A METHOD OF OBTAINING RADIANT ENERGY HAVING THE VISIBLE SPECTRAL DISTRIBUTION OF A COMPLETE RADIATOR AT VERY HIGH TEMPERATURES.¹

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THE author has previously published several detached notices and papers showing the utility of rotatory dispersion in producing radiant energy of some desired spectral distribution.² It is possible to obtain by this artifice spectral distributions corresponding to a complete radiator (black body) at temperatures far above anything possible in the actual operation of a furnace, or any artificial incandescent source. In certain studies in colorimetry and physiologic optics³ it is desirable to be able to produce at will such high temperature energy distributions in the visible spectrum. In the previous papers this matter was not treated in a sufficiently unified manner, and data now at hand were not available when they were published. *The purpose of the present notice is to state the precise specifications for producing radiant energy of the visible spectral distribution of a theoretical complete radiator (by Planck's formula, $c_2 = 14350$) at any temperature between 3100° K and 7000° K, by means of an apparatus which permits of the convenient adjustment of the distribution to correspond to any temperature within this range.⁴* The detailed treatment of the theory of this method and the computations leading to these results are reserved for a subsequent paper.⁵

The source of radiant energy is a gas-filled tungsten lamp⁶

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²*Phys. Rev.* (2) 6, p. 64, July, 1915; (2) 9, p. 341, Apr., 1917; (2) 10, p. 208, Aug., 1917; (2) 11, p. 502, June, 1918; (2) 14, p. 264, Sept., 1919; (2) 15, p. 538, June, 1920. *J. Op. Soc. Am.*, Nov. 1920.

³*E.g.*, Troland: *Trans. I. E. S.*, 13, p. 26, 1918. Priest: *New Study of the Leucoscope*, *J. Op. Soc. Am.*, Nov., 1920.

⁴Temperatures up to about 3000° K can be attained in actual incandescent sources—gas-filled tungsten lamps.

⁵The Application of Rotatory Dispersion to Colorimetry, *B. S. Sci. Paper*.

⁶*B. S. Lamp 1717*. The color temperature has been derived from the energy distribution curve determined radiometrically by Dr. W. W. Coblentz.

at a color temperature of 2830°K (Cf. Fig. 1). The distribution is modified by the rotatory dispersion of quartz,⁷ using a quartz

FIG. 1.

Spectral Distribution of Energy.

Solid curve: Complete radiator at temperature 2830°K , by Planck's formula with $c_2 = 14350$. The small solid black circles indicate the points actually computed by Planck's formula. Open circles: B. S. Lamp 1717 at 118.0 volts (about 15.6 l. p. w.) determined radiometrically by W. W. Coblentz.

FIG. 2.

Simple Arrangement of One Quartz Plate Between Nicols.

The spectral distribution of energy emerging from Nicol 2 in the direction of the dotted arrow may be adjusted by rotation of Nicol 2 relative to Nicol 1 (angle, ϕ).

plate 0.500 mm. thick. Two arrangements of apparatus are used, namely:

- (1) The simple arrangement (Fig. 2);
- (2) The duplex arrangement (Fig. 3).

The combinations of nicol prisms and quartz plates shown

⁷ Cf. Priest: A New Study of the Leucoscope, Appendix I, J. Op. Soc. Am., Nov., 1920.

in these figures constitute, in effect, selective ray filters of adjustable spectral transmission. The relative transmissions as a function of wave-length are:

(1) For the simple arrangement,

$$\sin^2 (\phi - 0.5 \alpha_\lambda); \dots \dots \dots (1)$$

(2) For the duplex arrangement,

$$\sin^2 (\phi_1 - 0.5 \alpha_\lambda) \sin^2 (\phi_2 - 0.5 \alpha_\lambda); \dots \dots \dots (2)$$

FIG. 3.

Duplex Arrangement of Two Quartz Plates and Three Nicols.
Nicols 1 and 2 are fixed. The spectral distribution of energy emerging from Nicol 3 in the direction of the dotted arrow may be adjusted by rotation of Nicol 3 relative to Nicol 2 (angle, ϕ_2).

FIG. 4.

