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Electroluminescence, Design Criteria and Recommendations for Use in Aerospace Vehicle Crew Station Areas

RATIONALE

This document has been determined to contain basic and stable technology which is not dynamic in nature.

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INTRODUCTION

The recommendations set forth herein are the results of the combined efforts of engineers associated with manufacturing of lamps, instrumentation, aircraft, aerospace equipment and vehicles, Air Transport and interested Government Agencies.

The information contained in this initial release of the ARP is general in nature and will suffice as an introduction to this type of lighting. However, it is recommended that it be developed, in further revisions, into a more specific document.

1. SCOPE:

1.1 The scope of this ARP is to provide general requirements for application of electroluminescence to Aerospace Vehicle Crew Station Area instruments and control panels. The design brightness and color recommendations stated in this ARP are intended to apply where a crew station has multiple usage of electroluminescence in both instruments and control panels and when different manufacturers may be involved. These recommendations may also be helpful for the design of individually used displays incorporating electroluminescence, however, this light source has extensive design versatility through variance of manufacturing and operating parameters and the numerous acceptable design recommendations will not be stated herein. Electroluminescence will herein be referred to as EL.

2. REFERENCES:

See Appendix A, Bibliography.

3. OBJECTIVE:

3.1 The objective of this ARP is to recommend basic design considerations and criteria which the designer should employ when utilizing electroluminescence as a light source in Aerospace Vehicle Crew Station areas.

4. RECOMMENDATIONS:

4.1 General:

It is recognized that numerous techniques are applicable when lighting instruments and control panels with EL and the criteria stated in this ARP is intended to be sufficiently general to allow the designer to apply the technique most suited to the particular problem.

4.2 Application:

EL presents a method of obtaining uniform illumination over relatively large or complex shaped surfaces in a compact lightweight design with many colors of light available. This characteristic difference from point sources makes EL a well suited source for application in flight vehicles to illuminate instruments, control panels, nameplates, markers, signals and other displays. EL is recommended for use where a very thin "area" source of diffuse light is required, where a special shape or size of light-emitting surface would be advantageous for the application in question or where power, weight and vibration factors are design-limiting. EL will be applied to the best advantage where low ambient light levels are present and relatively low levels of emitted light are required.

4.3 Color:

Color of EL is dependent upon phosphors employed and to some extent, the voltage and frequency applied. Many colors of EL are available and usable, however for the purposes of this document only green, red, white and yellow will be covered.

4.3.1 Green: This color exhibits the characteristics of greatest luminance and efficiency. This color should be used where these factors are of prime importance and specific color requirements are not critical.

4.3.2 Red: This color has the lowest luminous efficiency but is available in brightness levels which are acceptable for many uses. Red EL may be achieved by dyeing phosphors, filtering the light or by excitation of photoluminescent material that in turn emits red light.

4.3.3 White: This is available in various hues. White EL is obtained by phosphor mixtures or by excitation of additional layers of material to emit spectral components that combine to produce white light. Consideration should be given to the fact that white light produced by a phosphor or phosphor mixtures do not have spectral composition equivalent to that produced by tungsten and may not maintain a constant "color" due to unequal maintenance of light emission by the various component phosphor types, thereby resulting in color shift with age.

4.3.4 Yellow: This color usually exhibits luminous efficiencies between those of the green and red.

4.4 Design Criteria:

4.4.1 Moisture Seal: It is necessary to provide the best possible moisture seal with the least hygroscopic materials for a given application, since EL source useful life is shortened by moisture or water vapor coming into contact with the phosphors. Use of EL in hermetically sealed enclosures would be the optimum.

4.4.2 Temperature: Temperature extremes cause a decrease in EL light emission. Exposure to high temperature, while operating, permanently reduces the light emission and the useful life of the EL. Exposure to low temperature temporarily reduces light output with recovery occurring as temperature increases to normal. The brightness decrease resulting from operation in high ambient temperatures is a function of the temperature, color of EL and time of operation. Maximum environmental temperature limitations should be specified as a function of desired EL illuminated service life, in general should not exceed 150 °F, and operation at 150 °F will not be satisfactory unless the operation of the EL is on an intermittent basis since the time to 1/2 brightness may be only 10% of the time to 1/2 brightness when compared with operation at 75 °F. Maximum acceptable differential temperatures should be specified for attainment of satisfactory life expectancy.

