Brightness Requirements in Television Projection Tubes

The following table is calculated for a projected picture size of 18" x 24" and a highlight brightness of 2.7 footlamberts* on the projection screen. This figure is taken from a report of the Society of Motion Picture Engineers which states that in a moderately darkened room 11.8 footlamberts are required for complete comfort; however, a surface having a brightness of 2.7 footlamberts can be viewed without serious discomfort and even as low a surface brightness as 1 footlambert can be watched with some comfort in a well-darkened room.

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*The footlambert is a unit of brightness equal to $\frac{1}{\pi}$ candle per square foot or to the uniform brightness of a perfectly diffusing surface emitting or reflecting light at the rate of one lumen per square foot or to the average brightness of any surface emitting or reflecting light at that rate (from "Nomenclature and Photometric Standards of the Illuminating Engineering Society"). The average brightness of any reflecting surface is therefore the product of the illumination in footcandles and the reflection factor of the surface. The "footlambert" is a more suitable unit for expressing brightness of cathode ray tubes than the "footcandle" since the footcandle assumes a point source of light. However "footcandles" on a cathode ray tube as measured with a light meter is approximately equal to footlamberts.

Tube Diameter (inch)	3	3	4	5	5
Lens f/	1.5	2	1	1.5	2
Raster Size (inch^2)	4	4	8.6	12	12
Vertical Height of Raster (inch)	1.7	1.7	2.4	3	3
Magnification (Linear)	10	10	7.5	6	6
Tube Brightness (Footlambert)	1400	2200	250	600	900
Watt Input	10	16	1.8	4	6
Load (Watt/inch^2)	2.5	4.0	.23	.33	.5
Maximum Line Spacing for 525 line raster mm.	.08	.08	.12	0.14	0.14
mil.	3.2	3.2	4.8	5.6	5.6

The lens f/1 for the 4" tube and f/2 for the 5" tube assumes use of a Schmidt projection system.

Tube brightness is calculated using the following formula given by Myers (Electron Optics P. 486).

$$B_I = B_T \cdot \frac{\pi}{4} \cdot \frac{1}{(m + 1)^2} \cdot \frac{1}{K^2}$$

where

B_I = Brightness of projected image
B_T = Brightness on face of tube
m = Linear magnification
K = f/- Number of lens

30% was added to the values obtained from this formula to account for light losses in lenses. The value obtained from the 3" tube -f/1.5 lens checks fairly well with the value of 400 candles per square foot (1270 footlambert) given by Zworykin and Morton (Television, P. 361) for this system.

Watt input is calculated for an efficiency of the luminescent screen of 150 footlambert per watt. This figure varies, of course, with type of phosphor, voltage, current density, presence of metallic backings, and attenuating layers. Values between 100 and 300 footlamberts were obtained and the figures should be considered tentative until further tests.

Load. The maximum permissible load on sulphide screens is 1.5 watt/inch^2 higher load will decrease efficiency and life. The loss of efficiency is presumably due to current saturation and heat (according to Leverenz (R.C.A. Review October 1940) the light output of a phosphor decreased 50% between 200 and 300°C). A 3" tube even with a f/1.5 lens operates considerably above the save level.

Spot Diameter. The values in the last line of the table are obtained by dividing raster height by 525. However since the light distribution across one line is not uniform, a certain amount of overlap can be tolerated. Even so, the values are much smaller than the spot diameter obtained at high currents with present guns (about 0.2 to 0.3 mm).

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