ABSTRACT: A balancing means and a method for producing spectrally balanced light is provided which comprises an optical transmission carrier and dye thereon selectively absorbing at least about 25 percent of the peak emissions of mercury discharge spectral energy sources.
SPECTRAL BALANCING FILTER FOR FLUORESCENT SOURCES

This invention relates to spectral balancing means and methods of spectral balancing and particularly to spectral balancing means for use in order to properly balance the spectral emission of carbon arc and mercury discharge spectral energy sources.

I shall particularly describe the invention in connection with a typical mercury discharge spectral energy source, fluorescent lighting. Fluorescent lighting is very much used for illumination in offices, public buildings and homes. It has many advantages for general illumination, being soft, and very efficient. However, it is well known that fluorescent lighting is unbalanced in its spectral emission characteristics and cannot be satisfactorily used for many purposes where a balanced spectrum is required. Many attempts have been made in the past to find a satisfactory method for balancing the spectral emission of fluorescent sources or to correct the inherent difficulties by modifying the spectral distribution characteristics of fluorescent sources, but without success. I have invented a means and method of spectrally balancing fluorescent sources which may be used wherever a balanced fluorescent source is desired.

I shall particularly describe the invention in connection with photography using color film. It is well known that fluorescent lighting cannot be used satisfactorily for color photography. Consequently, when television or motion picture cameras are being used for color reproduction under artificial light, special lighting sources must be used. If the objects to be photographed are also illuminated by fluorescent artificial light sources, the special lighting sources must overpower them; if such special lighting sources are not permanently installed at the area, they must be carried there and installed and used. This is expensive and inconvenient, but is necessary because no satisfactory method for balancing the spectral emission of fluorescent sources has been found prior to the present invention.

I have discovered a means and a method of balancing the spectral emission of fluorescent sources which makes it possible to use conventional fluorescent light sources for color reproduction. I have successfully produced photographic results under fluorescent lighting which are completely free from the "washed out" appearance characteristic of color reproduction by fluorescent lighting in the past and which are comparable to color reproduction by daylight illumination.

In a preferred embodiment of my invention, I provide a spectral balancing means absorbing ultraviolet radiation without distortion of violet and deep blues and with a relative strengthening of blue green and green wavelengths of light. A device of my invention preferably selectively reduces the peaks at \(3,650\) angstroms, \(4,030\) angstroms and \(4,360\) angstroms and substantially absorbs the \(3,130\) angstroms peak characteristic of all white fluorescent light sources (cool and warm whites) presently in use. The device of my invention is preferably prepared by combining known color filter materials to produce the peculiar advantages here set out. Preferably, I combine dyes on a suitable carrier to selectively reduce the emission peaks which are characteristic of all white fluorescent light sources. Preferably, dyes are combined to get an absorbance curve similar to curves hereafter described.

Preferably, I use gelatin as the carrier although any other suitable optical transmission carrier may be used to carry the dyes.

In the foregoing general statement of my invention, I have set out certain objects, purposes and advantages of my invention. Other objects, purposes and advantages will be apparent from the following description and the accompanying drawings in which:

Fig. 1 is a curve of absorbance characteristics of one of the dyes combined according to my invention;

Fig. 2 is a curve of absorbance characteristics of a second dye to be combined with the dye of Fig. 1 to produce a spectral balancing means according to my invention;

Fig. 3 is a curve of absorbance of spectral emission in a preferred embodiment of my invention;

Fig. 4 is a curve of absorbance of spectral emission in a second embodiment of my invention;

Fig. 5 is a curve of absorbance of spectral emission in a third embodiment of my invention;

Fig. 6 is a spectral response curve of an orthochromatic film exposed to the spectral emission of a typical cool-white fluorescent light source without balancing its spectral emission;

Fig. 7 is a spectral response curve of an orthochromatic film exposed to the spectral emission of a typical cool-white fluorescent light source using the embodiment of my invention of Fig. 3;

Fig. 8 is a curve as in Fig. 7 using the embodiment of my invention of Fig. 4;

Fig. 9 is a curve as in Fig. 7 using the embodiment of my invention of Fig. 5;

Fig. 10 is a spectral response curve of an orthochromatic film exposed to the spectral emission of a typical warm-white fluorescent light source without balancing its spectral emission;

Fig. 11 is a curve as in Fig. 10 using the embodiment of my invention which was also used in Fig. 3;

Fig. 12 is a curve as in Fig. 10 using the embodiment of my invention which was used in Fig. 4, and

Fig. 13 is a curve as in Fig. 10 using the embodiment of my invention which was also used in Fig. 6.