4.4.3 Electromagnetic Interference: EL sources do not normally create electromagnetic interference. When operating normally, these sources act as capacitors that have appreciable power loss (higher than normal power factor for a capacitor).

4.4.4 Electrical Recommendations:

4.4.4.1 Power Requirements: EL devices shall be designed to operate on 115 ± 5 volts and a sinusoidol frequency of 400 ± 20 cps.

4.4.4.2 Insulation: EL devices shall be suitably insulated to prevent contact with electrical potential present by operating or maintenance personnel. Insulation, grade and thickness, shall be adequate to protect against moisture which may be present in console, control or display areas.

4.4.4.3 Dielectric: The lamp circuit shall be able to withstand 500 V plus twice the lamp circuit design voltage at 60 cps for 1 minute between each terminal and the EL device periphery. Lamp terminals shall be connected to each other during this test.

4.4.4.4 Transients: The effect of transients upon EL sources is dependent upon the dielectric materials used in the EL lamp and voltage applied. Thus, each EL lamp construction method will have its own voltage transient limitation. EL lamps subjected to transients in excess of 200 volts may suffer an internal dielectric breakdown resulting in a small burn or dark spot within the lamp. This may repair itself or expand depending upon lamp construction. EL lamps shall be capable of withstanding the power generation transients of the power supply system when tested In accordance with MIL-STD-704. This specification establishes both transient limits and analytic methods. EL lamps shall also be capable of withstanding both load and fault transients of the power system. Protection from transients should be considered and may be incorporated within the EL lamp.

4.4.4.5 Connector: A two-conductor connector rated for the voltage and ambient conditions to be sustained shall be used to supply electrical power to the EL device. In displays requiring electrical contacts other than for the EL, the EL electrical contacts may be included in the connector used for these contacts.

4.4.4.6 Panel Connector Location: A cross (+) approximately .08 inch by .08 inch shall be located on the front surface of the panel directly above the electrical connector. The cross (+) used to locate the connector should be as unobtrusive as possible to avoid interaction between it and other markings on the panel. When required nomenclature interferes with the marking, the cross (+) shall be located as close as possible to the electrical connector. The cross (+) shall be of white color over an opaque surface and shall not be illuminated. The same technique should be applied to other displays where applicable.

4.4.4.7 Incandescent - EL Systems: Incandescent lamps and EL lamps do not have comparable voltage - brightness dimming curves, therefore, depending upon system objectives compensated dimming provisions may be necessary for mixed EL - incandescent lamp assemblies to obtain acceptable brightness uniformity.

4.4.5 Illumination Requirement:

4.4.5.1 Brightness: The initial brightness of illuminated markings when energized at 115 ± 2 volts and 400 ± 20 cps shall be in accordance with Table 1. Terminal brightness shall not be less than specified in Table 1 when operated at rated voltage in an ambient temperature of approximately 70 °F and a relative humidity of no more than 80% for the time listed.

TABLE 1

Application	Color of Light	Initial Brightness (FL)	Minimum Terminal Brightness (FL)	Terminal Brightness Time (Operating Hours)
Control Panels	Red	.5 ± .2	0.1	1200
	White	2.25 ± .75	0.5	1200
	Yellow	2.25 ± .75	0.5	1200
Instruments & Displays	Red	.5 ± .2	0.2	1200
	White	1.00 ± .5	0.2	1200
	Yellow	2.25 ± .75	0.5	1200
	Green	2.25 ± .75	0.5	1200
(Background Lighting)		.02 FL		

4.4.6 Color: The color of the white, yellow and green EL herein discussed shall be in accordance with MIL-C-25050 Aviation color requirements, unless otherwise specified in terms of limiting chromaticity coordinates. It is recommended that more restrictive chromaticity coordinates be specified for given applications. The color of the Red EL shall be in accordance with MIL-C-25050 instrument Red requirements. The chromaticity coordinates of the White EL shall be the equivalent of 2365 K when EL is mixed with white lighting from incandescent lamps.

