

SOME EFFECTS OF DIFFRACTION ON BRIGHTNESS
MEASUREMENTS MADE WITH THE HOLBORN-
KURLBAUM OPTICAL PYROMETER.

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INTRODUCTION.

THE study of the properties of many substances at high temperatures is often conveniently carried out with the substance mounted as a filament in a lamp bulb. Ordinarily such filaments will be small. In such cases particularly, in the opinion of the writers, the only method of optical pyrometry both convenient and theoretically safe which may be employed as an aid, is that one on which the Holborn-Kurlbaum pyrometer is based. Its underlying principles as described by the originators¹ are simple. Essentially as is indicated in Fig. 1, an image of a background *A* is formed by the lens *B* in the plane of a filament *D* which may be heated to incandescence. This filament will be referred to as the pyrometer filament. An eyepiece *F* backed with an approximately monochromatic glass filter *G* is used to view the pyrometer filament thus seen projected against the background. By varying the current through the pyrometer filament, it may under suitable conditions be made to match the background image in brightness, that is to disappear against the background. Evidently various backgrounds may be compared.

In attempting to determine the temperature of a certain tungsten lamp filament, first using an ordinary commercial Holborn-Kurlbaum pyrometer and then a modified one such as will be described in this paper both of which had been calibrated against the same black body, a difference of about 40° in temperature was obtained with the filament at about 2,300° Kelvin. This difference was too much to be ascribed to errors in measurement. An investigation of the causes has led to interesting results.

ARRANGEMENT OF APPARATUS.

The apparatus as arranged is indicated in Fig. 1. Large filament tungsten and carbon lamps served at various times for the background *A*. *B*, the objective lens, was a Zeiss-Tessar lens with a 28 mm. aperture and

¹ E. Holborn and F. Kurlbaum, *Ann. d. Phys.*, Vol. 10, p. 22, 1903; *Ber. d. K. Akad. d. Wiss.*, Vol. 30, p. 712, 1901.

a 21 cm. focal length. The entrance cone aperture in the diaphragm *C* was variable in size and circular in shape. Its actual location was between the component parts of the lens *B*. As pyrometer filaments at *D* various carbon, tungsten, and platinum filaments of different sizes were used. An ordinary piece of sheet metal with a circular aperture served as the diaphragm *E*. Various telescopes were used for the eyepiece *F*. As monochromatic glass filters, pieces of ruby and of blue uviol glass having maximums of transmissions respectively at about $\lambda = 0.66\mu$

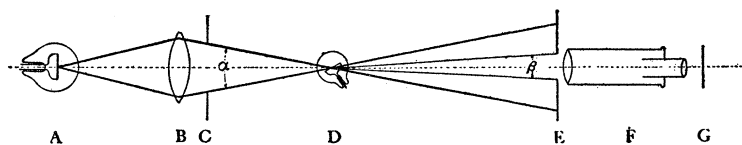


Fig. 1.

Diagram showing arrangement of apparatus. *A*, background; *B*, objective lens; *C*, entrance cone diaphragm; *D*, pyrometer filament; *E*, eyepiece diaphragm; *F*, eyepiece; *G*, monochromatic filter.

and at $\lambda = 0.46\mu$, were used. The various parts of the apparatus were independently adjustable and during the course of the work many shifts were made. Throughout great care was taken to see that the radiation from the background entirely filled the aperture at *E*, in other words to see that the angle α always exceeded the angle β , and to see that the apparatus was aligned axially.

EXPERIMENTAL RESULTS.

A large part of the work consisted in determining the apparent variations in the ratio of the brightness of the pyrometer filament to the brightness of the background image formed in its plane as functions of α . In this connection there were determined the various currents through the pyrometer filament at apparent brightness matches, corresponding to the various values of α . By means of similar measurements made with various sectorized discs between *C* and *D* and with the aperture at *C* constant, it was possible to calibrate the brightness of the pyrometer filament in terms of the current passing through it, and thus to reduce the previously determined filament currents to filament brightnesses.