Illustrating the Production of Radiant Energy Having the Spectral Distribution of a Complete Radiator by Means of the Simple Apparatus (Fig. 2).

The solid black curves represent Planck's formula with $c_2 = 1.4350$. The numbers attached to these curves indicate temperatures in degrees K.

The various circles represent distributions obtained by the arrangement shown in Fig. 2. Each different style and size of circle refers to a particular value of ϕ ; and the numbers attached to the circles indicate values of ϕ in circular degrees.

In all cases, Energy = 100.0 at wave-length 590 (arbitrary convention).

FIG. 5.

Illustrating the Production of Radiant Energy Having the Spectral Distribution of a Complete Radiator by Means of the Duplex Apparatus (Fig. 3). The solid black curves represent Planck's formula with $c_2 = 14350$. The numbers attached to these curves indicate temperatures in degrees K. The various circles represent distributions obtained by the arrangement shown in Fig. 3. Each different style and size of circle refers to a particular value of ϕ_1 ; and the numbers attached to the circles indicate values of ϕ_2 in circular degrees. ϕ_1 constant = 170° . In all cases, energy = 100.0 at wave-length 590 (arbitrary convention).

where:

$\alpha_\lambda \equiv$ rotation of the plane of polarization by 1.000 mm. of quartz for wave-length λ ;

$\phi \equiv$ rotation of nicol, 2, relative to nicol, 1, in the same sense as α , from the extinction position with quartz removed (Fig. 2);

$\phi_1 \equiv$ rotation of nicol, 1, relative to nicol, 2, in the direction *contrary* to α , from extinction position;

$\phi_2 \equiv$ rotation of nicol, 3, relative to nicol, 2, with the same conventions as for ϕ above. } (Fig. 3)

In Fig. 4 the solid curves show the spectral distributions of a theoretical complete radiator computed by Planck's distribution

FIG. 6.

Temperature of Energy Distribution as a Function of ϕ with the Arrangement shown in Fig. 2. (Plotted from inspection of Fig. 4.)

formula for various temperatures with $c_2 = 14350$. The numbers attached to the curves indicate temperatures in degrees K (absolute temperature). The various circles show distributions obtained by means of the arrangement shown in Fig. 2. The numbers attached to them indicate values of ϕ in circular degrees.

The same explanation applies to Fig. 5, except that it refers to distributions obtained by the arrangement shown in Fig. 3. ϕ_1 is a constant $= 170^\circ$. The numbers attached to the circles indicate values of ϕ_2 in circular degrees.

In Fig. 6 the temperature corresponding to the distribution obtained by the arrangement in Fig. 2 is shown as a function of ϕ .

Likewise, in Fig. 7, the temperature corresponding to the

distribution obtained by the arrangement shown in Fig. 3 is shown as a function of ϕ_2 (ϕ_1 being a constant = 170°).

It will be observed that very accurate representations of black-body distributions have been obtained by this method (Figs. 4 and 5). Curves drawn through each set of circles in Figs. 4 and 5 would be smooth curves very closely approximating the form of black-body curves, the only noticeable deviations occurring in the ends of the visible spectrum ($430m\mu > \lambda > 700m\mu$). Temperatures above 5000° K read as a function of ϕ_2 (Fig. 7) may be in error by about 100° ; but lower temperatures read from either Fig. 6 or Fig. 7 are apparently reliable to about 10° to 20° .

FIG. 7.

Temperature of Energy Distribution as a Function of ϕ_2 (for $\phi_1 = 170^\circ$) with the Arrangement shown in Fig. 3. (Plotted from inspection of Fig. 5.)

The Arons chromoscope⁸ or similar apparatus provides a convenient means for the experimental realization of the principles outlined above. By means of such apparatus the conclusions drawn above have been experimentally verified in several cases. A determination of the spectral distribution of "normal gray light" by means of this apparatus is in progress.⁹

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⁸ *Ann. der Phys.* (4) 33, p. 799, year 1910; and (4) 39, p. 545, year 1912.

⁹ See abstract, "The Spectral Distribution of Energy Required to Evoke the Gray Sensation," elsewhere in this number of this JOURNAL.