Cathode Ray Tube Phosphors

Of Interest To The Experimenter

RMA/ EIA U.S. Type	Intl E.U. Type	Flourescence	Phosphor-escence	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 Display Tubes
P1	GJ GK	Green to Yellowish-Green		525		Medium 1-100 ms	Zn_2SiO_4:Mn (Willemite circa 1948)	General purpose oscilloscopes Display Tubes
P2		Blue-Green	Green	543	450-640	Long		Special oscilloscopes Radar indicators
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		Yellow to Yellow-Green				Medium	zinc beryllium silicate with a manganese activator, written as $ZnBeSiO_4$:Mn	Early radar (c. 1939)
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				Medium	ZnS:Ag+(Zn,Cd)S:Ag	Black and white TV screens and display tubes
P5		Blue	Blue	348-575	430	18us		Photographic recording of high speed traces in special oscilloscopes
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
P6		White	White	416-695	563, 460	800us		Used in TV receivers for the “Goldmark/CBS color system”. P4 is seen as “bluish” compared to P6

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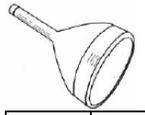

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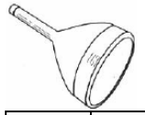
P6		White	White			Short 800us	ZnS:Ag+ZnS:CdS:Ag	Used in TV receivers for the “Goldmark/CBS color system”. P4 is seen as “bluish” compared to P6
P7		Blue-White	Yellow	390-650	558, 440	BluWh-Short Yel-Long		Dual-color, dual-persistence compound phosphor for Radar indicators
P7	YX	Blue-White	Yellow			BluWh-Short 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								Obsolete – replaced by P7
P9								Obsolete – registration of this type had been canceled 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	400-500	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			Very long	KCl (c. 1948)	Outside light source is used for observation and “erasing”. Persistence from several seconds to several months.
P11		Blue	Blue	400-550	460	2ms		Oscilloscopes for visual and photographic observation Display Tubes, Vacuum Fluorescent Display
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		Blue	Blue			Short	A*-ZnS:Ag (c. 1948)	Oscilloscopes for visual and photographic observation
P12		Orange	Orange	545-680	590	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
P14		Violet	Orange	390-710	601, 440	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		Blue	Red-Orange			BLU-Short RO-Long		Dual-color, dual-persistence compound phosphor for Radar indicators
P15		Blue-Green Ultraviolet	Blue-Green Ultraviolet	370-605	504, 391	3us		Television pickup of photographs by flying-spot scanning
P15	GG	Blue-Green Ultraviolet	Blue-Green Ultraviolet			Very short Very short	ZnO:Zn	Television pickup of photographs by flying-spot scanning
P16		Violet Near- Ultraviolet	Violet Near- Ultraviolet	370	335-437	5us		Television pickup of photographs by flying-spot scanning



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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
P17		Greenish-Yellow	Yellow	450, 554	380-635	GrYe-Extremely Short, Ye-Long		Cascade phosphor combines P7 and P15 characteristics
P17		Greenish-Yellow	Yellow			Short and long components		Cascade phosphor combines P7 and P15 characteristics
P18		White	Blue	540, 410	326-704	13ms		Low frame rate television applications
P18		White				Medium		Low frame rate television applications
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		Display tubes
P20	KA	Yellow Yellow-Green				Short Medium 1-100 ms	(Zn,Cd)S:Ag or (Zn,Cd)S:Cu	Display tubes
P21		Yellow	Yellow	606	554-650	Very Long		
P21		Yellow-Orange				Medium long		
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				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		Similar to P4 used in television
P23		White				Medium		Persistence similar to P4 used in television
P24		Blue-Green	Blue-Green	507	426-640	1.5us		
P24	GE	Green		505		Short 1-10 µs	ZnO:Zn	Vacuum fluorescent display
P24		White				Short		Color flying spot scanner
P25		Orange	Orange	610	530-710	Very Long		Storage phosphor
P25	LJ	Orange				Long	$CaSiO_3:Mn,Pb$	Storage phosphor
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
P28	KE	Yellow				Medium	(Zn,Cd)S:Cu,Cl	Display tubes
P28		Yellow-Green				Long		Display tubes
P31	GH	Yellowish-Green				Medium short 0.01-1 ms	ZnS:Cu or ZnS:Cu,Ag	Oscilloscopes Oscilloscopes for printing
P33	LD	Orange		590		Very long >1000ms	$MgF_2:Mn$	Radar screen
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
P40	GA	White				Long	ZnS:Ag + (Zn,Cd)S:Cu	Display tubes
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

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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

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
- Clinton Displays CRT Division (Internet)
- Wikipedia (Internet)
- The WWW

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 what is a given 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.
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.

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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).