Referring to the drawings, I have illustrated in Fig. 1 an absorbance curve of one preferred dye component for combining to form the balancing means of my invention and in Fig. 2 an absorbance curve of a second preferred dye component for combining with the dye of Fig. 1 to form the balancing means of my invention.

In order to illustrate the effectiveness of the spectral balancing means, I prepared three gelatin carriers with dye combinations which would effectively balance the spectral emission of fluorescent sources. The absorbance values of each device were determined using a spectrophotometer and appear in Table I below.

<table>
<thead>
<tr>
<th>Wavelengths in Angstroms</th>
<th>Embed-</th>
<th>Embed-</th>
<th>Embed-</th>
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<tbody>
<tr>
<td></td>
<td>diment</td>
<td>diment</td>
<td>diment</td>
</tr>
<tr>
<td>3,600</td>
<td>1.46</td>
<td>0.65</td>
<td>1.50</td>
</tr>
<tr>
<td>3,100</td>
<td>1.35</td>
<td>0.40</td>
<td>1.30</td>
</tr>
<tr>
<td>3,200</td>
<td>0.90</td>
<td>0.45</td>
<td>1.30</td>
</tr>
<tr>
<td>3,300</td>
<td>0.90</td>
<td>0.30</td>
<td>0.83</td>
</tr>
<tr>
<td>3,400</td>
<td>0.65</td>
<td>0.27</td>
<td>0.93</td>
</tr>
<tr>
<td>3,500</td>
<td>0.70</td>
<td>0.24</td>
<td>0.94</td>
</tr>
<tr>
<td>3,900</td>
<td>0.55</td>
<td>0.26</td>
<td>0.85</td>
</tr>
<tr>
<td>3,900</td>
<td>0.50</td>
<td>0.27</td>
<td>0.90</td>
</tr>
<tr>
<td>4,000</td>
<td>0.62</td>
<td>0.30</td>
<td>1.00</td>
</tr>
<tr>
<td>4,100</td>
<td>0.60</td>
<td>0.34</td>
<td>1.05</td>
</tr>
<tr>
<td>4,200</td>
<td>0.68</td>
<td>0.35</td>
<td>1.06</td>
</tr>
<tr>
<td>4,300</td>
<td>0.64</td>
<td>0.37</td>
<td>1.02</td>
</tr>
<tr>
<td>4,400</td>
<td>0.85</td>
<td>0.35</td>
<td>0.95</td>
</tr>
<tr>
<td>4,500</td>
<td>0.50</td>
<td>0.22</td>
<td>0.83</td>
</tr>
<tr>
<td>4,600</td>
<td>0.44</td>
<td>0.26</td>
<td>0.72</td>
</tr>
<tr>
<td>4,700</td>
<td>0.34</td>
<td>0.20</td>
<td>0.74</td>
</tr>
<tr>
<td>4,800</td>
<td>0.33</td>
<td>0.19</td>
<td>0.65</td>
</tr>
<tr>
<td>4,900</td>
<td>0.38</td>
<td>0.24</td>
<td>0.62</td>
</tr>
<tr>
<td>5,000</td>
<td>0.40</td>
<td>0.22</td>
<td>0.50</td>
</tr>
<tr>
<td>5,100</td>
<td>0.38</td>
<td>0.20</td>
<td>0.49</td>
</tr>
<tr>
<td>5,200</td>
<td>0.40</td>
<td>0.18</td>
<td>0.46</td>
</tr>
<tr>
<td>5,300</td>
<td>0.36</td>
<td>0.18</td>
<td>0.44</td>
</tr>
<tr>
<td>5,400</td>
<td>0.30</td>
<td>0.16</td>
<td>0.35</td>
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<td>5,500</td>
<td>0.10</td>
<td>0.05</td>
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<tr>
<td>5,600</td>
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<tr>
<td>5,800</td>
<td>0.00</td>
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<td>0.00</td>
</tr>
</tbody>
</table>

*At any given wavelength, the spectral absorbance value relates the amount of spectral energy (of that specific wavelength) entering the spectral balancing means to the amount of spectral energy transmitted.

