Analysis of Mercury Lamps and Filter Combinations for Use as Aviation-Green Lights
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Radio Standards. High Frequency Standards. Microwave Standards.

- Office of Basic Instrumentation
- Office of Weights and Measures
Analysis of Mercury Lamps and Filter Combinations for Use as Aviation-Green Lights

by

I. Nimeroff

Prepared for

Equipment Laboratory
Wright Air Development Center
Department of the Air Force
Analysis of Mercury Lamps and Filter Combinations for Use as Aviation-Green Lights

1. PURPOSE OF ANALYSIS

The purpose of this analysis is to compute the luminous transmittance and chromaticity coordinates of present aviation-green filters (designed for use with incandescent lamps) when they are used in combination with currently available mercury lamps. Should these combinations fail to meet either the present or proposed aviation-green light specification, suitable filters would then be designed.

2. MERCURY LAMPS

The energy radiated in the visible region by mercury lamps consists of spectral lines and a continuum. The spectral-emittance data for mercury lamps used in this analysis were obtained from General Electric Company's brochure LS-103, June 1955. The performance of the following lamp types was analyzed: H250-A5, BH6, H400-E1 and H1000-A15. The relative spectral-emittance data for these lamps are shown in figure 1.

The luminous efficiency index of each of these lamps and of an incandescent lamp operated at 2854°C K, listed in table I, indicates that the mercury lamps are relatively efficient in the production of visible radiant energy. The luminous-efficiency index of a lamp is defined as:

\[
\frac{\int_{380}^{760} P_\lambda \overline{y}_\lambda \, d\lambda}{\int_{380}^{760} P_\lambda \, d\lambda}
\]

where \( P_\lambda \) is the spectral radiant flux and \( \overline{y}_\lambda \) is the CIE relative luminous-efficiency function.

Also listed in table I are the chromaticities of mercury lamps, H250-A5 and BH6 and of an incandescent lamp operating at 2854°C K. The chromaticity coordinates of these lamps are plotted
on figure 2. Detailed analysis of the H250-A5 lamp was undertaken because its spectral distribution closely resembles that for H400-E1 and H1000-A15. Detailed analysis of the BH6 lamp was undertaken because this lamp differs from the others by having a higher spectral continuum.

Table I

Chromaticity, Luminous-Efficiency Index, and Efficiency of Mercury and Incandescent Lamps

<table>
<thead>
<tr>
<th>Lamp Type</th>
<th>Chromaticity Coordinates</th>
<th>Luminous-Efficiency Index</th>
<th>Efficiency (Rated Lumens per Watt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H250-A5</td>
<td>0.318 0.379 0.303</td>
<td>54</td>
<td>44</td>
</tr>
<tr>
<td>BH6</td>
<td>.277 .330 .393</td>
<td>40</td>
<td>65</td>
</tr>
<tr>
<td>H400-E1</td>
<td>-- -- --</td>
<td>55</td>
<td>50</td>
</tr>
<tr>
<td>H1000-A15</td>
<td>-- -- --</td>
<td>55</td>
<td>52</td>
</tr>
<tr>
<td>Incandescent</td>
<td>.448 .408 .144</td>
<td>25</td>
<td>20</td>
</tr>
</tbody>
</table>

2.1 Performance of Mercury Lamps with Conventional Aviation-Green Filters.

In computing the performance of the lamps with aviation-green filters, spectral transmittance data, T<sub>λ</sub>, for the transmittance standard, WF590, were used. Luminous transmittance, T, of this filter was computed for an incandescent tungsten lamp operated at 2854°K as well as for the mercury lamps. Chromaticity coordinates, x, y, and z, and luminous transmittance were computed for the H250-A5 and BH6 mercury lamps and the incandescent lamp. These computed results are listed in table II. The chromaticity coordinates are plotted on figure 2.

Table II

Luminous Transmittance and Chromaticity Coordinates of Lamp and Aviation-Green Filter Combinations

<table>
<thead>
<tr>
<th>Lamp Type</th>
<th>Chromaticity Coordinates</th>
<th>T (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H250-A5</td>
<td>0.232 0.276 0.492</td>
<td>22</td>
</tr>
<tr>
<td>BH6</td>
<td>.192 .249 .559</td>
<td>27</td>
</tr>
<tr>
<td>H400-E1</td>
<td>-- -- --</td>
<td>21</td>
</tr>
<tr>
<td>H1000-A15</td>
<td>-- -- --</td>
<td>22</td>
</tr>
<tr>
<td>Incandescent</td>
<td>.205 .400 .395</td>
<td>20</td>
</tr>
</tbody>
</table>
The colors of the combination of the aviation-green filter and the mercury lamps are obviously too blue for use as aviation-green lights. The mercury lamps provide little increase in luminous transmittance over the incandescent lamp.

