Phosphor Materials and Color

The inside of a fluorescent lamp is coated with a mixture of phosphors. Many compounds fluoresce when exposed to ultraviolet radiation, but for maximum efficiency the phosphors used should have maximum response near 253.7 nanometers because this is the wavelength most efficiently generated by the mercury arc.

Phosphors for use in fluorescent lamps have been selected with maximum sensitivity as near 253.7 nanometers as possible. The range 250-260 nanometers is considered ideal. The most commonly used phosphors (see table below) have their peak sensitivity very near this ideal range.

Calcium halophosphate is the basic phosphor used in white fluorescent lamps. Although the maximum sensitivity of calcium halophosphate occurs at 250 nanometers, this material is also highly responsive to 253.7-nanometer radiation. The maximum sensitivity of magnesium tungstate, which produces bluish-white light, occurs at about 285 nanometers; energy at 253.7 nanometers yields only about 80% as much light as the same amount of energy at 285 nanometers.

Suitable phosphors are available to produce a variety of shades of white and a number of colors of light. For some saturated colors, red and gold, a pigment is applied to the tube before the phosphor coating.

CONVERSION TABLE FOR FREQUENTLY USED WAVELENGTH UNITS

Unit	Equals	Exponential Notation
1 millimeter (mm)	one thousandth of a meter	10^{-3}
1 micrometer (μm)	one millionth of a meter	10^{-6}
1 nanometer (nm)	one billionth of a meter	10^{-9}

NOTE: Current engineering practice favors the use of the units shown for dimensions. Some older terms superseded by this practice are: **micron** (equivalent to micrometer); **millimicron** (equivalent to nanometer); and **Angstrom unit** (equivalent to 1/10 of a nanometer)

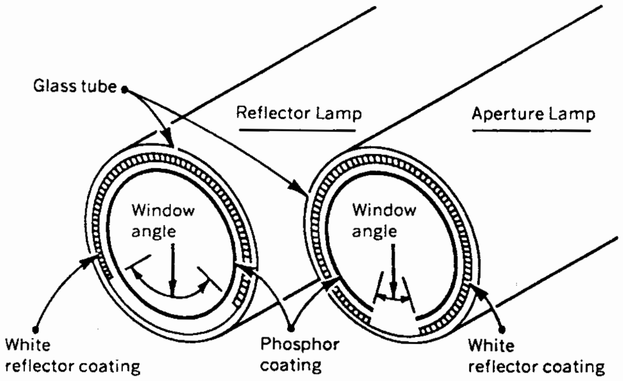
FLUORESCENT CHEMICALS

Phosphor	Lamp Color	Excitation Range*	Sensitivity Peak*	Emitted Range*	Emitted Peak*
Barium Silicate	Black Light	180–280	200–240	310–400	346
Barium — Strontium — Magnesium Silicate	Black Light	180–280	200–250	310–450	360
Cadmium Borate	Pink	220–360	250	520–750	615
Calcium Halophosphate	White	180–320	250	350–750	580
Calcium Silicate	Orange	220–300	253.7	500–720	610
Calcium Tungstate	Blue	220–300	272	310–700	440
Magnesium Tungstate	Blue-White	220–320	285	360–720	480
Strontium Halophosphate	Greenish-blue	180–300	230	400–700	500
Strontium Ortho Phosphate	Orange	180–320	210	450–750	610
Zinc Silicate	Green	220–296	253.7	460–640	525

*nanometers

DIRECTIONAL FLUORESCENT LAMPS

Several sizes of fluorescent lamps are available with an internal white reflector on part of the inner surface to provide built-in light control. The unreflectorized portion of the tube is called "the window." Candlepower in the direction of the window is significantly increased; however, total light output is reduced. Except in applications with special requirements, regular lamps with an efficient fixture will usually provide better performance. For certain applications, special fluorescent lamps are made with both the reflector and the phosphor coating removed from the window aperture, which makes this an aperture lamp.