4.4.7 Contrast: There should be adequate contrast between indicia and opaque surface of the EL device. The values of contrast when measured under daylight or large area diffuse artificial sources of illumination should be 9 for white indicia against a black background and 3.5 for white indicia on a grey background. Contrast "C" is defined as:

$$C = \frac{B_2 - B_1}{B_1} \qquad \text{(Eq. 1)}$$

where B_1 is the brightness of the background and B_2 is the brightness of the indicia.

4.4.8 Lamp Aging: EL lamps should be aged by the manufacturer to attain the required brightness levels.

4.4.9 Dimensioning: Panels shall be dimensioned in accordance with ARP498.

4.4.10 Indicia: Indicia shall be located such that it will not be over nonlight producing areas such as connector areas, circuit areas or edge areas required for sealing. Normally a connector can be located where lettering is not required.

4.4.11 Standard Practices: Standard design practices such as plastic plate thickness shall be adhered to where necessary to accommodate standard parts such as knobs, control shafts, switches and fasteners. Display panels not affecting standard parts may be designed to fit the specific application, for example, a curved throttle surface panel or a circuit breaker panel could be less than standard panel thickness.

4.5 Instrument Construction:

4.5.1 Hermetic Seal: Instruments containing EL sources shall be hermetically sealed when possible. If a hermetic seal cannot be provided, all EL lamps must be adequately sealed against moisture in nonhygroscopic materials.

4.5.2 Background Illumination: Background illumination shall be provided in instruments to prevent apparent indicia floating.

4.5.3 Solid State Circuitry: EL instruments and displays of the Alpha Numeric, thermometer and x - y matrix type shall utilize solid state circuitry where possible.

4.5.4 Dials and Indicia: Instruments containing moving EL lighted pointers, dials, and flags may contain slip rings to supply the required power. Silhouette type pointers may be used where advantageous to preclude the use of slip rings.

5. TEST PROCEDURE AND EQUIPMENT:

5.1 Color:

Numerous methods of color determination exist, however, most are designed for specific purposes and none have the required accuracy necessary to measure the color of light emitted by indicia of aerospace vehicle displays. This can be circumvented by using available color measurement devices to measure larger test samples of EL. These test samples shall be taken from lots of EL manufactured for incorporation into instruments and panels.

5.1.1 Equipment: It is recommended that the color measuring equipment consist of a suitable recording spectrophotometer or an abridged spectro-radiometer. Should other methods be utilized for color measurement, they shall be directly traceable to spectro-radiometric measurements. The equipment shall be accurately calibrated prior to sample measurement. Should more than one color measurement device be utilized, inter-checks between equipment must be accomplished and calibration correlation achieved.

5.1.2 Procedure: It is recommended that equipment manufacturers instructions be followed for the specific equipment utilized. The spectral distribution data obtained should be converted to the CIE color coordinate system for location on the color diagram by x-y coordinates.

5.2 Contrast:

5.2.1 Equipment: The measuring equipment shall consist of a suitable photometer or reflectometer mounted sufficiently far from the indicia and background to focus upon the object on the panel to be measured.

5.2.2 Procedure: The front surface of the EL device shall be perpendicular to the optical viewing axis of the photometer or reflectometer. The lamp shall not be energized. Illumination of the assembly shall be provided by diffuse daylight or by diffuse uniform artificial illumination. The brightness of the white indicia and of the background adjacent to these indicia shall be measured to determine the contrast between the background and indicia. When the contrast is measured with a photometer, measurements should be made with an angle of 60 degrees on both sides of the normal to the area being observed. Measurements must include values taken at 60, 45, 30 and at normal. An average of the brightness values obtained shall be used in computing the contrast.

5.3 Brightness:

5.3.1 Equipment: The measuring equipment shall consist of a suitable physical brightness photometer with a spectral sensitivity which matches the luminous efficiency curve of the CIE standard observer.

5.3.2 Calibration: Measurement of EL illuminated display indicia brightness requires that a spectrophotometric curve of the color of EL being measured be used for calibration of the brightness photometer. A calibration curve is constructed from this calibration for the particular photometer to be used and then brightness measurements can be made of the spectral color of EL involved and corrected to an accurate value with the calibration curve.