3. DESIGN OF FILTERS FOR MERCURY LAMPS TO YIELD AVIATION-GREEN LIGHT

If the radiant energy emitted by the mercury lamp in the visible region of the spectrum were composed entirely of spectral lines 404.7, 435.8, 546.1, and 578.0 μm, the color of any mercury lamp-filter combination would lie within a chromaticity region defined by these spectral lines. This chromaticity region is shown by dashes on figure 2. If we wish to obtain a color that will lie in the aviation-green chromaticity region, a filter is required that will almost completely absorb the energy of line 578.0 μm and will partially absorb the energy of lines 404.7 and 435.8 μm.

As no single filter known can satisfy these requirements, two-component filter combinations of Didymium and Noviol filters were tried. Didymium filters have an absorption band in the region of 578 μm and Noviol filters absorb energy in the blue and violet regions of the spectrum.

The design data for the two combinations that show promise of usefulness are listed in table III. The thickness of each filter component is designed on the basis of spectral data published in Glass Color Filters, Corning, 1948, for stock thickness t₀.

Table III
Filter Design Data

<table>
<thead>
<tr>
<th>Filter Designation</th>
<th>Corning Ident. No.</th>
<th>Relative Thickness</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1-63</td>
<td>0.4 t₀</td>
<td>Didymium</td>
</tr>
<tr>
<td></td>
<td>3-72</td>
<td>0.5 t₀</td>
<td>Noviol B</td>
</tr>
<tr>
<td>B</td>
<td>1-63</td>
<td>1.0 t₀</td>
<td>Didymium</td>
</tr>
<tr>
<td></td>
<td>3-73</td>
<td>1.0 t₀</td>
<td>Noviol A</td>
</tr>
</tbody>
</table>

Figure 3 shows the computed spectral transmittance of the components and the combination of designed filter A. Figure 4 shows the computed spectral transmittance of the components and
the combination of designed filter B. The location of each mercury spectral line is indicated by an arrow on figures 3 and 4.

The chromaticity coordinates and luminous transmittance of filters A and B in combination with lamps H250-A5 and BH6 were computed. The results of these computations are listed in table IV. The chromaticity coordinates are plotted on figure 2.

Table IV

<table>
<thead>
<tr>
<th>Filter Designation</th>
<th>Lamp Type</th>
<th>Chromaticity Coordinates</th>
<th>Luminous Transmittance (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>H250-A5</td>
<td>0.356 0.587 0.057</td>
<td>60</td>
</tr>
<tr>
<td>A</td>
<td>BH6</td>
<td>0.313 0.522 0.165</td>
<td>66</td>
</tr>
<tr>
<td>B</td>
<td>H250-A5</td>
<td>0.273 0.425 0.302</td>
<td>48</td>
</tr>
<tr>
<td>B</td>
<td>BH6</td>
<td>0.267 0.376 0.358</td>
<td>56</td>
</tr>
</tbody>
</table>

4. DISCUSSION

The chromaticity coordinates for mercury lights show that the color of each light lies on the green side of the Planckian Locus near 6000°K. The chromaticity of the mercury lamps in combination with the present aviation-green filter indicates that the resulting color is too blue for aviation green. The H250-A5 lamp in combination with designed filter B and the BH6 lamp in combination with designed filter A satisfy the proposed aviation green limits. Designed filter A shifts the color of mercury lamps toward yellow-green, while designed filter B shifts the color of the mercury lamp toward green.

The mercury lines plotted as points on the spectrum locus of figure 2 serve to define approximately the chromaticity region within which chromaticities of mercury lamp-filter combinations will lie. The BH6 lamp in combination with the present aviation-green filter falls just outside of this region because of the high spectral continuum in the spectral region of 490 μm.

The chromaticity region defined by the mercury lines indicates that use of mercury lamps is theoretically possible for lunar white,
aviation blue, and aviation green. For lunar white, line 546 μm needs to be eliminated. For aviation blue, lines 546 μm and 578 μm need to be greatly reduced. For aviation green, line 578 μm needs to be eliminated, and lines 405 μm and 436 μm reduced.

In the use of mercury lamps, precaution should be taken to dissipate the heat produced by the ultraviolet radiation that will be absorbed by the filter. The absorbed radiation might heat the filter to the cracking point. Incandescent lamps emit very little ultraviolet radiant energy but have much infrared. The filters in use with incandescent lamps generally transmit the infrared so no special precautions need be taken.
SPECTRAL CHARACTERISTICS OF MERCURY LAMPS

Figure 1

Wavelength (nm)

Relative Radiance %
SPECTRAL TRANSMITTANCE OF FILTER COMBINATION A

$0.4 t_0$ Didymium (1-63) and $0.5 t_0$ Noviol B (3-72)

Wavelength, $\mu m$

Figure 3
SPECTRAL TRANSMITTANCE OF FILTER COMBINATION B

$D_0$, Didymium (1-63) and $t_0$, Noviol A (3-73)

Figure 4
THE NATIONAL BUREAU OF STANDARDS

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