The absorbance curve of Embodiment 1 is plotted in Fig. 3, that of Embodiment 02 in Fig. 4, and that of Embodiment 03 in Fig. 5. Known color balancing filters for color photo-
To illustrate the effect of my invention on the response of photographic emulsions and materials to spectral emission from fluorescent sources I had spectrographic negatives prepared exposing photographic material to fluorescent sources through a spectral balancing means of my invention and with none at all. Orthochromatic film was used rather than panchromatic film because the described spectral balancing means exhibit little transmission difference above approximately 5,800 angstroms.

When the orthochromatic film was exposed to the fluorescent source, a step-density wedge of fine-grain silver was interposed. Each step of the wedge had an incremental density of 0.14. Thus, for example, two increments totaled 0.28, which for practical purposes represents a 2X difference in transmission or, in other terms, a one stop difference in lens aperture. These density increments are directly equivalent to absorption values of 0.14, 0.28, etc.

After the orthochromatic film was exposed, it was developed in a high-contrast, catalytic, paraformaldehydehydroquinone developer to a gamma above 3.0 and a "toe" density less than 0.30. Low-contrast continuous tone spectrographic negatives were also produced, in order to verify the results of this high-contrast procedure.

To determine the spectral response curves of the orthochromatic film, positive prints were made from the spectrographic negatives onto high gama paper and developed to high contrast. The printing exposures were timed to print maximum possible density for all densities in the original negatives of 0.40 or less. The resulting positive prints thus show directly the contour of the photographic response from all wavelengths between 3,000 and 5,800 angstroms. From the prints data were tabulated into the following Table II and Table III and spectral response curves were plotted, which are FIGS. 6 through 13.

| Table III—Spectral Response of an Orthochromatic Film to the Spectral Emission of a Warm White Fluorescent Light Source |
|---|---|---|---|
| Wavelengths in Angstroms | Without Balancing Effects of my Invention | Balanced by Embodiment 1 | Balanced by Embodiment 2 |
| 3,000* | .42 | .14 | .26 |
| 3,100 | .44 | .14 | .28 |
| 3,200* | .43 | .14 | .26 |
| 3,300 | .42 | .14 | .26 |
| 3,400 | .42 | .14 | .26 |
| 3,500 | .42 | .14 | .26 |
| 3,600* | .42 | .14 | .26 |
| 3,700 | .41 | .14 | .26 |
| 3,800 | .42 | .14 | .26 |
| 3,900 | .42 | .14 | .26 |
| 4,000 | .42 | .14 | .26 |
| 4,100* | 1.12 | .70 | .42 |
| 4,200 | .42 | .26 | .12 |
| 4,300 | .42 | .14 | .26 |
| 4,400 | .42 | .14 | .26 |
| 4,500 | .42 | .14 | .26 |
| 4,600 | .42 | .14 | .26 |
| 4,700 | .42 | .14 | .26 |
| 4,800 | .42 | .14 | .26 |
| 4,900 | .42 | .14 | .26 |
| 5,000* | .70 | .42 | .70 |
| 5,100 | .70 | .42 | .70 |
| 5,200 | .70 | .42 | .70 |
| 5,300 | .70 | .42 | .70 |
| 5,400 | .70 | .42 | .70 |
| 5,500 | .70 | .42 | .70 |
| 5,600* | 1.12 | .70 | .42 |
| 5,700 | .42 | .14 | .26 |
| 5,800 | .42 | .14 | .26 |
| 5,900 | .42 | .14 | .26 |

*The printing exposures for making positive prints were timed to print maximum possible density for all densities in the original negatives of 0.40 or less.

**This wavelength designates an average of those wavelengths which comprise this "peak", which is characteristic of the spectral emission of a typical fluorescent light source.