5.3.3 Spectrophotometric Curves: Graphs 1 through 5 show some spectrophotometric curves available for EL. The 4000 cycle per second data is presented for information only because EL life when operated at this frequency would be short for practical panel and instrument applications.

5.3.4 Procedure: The front surface of the EL device shall be perpendicular to the optical viewing axis of the photometer. Tests shall be conducted in a darkroom. The brightness of a sufficient number of the indicia illuminated by the EL device shall be measured to determine variations of brightness over the illuminated surface. When a single character appears visually non-uniform, sufficient readings shall be taken of that character to establish ail average for that character. A minimum and maximum brightness values shall be measured. The EL device shall be operated at maximum rated voltage during these tests.

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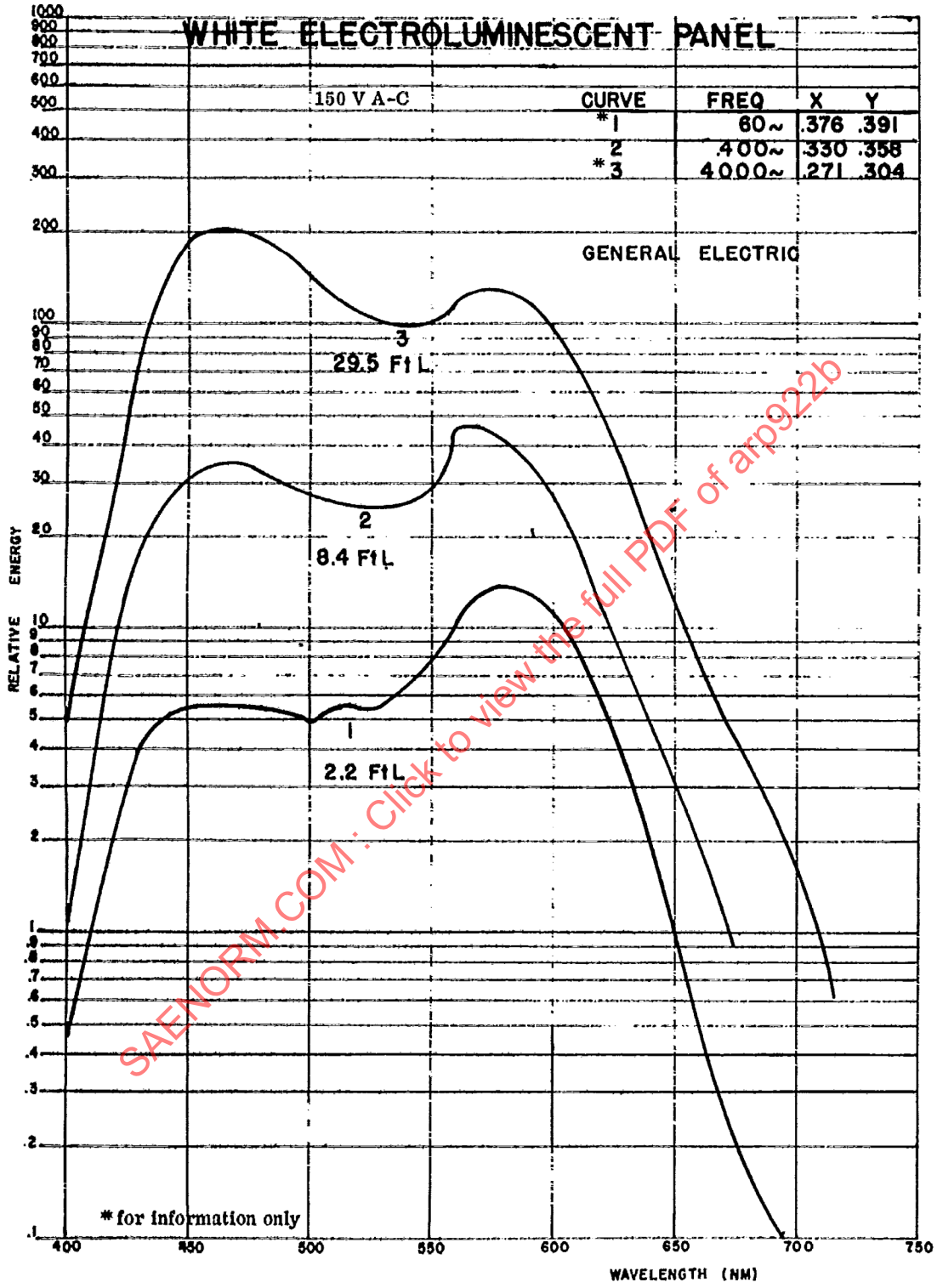