Fluorescent Lamp Spectral

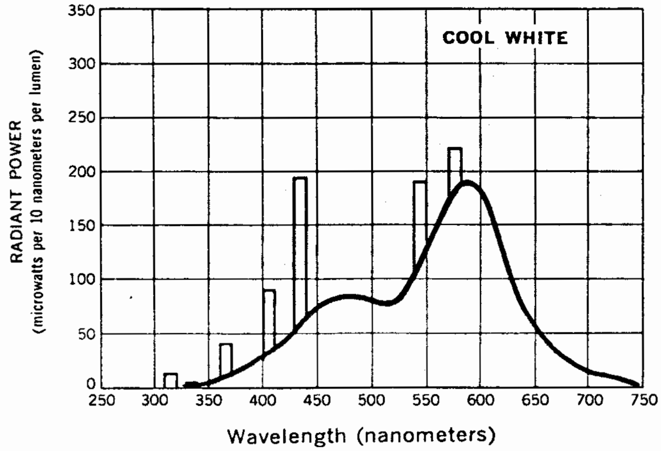
The relative energy output of various types of 40-watt fluorescent lamps is shown. The smooth curves represent only the light resulting from phosphor excitation. Some visible light is generated directly by the mercury arc, and the bars added to the top of each curve show where this energy is concentrated.

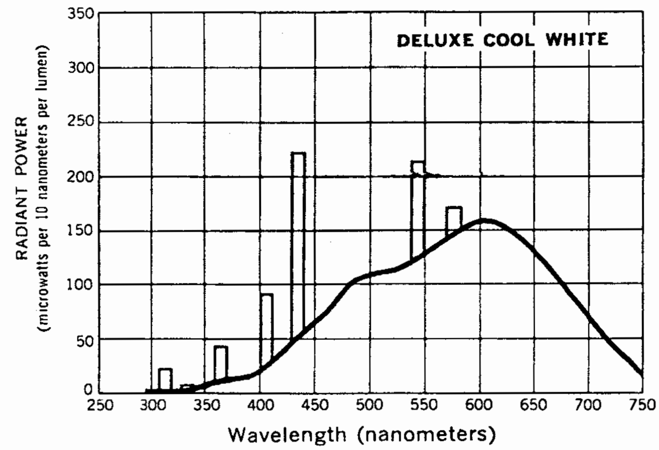
Appearance of the light source alone does not indicate how colors will look when lighted by it. It is possible to make a light source that looks white itself, and makes white surfaces and objects look white, but renders colors poorly. Since their introduction, fluorescent lamps have been greatly improved in color rendition. After many years of research on phosphors, a line of white fluorescent lamps evolved that meets nearly all needs for white light. This line consists of ten lamp types represented by the curves on this spread.

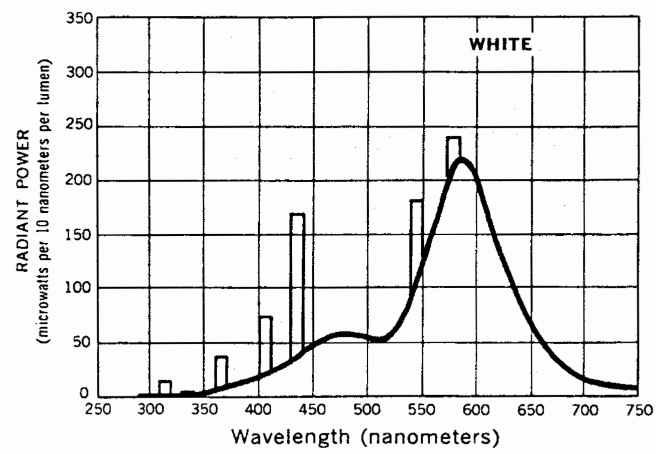
Fluorescent lamp color choice takes into account three elements important in lighting effects: 1. Luminous efficacy (lumens output per watt input), 2. Color rendition: 3. Whiteness. The choice among fluorescent "whites" always involves a compromise among these three items. Obtaining best color rendition necessitates reduction in efficacy. Choice of whiteness affects both efficacy and color rendition for most applications.

