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DEPARTMENT OF COMMERCE AND LABOR

BUREAU OF STANDARDS

S. W. STRATTON, Director

RADIATION FROM AND MELTING POINTS OF PALLADIUM AND PLATINUM

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Bureau of Standards

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THE RADIATION FROM AND THE MELTING POINTS OF PALLADIUM AND PLATINUM.

By C. W. Waidner and G. K. Burgess.

CONTENTS.

I. INTRODUCTION.

The scale to which all measurements of temperature, from the lowest attainable to 1200° C, are now referred is that of the gas thermometer. A consideration of the best experimental data now available leads to the conclusion that the scale of the nitrogen gas thermometer, which is the standard above 200°, is probably in agreement with the absolute thermodynamic scale to within the limits of accuracy at present attainable in high temperature gas thermometry (above 500°). The present upper limit of the gas scale is about 1200°, i. e., where the limit of reasonably certain accuracy is 5°. With facilities that are now attainable this limit could perhaps be raised some 300° or 400°. For the range of temperatures above 1500° the scale must be based, for the present at least, on extrapolation by means of the radiation laws, which have some theoretical support, and can be tested within the range of the gas scale.

In the practical establishment and use of the scale it is convenient to have certain easily reproducible fixed points. Two standard temperatures of reference that have been made the basis of numerous investigations are the melting points of palladium and platinum. The best determinations of these melting points have differed by some 70° within the past two years, and the true values may still be regarded as uncertain by 40°.

In the present paper are described the results of experiments on the melting points of these metals, as determined by several different methods, and in particular the results obtained by the application of the Wein[1] equation giving the relation between the absolute temperature of a black-body and the intensity of any monochromatic radiation.

The first part of the paper is devoted to a description of the calibration of the optical pyrometer and accessories used in the investigation, and includes a discussion of the practical realization of blackness in certain furnaces used as light sources. It was also found necessary to study in detail the effect, on the temperature measurments, of the lack of monochromatism in the glasses used with the pyrometer. The observations on the monochromatic radiation from palladium and platinum strips, which is next undertaken, using red, green, and blue light, give results in very close agreement when applied to the determination of melting points. These optical determinations also agree with the more exact optical measurments made on the melting points of the metals placed within an irridium tube furnace which approximates a black-body. The values of the melting points as determined by the usual thermoelectric method are some 45° lower than those found by the two optical methods.

II. STANDARDIZATION OF OPTICAL PYROMETER.

The optical pyrometer used in the present investigation is of the Holborn-Kurlbaum type[2] in the form in which it was originally

[1] The Wien equation $J = c_1 \lambda^{-5} e^{-\frac{c_2}{\lambda T}}$ is a sufficiently close approximation to the more general equation of Planck $J = c_1 \lambda^{-5} \left(e^{+\frac{c_2}{\lambda T}} - 1 \right)^{-1}$ within the visible spectrum and for any attainable temperature.

[2] Holborn and Kurlbaum, Berichte Berlin Akad. d. Wiss., p. 712; 1901. Ann. d. Physik, 10, p. 225; 1903.

constructed by Siemens and Halske, embodying the disappearing filament principle.[3] The suitability of this instrument for temperature measurements, the order of accuracy attainable, and the constancy of the lamps have been discussed in a previous paper.[4]

Experimental Black-Body.—The only perfectly definite radiation independent of the physical properties of the radiator, and dependent only on the temperature, is the radiation of a Kirchhoff black-body. In the absence of definite knowledge concerning the law of radiation for each particular substance, it is not possible at present to measure the true temperature on the thermodynamic scale by the intensity of the radiation of any such substance. It is only feasible at present to express very high temperatures on the black-body scale,[5] and it is therefore necessary for the realization of this scale, to construct a black-body that can be used experimentally for the calibration of optical pyrometers.