FIGURE 1 - Graph 1

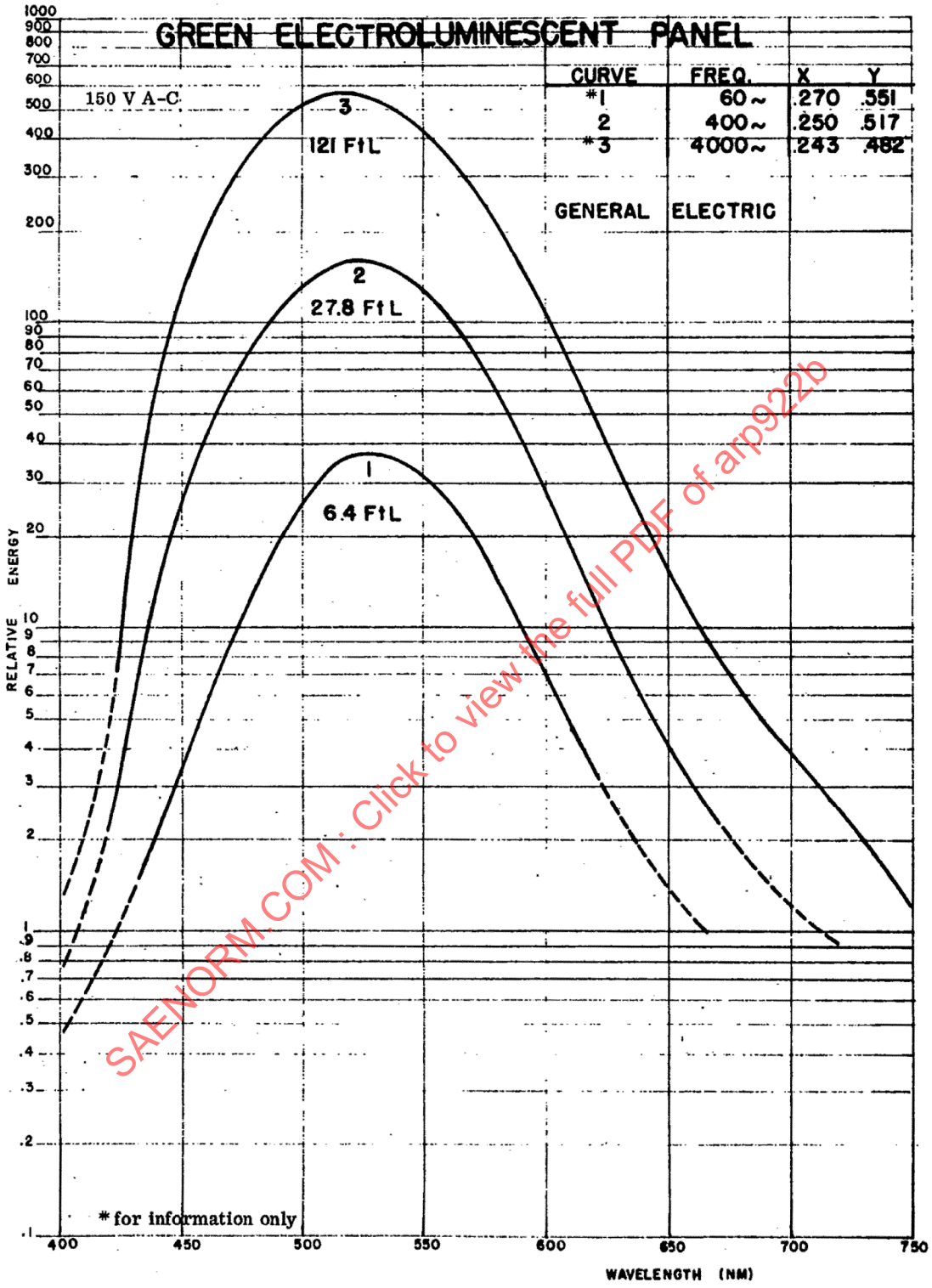

FIGURE 2 - Graph 2