The results thus obtained for a particular arrangement of apparatus ($AB = 25$ cms.; $BD = 128$ cms.; $DE = 185$ cms.; diameter of aperture at *E* = 9 mm.) for a succession of values of α , when various pyrometer filaments were successively substituted at *D*, are presented in Fig. 2. The method of obtaining the actual value of the ratio platted as ordinates

will be discussed later. It is sufficient to consider at present the relative variations occurring in the curves for each individual pyrometer filament. In each instance decreasing the entrance cone angle α apparently de-

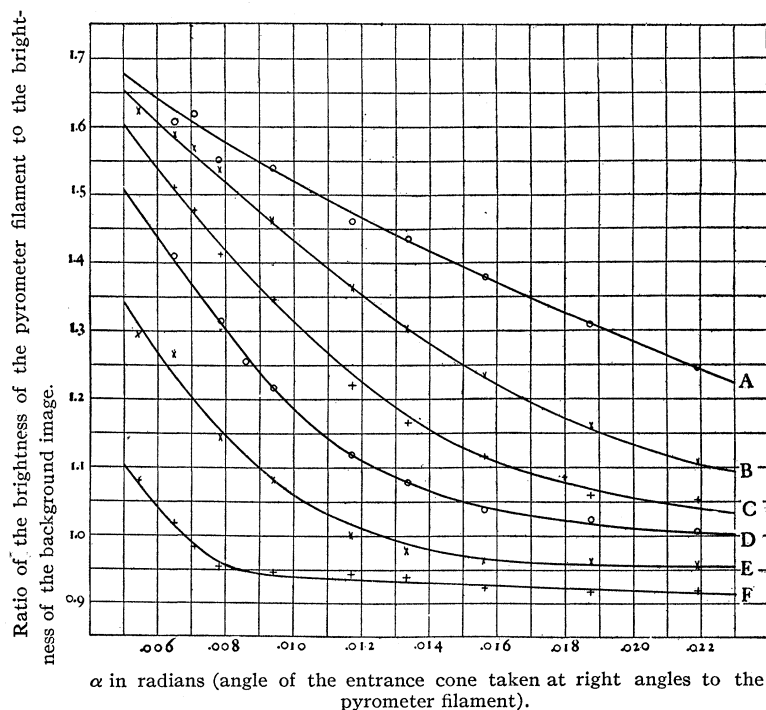


Fig. 2.

Variations in the apparent brightness of the background image with α for various sized pyrometer filaments.

| Curve. | Diameter of Pyrometer Filament. | Material of Pyrometer Filament. | Average Wave-length of Light Used. |
|--------|---------------------------------|---------------------------------|------------------------------------|
| A | 0.016 mm. | tungsten | 0.66 |
| B | 0.025 mm. | " | 0.66 |
| C | 0.025 mm. | " | 0.46 |
| D | 0.045 mm. | carbon | 0.66 |
| E | 0.050 mm. | tungsten | 0.66 |
| F | 0.100 mm. | " | 0.66 |

creased the brightness of the pyrometer filament or increased the brightness of the background. Evidently no actual changes in the brightness of the pyrometer filament or of the background could be thus produced. There is also a change in this variation depending upon the size of the pyrometer filament but no change to any appreciable extent depending upon the material of the filament. Further, curves B and C indicate

that the variations are different for the same pyrometer filament when different colored lights are used.

SUGGESTED EXPLANATIONS.

Possible explanations which have occurred to the writers which might wholly or in part explain the general phenomena are:

- 1st. The lens and mirror actions of the pyrometer lamp bulb.
- 2d. The heating of the pyrometer filament by radiation from the background.
- 3d. The reflection into the eyepiece of light from the background at the edges of the pyrometer filament.
- 4th. A possible transmission by the pyrometer filament of light from the background incident on it.
- 5th. A possible change in the emissive properties of the pyrometer filament due to incident radiation from the background.
- 6th. The diffraction of light from the background at the edges of the pyrometer filament.

The using of a platinum wire in air free from an enclosing glass bulb as a pyrometer filament, the interposing of a water cell between *A* and *D*, the geometrical consideration of the areas of the pyrometer filament which could serve as surfaces reflecting incident radiation into the eyepiece, the fact that the effect noted was found to be independent of the material and the temperature of the pyrometer filament, and the fact that the effect noted was found with the aid of variable rectangular apertures at *C* to depend upon the angle of the entrance cone of radiation taken in a plane normal to the pyrometer filament and not at all upon the angle taken in a plane parallel to it, respectively showed that the first five suggested explanations could not account for the variation noted. None of these modifications have yielded results inconsistent with diffraction as an explanation, in fact the results obtained with the rectangular apertures at *C* form positive evidence in its favor.