The black-body used in this work is a modified form of the electrically heated black-body devised by Lummer and Kurlbaum.[6] The modification consists in the addition of supplementary heating coils, on independent electrical circuits, wound on a porcelain tube inclosing the black-body. These coils, which project 8 cms beyond each end, are wound so as to give a very uniform temperature distribution throughout the black-body, a condition which can be realized with a few trials. The winding of these secondary coils is very close about the ends of the black-body and very open about the center.

The accompanying Table I will serve as an illustration of the uniformity of temperature obtainable throughout the interior of this compensated black-body. Temperatures were measured by an exploring thermocouple. The distance from the central diaphragm used as a radiating source to the opening is 19 cms.

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[3] Morse, U. S. Letters Patent, 696878, 696916; 1902.

[4] Waidner and Burgess, Optical Pyrometry, this bulletin, **1**, p. 189; 1905.

[5] The *black-body temperature*, s°, is the temperature at which the ideal black-body radiator of Kirchhoff would emit radiation of the same intensity as a substance at a temperature t° for the particular wave length under consideration. Black-body temperatures might conveniently be indicated by $t^\circ K$ where $^\circ K$ means the Kirchhoff absolute scale. When it is necessary to specify the wave length, this could be done as follows ($t^\circ K_\lambda$): For example, the expression "1000° Abs. black-body temperature for wave length 0.650 μ," becomes 1000° $K_{0.650}$ or 727° $K_{0.650}$ *C.*

[6] Lummer and Kurlbaum, Verh. Deut. Phys. Ges., **17**, p. 106; 1898. Ann. d. Physik. **5**, p. 829; 1901.

TABLE I.

Temperature Distribution Within Black-Body.

Distance in cm from central diaphragms		0	2	4	8	12
Temperature	Series I......	621°	621°	620°	612	....
	Series II......	1041	1042	1042	1032	....
	Series III......	1308	1310	1311	1300	....
	Series IV......	1244.9	1244.9	1244.7	1244.7	1244.8

In order to determine the temperature of the radiating wall accurately, it is important that its front and back surfaces be at approximately the same temperature. Two thermocouples were therefore used with the junctions in contact with these surfaces.

The ordinary form of black-body uniformly wound with platinum ribbon does not realize with the highest attainable accuracy the two necessary conditions for ideal black-body radiation, namely, uniform temperature distribution throughout the radiating inclosure and a determinable temperature of the radiating wall. This is illustrated in Fig. 1, where A is such a black-body,[7] provided with diaphragms both in front and back of the radiating wall. The plot immediately below A gives the temperature distribution as measured by thermocouples in the manner indicated. It will be seen that the temperature distribution is not uniform, and that the back and front of the radiating wall differ considerably in temperature.

If the diaphragms back of the radiating wall are removed, as in B, the temperature distribution in front of the radiating wall may be improved, but the actual temperature of the radiating wall itself is impossible of exact determination. The temperature distribution in the ordinary black-body (A of Fig. 1) can be improved without the use of supplementary heating coils, by winding it with a platinum ribbon cut so that its width diminishes as the ends are approached.

After the calibration of the pyrometer lamps in terms of the radiation of the nearly ideal black-body described above, they were applied to an investigation of the degree of approximation to blackness of various forms of electrically heated furnaces. Measurements

[7] The black-body radiator alone is shown in the illustration. In use this was surrounded by concentric porcelain tubes.

up to 1300° made on ordinary Heraeus resistance furnaces, in which the porcelain heating tube (2 cm diam.; length of winding equals 25 diameters) is uniformly wound with platinum ribbon, gives an approximation to black-body radiation to within 5°, for a radiating surface at the center of the furnace. Experiments with the interior of the furnaces, both coated with black oxides and uncoated, gave no certain difference. When thermocouples are used in furnaces coated with metallic oxides, which conduct at lower temperatures than porcelain, care must be take to avoid leakage from the heating