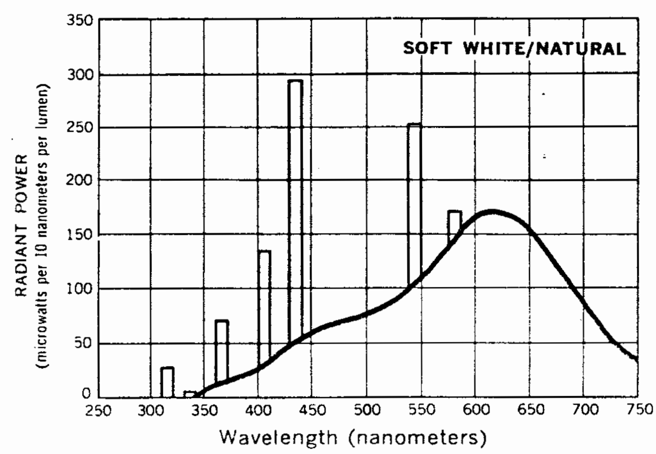
Cool White, Warm White, White, and Daylight lamps are designed for highest efficacy consistent with acceptable color rendition for most applications. These lamps are relatively weak in red rendition.

Deluxe Cool White and Deluxe Warm White lamps are designed to give colored materials and complexions the most natural and complimentary appearance, at reasonable efficacy. In these lamps, the spectrum is given better balance by the addition of red light to the output. The human eye is less efficient in response to red energy, which constitutes a higher proportion of the energy from Deluxe lamps; thus luminous efficacy is reduced. Deluxe lamps give about 30% less light than the standard lamps, but the difference usually does not appear so great because of the increased vividness of colors. Natural is used where there is a desire for light rich in red and having an overall pinkish cast. Sign White is designed for plastic signs and other applications where a cool, "crisp" white light with good color rendition is desired. It is between Cool White and Daylight in whiteness and provides better color rendition than either.









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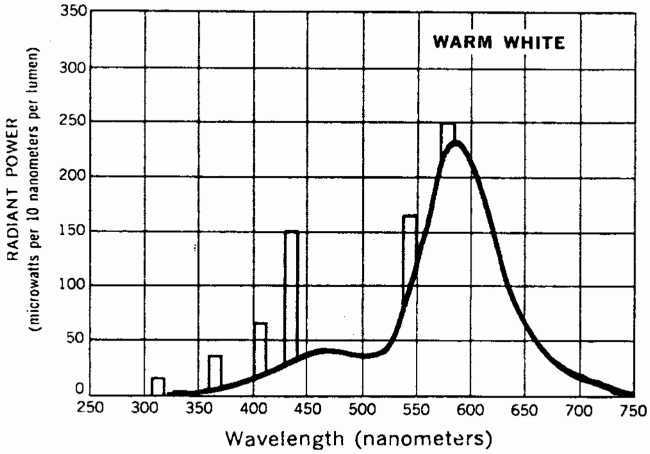
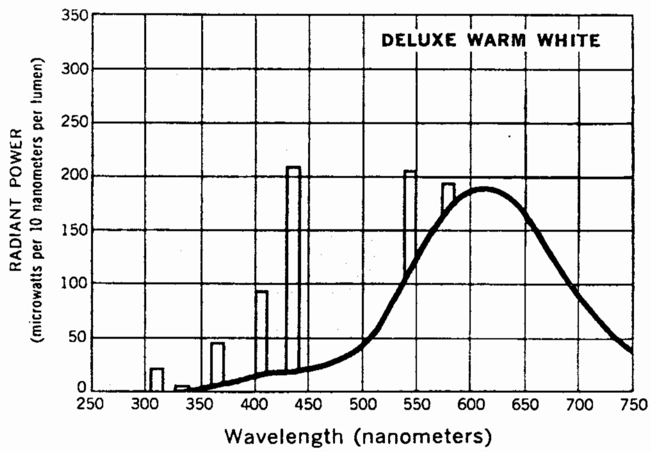
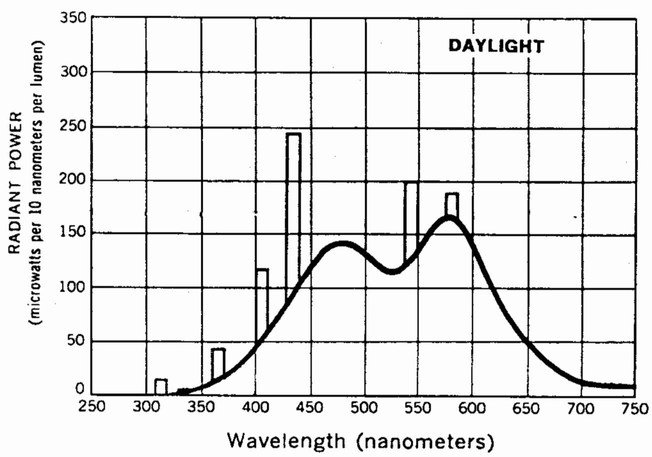
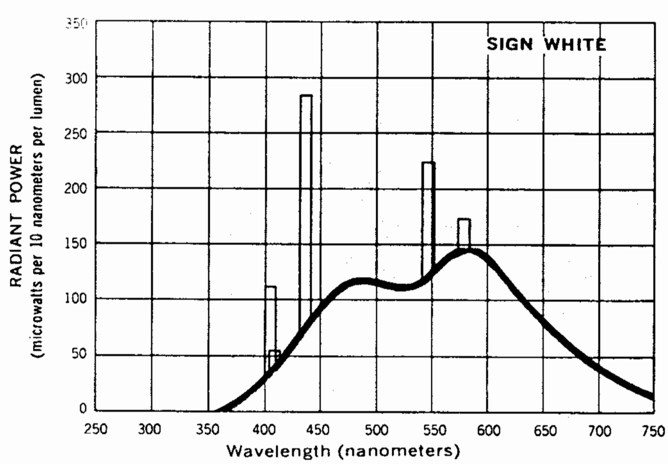
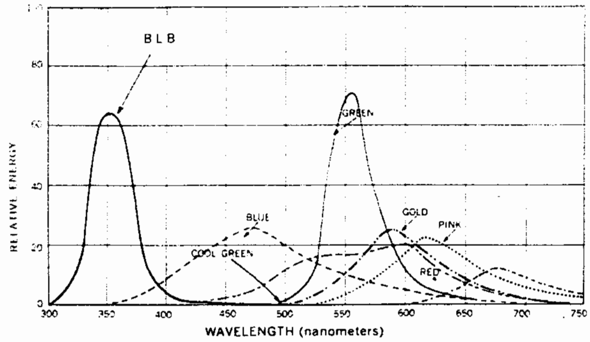