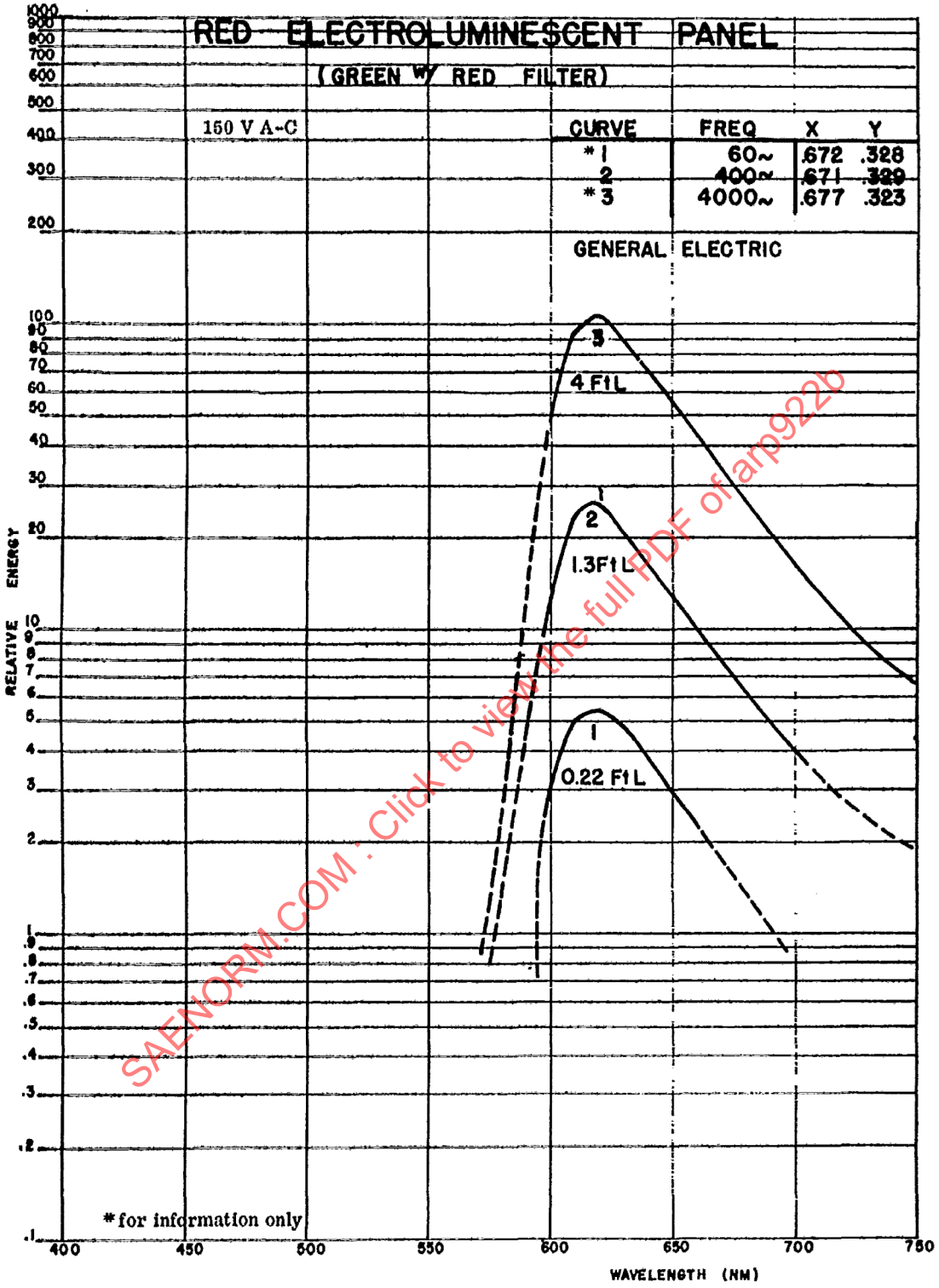

FIGURE 3 - Graph 3

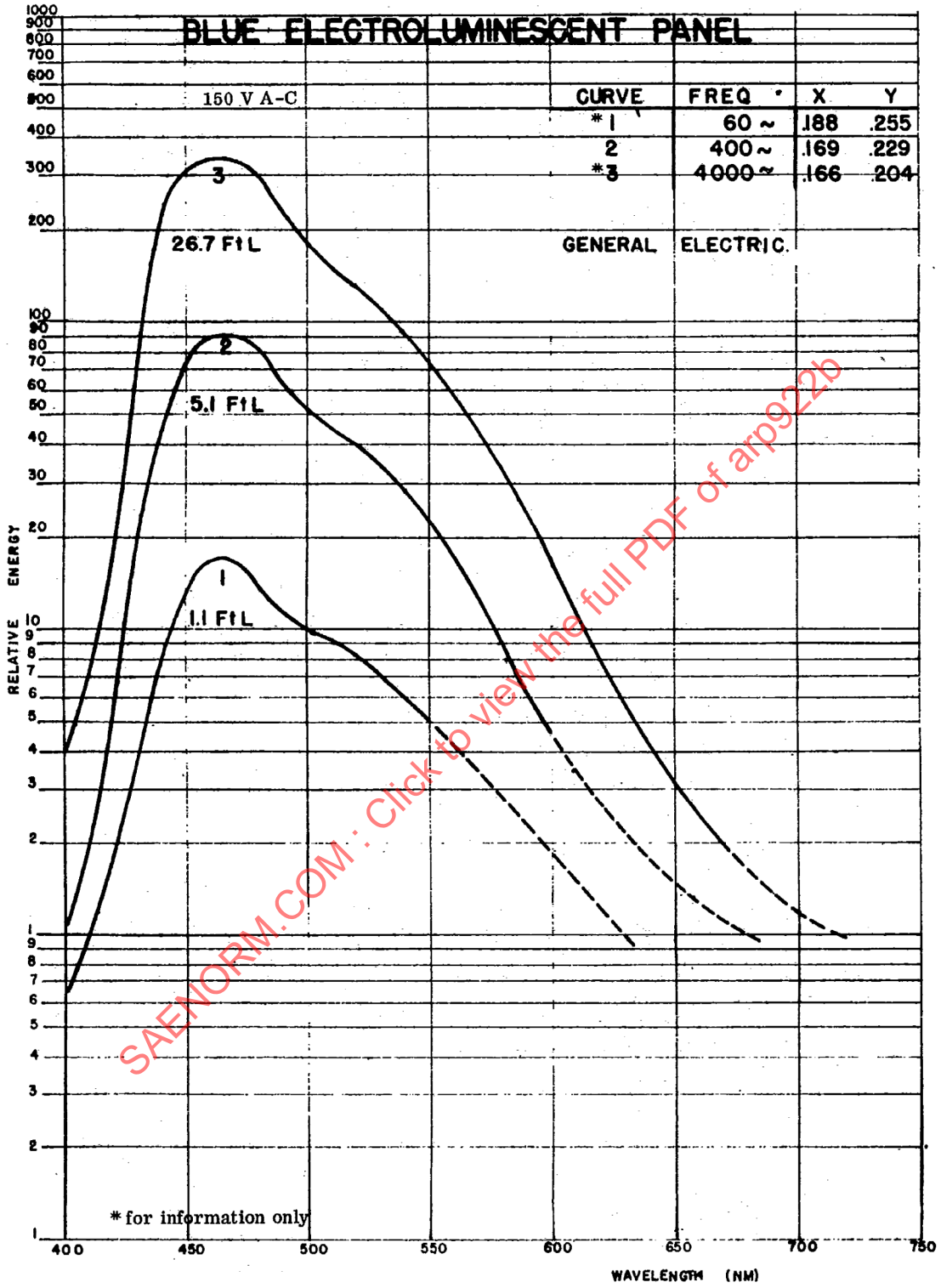