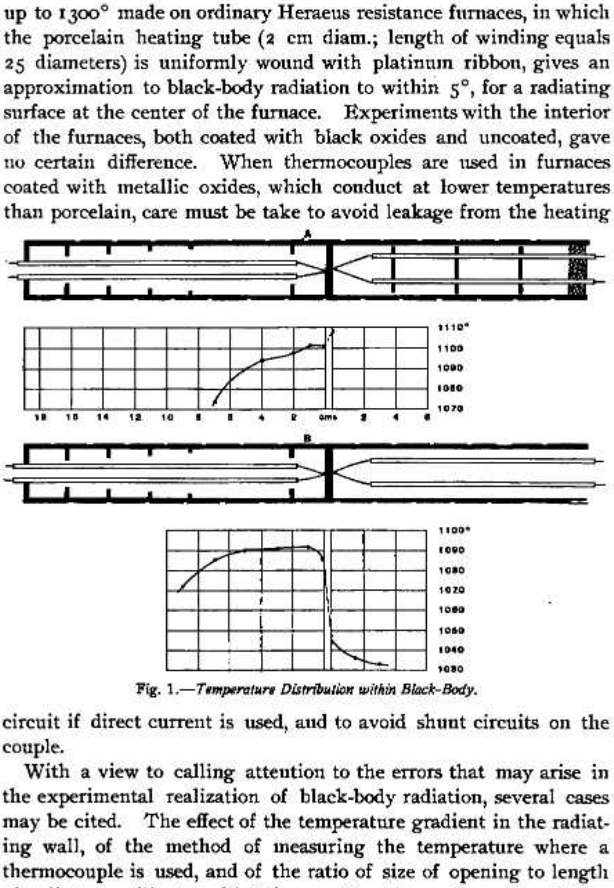

Fig. 1.—*Temperature Distribution within Black-Body.*

circuit if direct current is used, and to avoid shunt circuits on the couple.

With a view to calling attention to the errors that may arise in the experimental realization of black-body radiation, several cases may be cited. The effect of the temperature gradient in the radiating wall, of the method of measuring the temperature where a thermocouple is used, and of the ratio of size of opening to length of radiator are illustrated in Fig. 2. Here the numbers given below each illustration are the values of the temperature indicated by a thermocouple minus the temperature indicated by the optical pyrometer. The arrows indicate the direction in which the optical pyrometer was sighted.

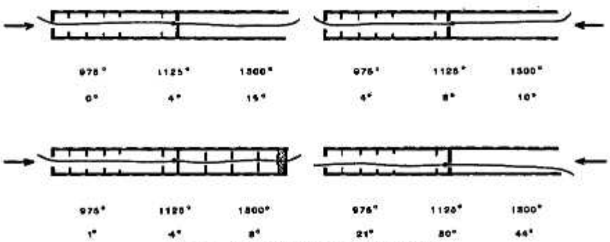

Fig. 2.—*Approximations to a Black-Body.*

Lamp Calibration.—The pyrometer lamps used in the Holborn-Kurlbaum pyrometer were four-volt carbon filament lamps, which were aged at a temperature of about 1800° for a period of twenty-five hours previous to their calibration. These lamps were calibrated by measuring the current when the filament had the same brightness (for red light) as the compensated black-body described above, whose temperature was measured by two thermocouples. The milliammeter with its shunt was calibrated frequently during the progress of the work, and its temperature coefficient determined. The calibration of lamp No. 140 is cited as an illustration (Table II).

TABLE II.

Calibration of Lamp 140.

Temperature (Observed)	Current (Observed)	Temperature (Computed)	$\text{Temp.}_{obs}-\text{Tem.}_{calc}$
920°	0.4486	921°	−1°
1087.5	.5305	1087.5	0
650	.3357	649	+1
1221	.6023	1221	0
692	.3525	692.5	−0.5
1285	.6393	1285	0
1089	.5309	1088.5	+0.5