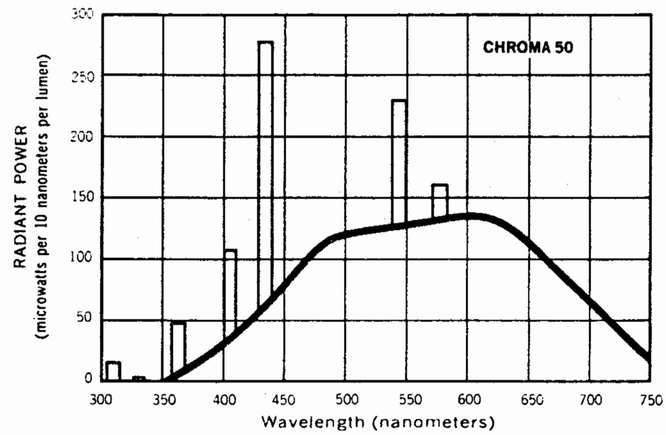


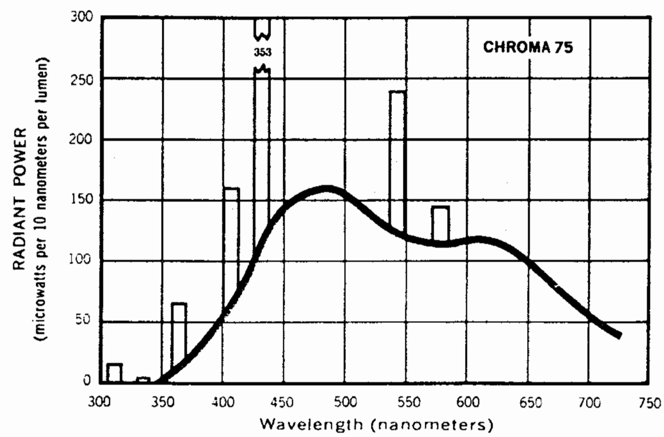






These curves show the relative energy outputs from colored fluorescent lamps of equal wattage. They represent only the energy transferred by phosphor conversion. Some energy generated by the mercury arc source is originally in the visible region. This direct generation of light represents less than 10% of the lumen output, but does influence phosphor composition for final result. This applies to all but the gold and red lamps, in which the colored coatings inside the bulb absorb not only the directly radiated mercury but also the shorter wavelength by the phosphors.





