radar screen
P39	GR	Green			525		Long	Zn_2SiO_4:Mn,As	Display tubes



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P39		Yellow-Green		Yellow-Green			Long		RADAR (J. Whitaker)
P40	GA	White					Long	ZnS:Ag + (Zn,Cd)S:Cu	Display tubes
P40		Blue		Yellow-Green			Blue Med. Short Yel-Green Long		Low repetition rate After J. Whitaler
P41		Ultraviolet		Orange			UV very short Orange long		Radar with light trigger (J. Whitaker)
P43	GY	Yellow-Green			545		Medium	Gd_2O_2S:Tb	Display tubes
P45	WB	White					Medium	Y_2O_2S:	Viewfinders
P45	RED- ENH							Y_2O_2S:Tb,Eu	
P46	KG	Green			530		Very short	$Y_3Al_5O_{12}$:Ce	Beam index tubes
P47	BH	Blue			400		Very short	Y_2SiO_5:Ce	Beam index tubes
P48	KH	Blue Green					Very short Short	(P46+P47 BLEND)	Combination phosphor
P53	KJ	Yellow-Green			544		Medium	$Y_3Al_5O_{12}$:Tb	Projection tubes
P55	BM	Blue			450		Medium short	ZnS:Ag,Al	Projection tubes
P56	RF	Red			610		Medium	Y_2O_3:Eu	Projection tubes

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Research references for this report are too numerous to list.

- "A STUDY OF THE PERSISTENCE CHARACTERISTICS OF VARIOUS CATHODE RAY TUBE PHOSPHORS" W. T. DYALL (M.I.T. 1948)
- Sylvania tube manual 1943, 1949, 1959
- ARRL Handbook, various editions
- Tektronix, Inc.
- E.I.A.
- JEDEC
- RETMA
- Bill & Stan's Tektronix Resource Site (www)
- Clinton Displays CRT Division (www)
- Wikipedia (www)

*Tektronix:
Relative Luminance taken with Spectra Brightness Spot Meter which incorporates CIE standard eye filter. Representative of 10KV aluminized screens.
Relative writing speed taken with 10,000 ASA Polaroid film for 10 KV aluminized screeens.

**Phosphorescence:
If not noted, is generally the same spectrum as the fluorescence.

Author's Notes:
Concerning certain phosphors used before 1948:
1. Exponential decay screens -- P1, P3, P12, and P13.
2. Long persistence inverse power law decay screens -- P2, P7, and P14.
3. Medium persistence combination exponential and inverse power law decay screen -- P4.
4. Short persistence inverse power law decay screens -- P5, P6, and P11
5. Very long variable persistence dark trace screen -- P10.

Concerning the composition of this document:
1. Noncommercial research document created according to "fair use". Document may be distributed for educational purposes if kept intact.
2. Definitions of color such as yellow, green, orange, or blue differ widely not only among the human population but also among the most august of published sources since the first phosphor-based CRT was ever implemented. Color descriptions have evolved with colorimetry.
3. In some cases, a single phosphor designation (P4 for example) is listed several times. In an attempt to make this reference as complete as possible while preserving accuracy, documents differing in presentation of characteristics for a given phosphor type, having as their sources various industrial or scientific publications as well as amateur scientific publications meeting certain criteria, were treated equally.
4. Rather than merge slightly incongruent data that could be accounted for by interdocumentary differences such as chemical composition or the evolution of a perceived phosphor color over time, data for each phosphor designation that were not in agreement were included separately.
5. Despite a few incongruities (i.e. the P24) that the author has no means to resolve, the author believes this poor report will be useful to those having an interest in CRTs and the phosphors used therein, and convey a reasonable expectation of the colors to be produced by a particular CRT.
6. It is left as a pleasant exercise for the reader to weigh the data in the document when considering the use of a CRT or other phosphorescent electrical device.

If you want a definitve document and have around $200 to spend, you can order the standard: TEP116-C Optical Characteristics of Cathode Ray Tube Screens from the EIA.

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How the eye perceives colors:
Top Right: Typical response of the three cone types in human vision showing overlap.
From left to right:
1. The normalized peak wavelength response of the eye.
2. The combined response curve of the eye.
3. The general perception of color vs wavelength (No consumer printer or display can precisely reproduce the bandwidth detectable by the eye).