FIGURE 4 - Graph 4

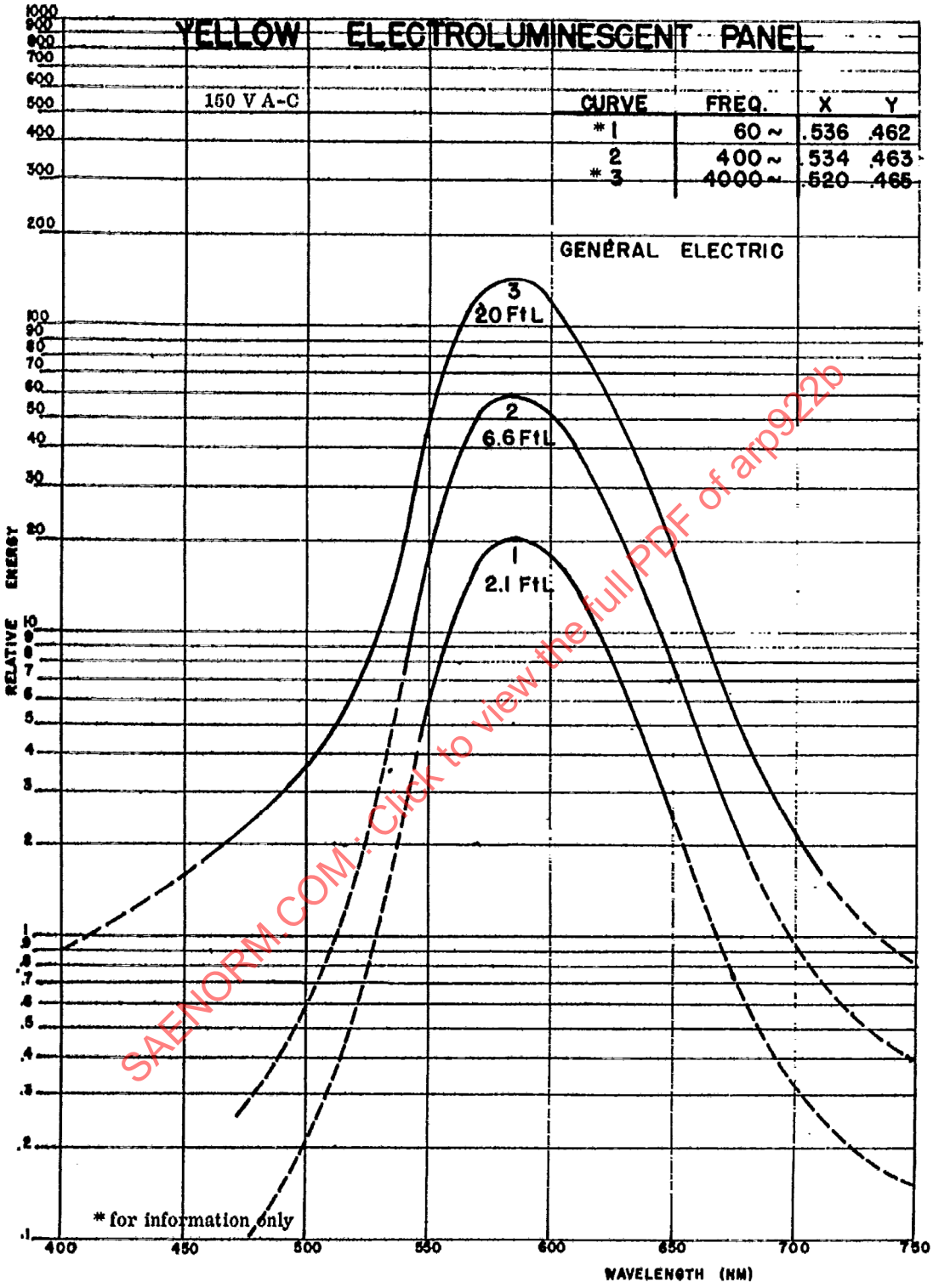

FIGURE 5 - Graph 5

APPENDIX A
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