Chroma Line lamps simulate color characteristics of natural daylight. C50, at 5000 K (degrees Kelvin), approximates noon sky plus sunlight. C75, at 7500 K, approximates north skylight. Chroma Line lamps produce a "cooler, whiter" appearance than CWX (cool white deluxe).

GE (Cont.)

cent lamps can withstand a relatively large r reduction in line voltage before they will ish. The degree will depend on the lamp d the ballast characteristics. For the 40 12 types, the approximate values are: Pre- %, Instant Start lead-lag 40%, Instant Start Sequence 50% and Rapid Start Series ce 20%.

t that best life and other performance char- ics are obtained when the voltage is kept ated value justifies special attention to the factor.

NG

arting of fluorescent lamps is affected by bient temperature. Low temperatures re- igher voltages for reliable starting. Most s provide voltages which will start lamps to 50°F. Ballasts are available for cer- np types which will start lamps down to 0°F wn to —20°F.

OUTPUT

ect of temperature on the performance of cent lamps is an important one. Rated output values are obtained when measured ambient temperature. Light output is a n of the mercury vapor pressure which is led by the coolest point on the bulb wall. es in ambient temperatures are accompan- similar changes in bulb wall temperatures. ample, a drop of 10°F ambient produces imately a 10°F change in bulb wall tem- e.

se of the changes in light output with tem- e, selection of the proper lamp for the tion temperature range is an important one.

LIFE

e of a fluorescent lamp is not affected by bient temperature in which it operates.

er, life can be affected by starting which enced by temperature. For example, the required for Rapid Start lamps at —20°F stant start" lamps at normal temperatures. nstant starting" will adversely affect lamp he degree will be dependent on the tem- e and the frequency of starts.

ITY vs LAMP STARTING

that are operated on Rapid Start or Instant ype circuits require a silicone coating on tside of the bulb to assure reliable starting humidity atmospheres.

TNESS

ghouse fluorescent lamps are low bright- ght sources even though the total light out- high. The brightness of a fluorescent lamp rmined principally by the length and dia- of the bulb, the current loading and the ncy of the phosphor.

T-12 Slimlines at 425 ma. develop a brightness approximately the same as the 40 watt lamp.

FLICKER AND STROBOSCOPIC EFFECT

The light output of individual fluorescent lamps operating from a 60-cycle ac supply vary slightly cyclically in their light output in an amount dependent upon phosphor persistence and ballast circuit, but largely independent of lamp size and wattage ratings. This effect is called flicker.

The flicker rate over the length of the lamp is 120 cycles per second with 60-cycle operation. At the ends of the lamp each alternate flash is comparatively weak. This gives an effective rate of 60 flashes per second.

The 120-cycle flicker is too fast to be visible. The 60-cycle flicker can be detected, but only by the periphery of the retina. For this reason, lamp flicker is seldom noticed except when observing the ends of the lamps out of the corner of the eye.

FLUORESCENT LAMP COLORS

Westinghouse offers a wide range of fluorescent lamp colors which include a complete line of whites and 5 colors — blue, green, gold, pink, and red.

The colored lamps, are used primarily for signs and other decorative applications. For lighting applications, however, the selection of a shade of white can be somewhat more complex. The following Lamp Evaluation chart shows some of the considerations which might enter into the selection of a lamp.

The atmosphere created by the lamp — A warm atmosphere has a connotation of friendliness or coziness. A cool atmosphere connotes efficiency and neatness.

The relative light output of the lamp — In general, the standard white lamps provide more light output than the high color rendering lamps.

The color rendering ability of a lamp — This is the ability of a lamp to render colors as accurately as possible (when compared to a theoretical perfect white light).

The ability of a lamp to flatter colors — This is the ability of a lamp to make colors appear not as they actually are but as people prefer to see them. This is an important consideration in merchandising and other commercial applications and prompted Westinghouse to develop the Living White lamp.

The standard white colors cool white, warm white, white, daylight and cool green are the most efficient and will normally be used in industry, general office areas and other places where economy of light production is required. Where a high degree of color rendition is desired, the cool white deluxe, warm white deluxe and Living White lamps should be used. The Living White lamp is particularly flattering to human complexions and reveals the full color beauty of all house furnishings, merchandise and colored objects.