The devices used in the foregoing tests were made of gelatin containing the following dye transfer (amibition) dyes:

**Embodyment 01 5 parts ASA magenta + 5 parts ASA yellow
**Embodyment 02 2 parts ASA magenta + 5 parts ASA yellow
**Embodyment 03 9 parts ASA magenta + 12 parts ASA yellow.

In order to compare the results of the using the foregoing Embodiments 01, 02, and 03 and the results of using the filters and combinations of filters presently known, and results not using any of them, color motion pictures for television transmission and for conventional projection were produced under both cool white and warm white fluorescent light sources. All the films exposed without use of my invention revealed the color imbalance characteristic of color film exposed to the spectral emission of fluorescent light sources. On the other hand, the films exposed using my invention had excellent color balance.

It will be apparent from the foregoing tables and curves that my invention has a very selective absorption characteristic for peak emissions of fluorescent light sources and at the same time changes the relative transmission of wavelengths in the band ±3,000 angstroms to ±6,300 angstroms. Accordingly, broadly stated, my invention has a selective absorption for peak emissions of fluorescent light sources and adjusts the relative transmission of wavelengths in the band ±3,000 A. to ±6,300 A. Preferably, the spectral balancing device of my invention has a spectral absorbance curve lying between the curve of FIG. 4 and FIG. 5 and particularly similar to that of FIG. 3.

The spectral balancing means of my invention may be applied to a fluorescent source envelope or to a separate carrier member as described herein, or it may be applied directly to the photographic film base and emulsion or material or as a modification of the fluorescent source phosphors.

While I have set out certain preferred embodiments and practices of my invention in the foregoing specification, it will be understood that this invention may be otherwise broadly.

| Table II—Spectral Response of an Orthochromatic Film to the Spectral Emission of a Cool White Fluorescent Light Source |
|---|---|---|---|
| Wavelengths in Angstroms | Without Balancing Effects of my Invention | Balanced by Embodiment 1 | Balanced by Embodiment 2 |
| 3,000* | .42 | .14 | .26 |
| 3,100 | .44 | .14 | .28 |
| 3,200* | .43 | .14 | .26 |
| 3,300 | .42 | .14 | .26 |
| 3,400 | .42 | .14 | .26 |
| 3,500 | .42 | .14 | .26 |
| 3,600* | .42 | .14 | .26 |
| 3,700 | .41 | .14 | .26 |
| 3,800 | .42 | .14 | .26 |
| 3,900 | .42 | .14 | .26 |
| 4,000 | .42 | .14 | .26 |
| 4,100* | 1.12 | .70 | .42 |
| 4,200 | .42 | .26 | .12 |
| 4,300 | .42 | .14 | .26 |
| 4,400 | .42 | .14 | .26 |
| 4,500 | .42 | .14 | .26 |
| 4,600 | .42 | .14 | .26 |
| 4,700 | .42 | .14 | .26 |
| 4,800 | .42 | .14 | .26 |
| 4,900 | .42 | .14 | .26 |
| 5,000* | .70 | .42 | .70 |
| 5,100 | .70 | .42 | .70 |
| 5,200 | .70 | .42 | .70 |
| 5,300 | .70 | .42 | .70 |
| 5,400 | .70 | .42 | .70 |
| 5,500 | .70 | .42 | .70 |
| 5,600* | 1.12 | .70 | .42 |
| 5,700 | .42 | .14 | .26 |
| 5,800 | .42 | .14 | .26 |
| 5,900 | .42 | .14 | .26 |
practiced within the scope of the following claims.

1. Balancing means for producing spectrally balanced light from fluorescent sources comprising in combination an optical transmission carrier and magenta and yellow transfer dyes in the ratios 1:1 to 2:5 thereon selectively absorbing at least about 25 percent of each of the peak emissions of said sources.

2. A filter for color photography under mercury discharge spectral energy sources comprising in combination a magenta filter and a yellow filter integrally associated to form a spectral transmission path which selectively reduces spectral energy emission peaks at ±3,650, ±4,050 and ±4,360 Å and substantially absorbs the peak at ±3,130 Å and which provides relatively increased transmission of spectral energy for the band ranging from ±3,000 Å to ±6,000 Å.