FLUORESCENT LAMP COLOR EVALUATION CHART

LAMP		Atmos-phere	Light Output	Color Rendering Ability	Color Flattery Ability	Lighted Appearance ICI Color Coord.	
						X	Y
Cool White	CW	Cool	100%	100%	100%	.372	.375
Cool White Deluxe	CWX	Cool	71	126	103	.369	.363
White	W	Warm	104	91	99	.409	.394
Warm White	WW	Warm	104	73	96	.435	.402
Warm White Deluxe	WWX	Warm	71	101	101	.430	.389
Daylight	D	Cool	85	93	102	.313	.337
Living White	LW	Cool	75	124	105	.369	.363
Cool Green	CG	Cool	92	—	—	.315	.366
Sign White	SGN	Cool	75	—	—	.332	.350
Soft White/Natural	SW/N	Warm	70	—	—	.392	.355
Supermarket White	SMW	Cool	74	—	—	.362	.375
Red	R	—	06	—	—	.690	.295
Pink	PK	—	45	—	—	.526	.356
Gold	GO	—	60	—	—	.510	.469
Green	G	—	140	—	—	.264	.630
Blue	B	—	45	—	—	.205	.183

A-C FREQUENCY

The current limiting characteristics of a reactor depend directly on the power supply frequency and for this reason fluorescent lamp ballasts must be used on the frequency for which they were designed. With lower frequencies, the inductive reactance of lag ballast is reduced and higher current will flow through the lamp. Shorter lamp life and overheated auxiliaries will result. With higher frequencies, less current will flow with adverse effects on the lamp life and its lumen output. On the other hand, in the lead leg of a two-lamp ballast the reactor is in series with a capacitor which causes the current in this leg of the circuit to decrease at lower frequencies and increase with higher frequencies.

Equipment designed for 60 cycles should not be used on 50 cycles, nor is the reverse satisfactory. Operation at low frequencies, such as 25 cycles, requires larger special ballasts and involves in addition a more serious problem in eliminating stroboscopic effect than is involved with standard 60 cycle power.

DIMMING AND FLASHING

Rapid Start lamps can be readily dimmed and flashed when operated on ballasts and circuits specifically designed for these applications. Dimming ballasts have continuous cathode heating circuits which supply full voltage to the electrodes at all times. The dimmer controls change the arc current and are either a thyraton, adjustable voltage transformer or adjustable reactor circuit. These circuits permit full control of light intensity from full brightness to nearly blackout. Normal dimming service does not adversely affect rated lamp life.

Similarly, flashing ballasts supply continuous but somewhat higher than normal cathode-heating current while controlling lamp arc current. An external flashing device is usually employed to regulate the lamps on and off time. Lamps can be flashed millions of times. Flashing life depends upon cathode voltage, cyclic flashing rate and type of ballast circuit. Normal flashing service (one-half to five seconds burning time) does not materially affect rated lamp life but long flashing cycles, for example, two minutes on and two minutes off can increase end discoloration and reduce life.

POWER FACTOR

To the contractor, the public utility and the operator, power factor is particularly important. The contractor finds it necessary to plan the wiring and equipment in excess of what is normally expected by the customer for a specified load. The public utility, while it charges for watts registered by a meter, in reality supplies current through a fixed voltage distribution system. Therefore, from generating plant to service entrances, its equipment must be based on uneconomical values when power factors are low.

To the owner or operator who pays for the wiring from service switch to outlet this extra cost and the size of equipment are duplicated.

The two-lamp ballasts now used in the majority of installations automatically correct power factor, reduce ballast cost and cut wattage losses in the auxiliaries. High power factor single lamp ballasts are recommended where the two-lamp type is not applicable.

RADIO INTERFERENCE

The mercury arc of fluorescent causes a sparkling action on the lamp electrodes which sets up a series of low power radio waves. These waves are picked up by nearby radios and may cause a buzzing sound to be superimposed on the music or speech from the broadcasting station. The noise is generally heard only between stations on the dial, but where signal strengths are weak it may also be noticeable over the entire broadcast band. Interference from fluorescent lamps or fixtures can readily be identified by tuning the set to the point where the interference is most pronounced,