Experiments by Gouy¹ on the diffraction of unpolarized light by a sharp edge, indicated that the light which was bent by diffraction into the geometrical shadow, was partially polarized in the plane parallel to the edge. With this in mind there were made some tests exactly similar to those already described in which polarized light was used. A nicol introduced just in front of the apertures at *E* was first set so that the plane of polarization was parallel to the pyrometer filament and then later at right-angles to it. A large carbon filament whose position was so oriented that the pyrometer filament was always seen projected along

¹ C. R., Vol. 98, p. 1573, 1884.

the center of and parallel to its image, was used as the background. This insured that the brightness of the background would be the same in the two cases. For a given relatively large aperture at *C*, the larger current was required through the pyrometer filament for an apparent brightness match in the case where the plane of polarization was perpendicular to the pyrometer filament. In this same case when the aperture at *C* was decreased to some relatively small value, the apparent relative change in brightness was less than with light polarized parallel to the filament. This is consistent with the results of Gouy noted above, on the assumption that the diffracted light to which the apparent changes in brightness are ascribed, was for the most part made up of light which had been bent by diffraction into the geometrical shadow. This assumption as will be noted later, was experimentally verified. The differences found in the apparent relative brightnesses of the pyrometer filament of tungsten for the two conditions of polarization noted, indicated an apparent polarization of 20 per cent. in the light from it. Taking into consideration the polarization of the light from the background which is diffracted, this is consistent with the value of 12 per cent. which may be obtained from data which have already been published by one of the writers.¹

If from the central part of the aperture at *C*, one blocks out a region such that from a consideration of geometrical optics only, none of the light coming from the background in the immediate neighborhood of the place where the pyrometer filament is seen projected can enter the aperture at *E*, and if no current is passed through the pyrometer filament, one can still see the filament apparently glowing where it crosses the background image when looking at it through the eyepiece. In case the resolving power of the eyepiece is sufficiently great, this apparent brightness of the pyrometer filament is seen to consist of two bright streaks along the edges. Whether or not the axes of these bright streaks actually lie within or without the boundaries of the pyrometer filament is very difficult of determination. The fact that with eyepieces of small resolving power they seem to cover the entire filament and more is due largely to irradiation. A photograph of such a case is shown in Fig. 3, *a*. Fig. 3, *b* indicates a similar condition in which case, however, the pyrometer filament was rendered visible by means of a small current. By blocking out first the upper and then the lower portions of the remaining part of the aperture at *C*, it was easily demonstrable that this light consisted largely of light which was bent by diffraction into the geometrical shadow, and but to a comparatively small extent to light which was diffracted in the other direction.

¹ A. G. Worthing, *Astrophys. Jour.*, Vol. 34, p. 345, 1912.

The apparent brightness which these lines of diffracted light gave to the pyrometer filament were found to account in magnitude for the variations noted. By means of an extra lens and an extra pyrometer filament located between *D* and *E* (Fig. 1), there were measured first the apparent brightness of the unheated pyrometer filament at *D* due to



Fig. 3.

Photographs showing apparent brightness of pyrometer filament due to light from the background diffracted by it. *a*, pyrometer filament cold; *b*, pyrometer filament made luminous by a small current.

this diffracted light when the central part of the aperture at *C* was blocked out as just noted, and then the apparent brightness of the heated pyrometer filament when the aperture at *C* was equal to that portion which previously had been blocked out. The results for three such cases are given in Table I. The agreement in the brightness sums was better than one could reasonably expect.

TABLE I.

Effects of the Different Elements of the Entrance Cone of Radiation on the Apparent Brightness of a 0.050 mm. Tungsten Pyrometer Filament.

| Outer Edge of Lens Screened Off. | | Central Part of Lens Screened Off. | | Brightness Sums. |
|--------------------------------------|--|------------------------------------|--|------------------|
| Angles Subtended by Central Opening. | Relative Brightness of Pyrometer Filament. | Angle Subtended by Central Screen. | Relative Brightness of Pyrometer Filament. | |
| 0.012 radians | 0.755 | 0.012 radians | 0.240 | 0.995 |
| 0.028 | 0.888 | 0.028 | 0.117 | 1.005 |
| 0.038 | 0.936 | 0.038 | 0.064 | 1.000 |

The results with rectangular apertures at *C* led to the trying of similar apertures at *E*. In this case with the aperture at *C* circular, some small variations were found only when the aperture was varied in a direction parallel to the pyrometer filament. These were accounted for in magnitude and direction by computations based on the fact that as the aper-

ture at E was thus enlarged the average value of the entrance cone angle α was diminished.

The results obtained with the rectangular apertures at C , the obtaining of results with the aid of polarized light which are consistent with previously obtained results, the resolution of the apparent added brightness of the pyrometer filament in certain cases into two narrow lines of light along its edge, and the accounting in magnitude for the variations in brightness of the pyrometer filament by means of the apparent added brightness due to these narrow lines of light seem to indicate conclusively that the phenomena are wholly due to diffraction.

RELATION BETWEEN THE BRIGHTNESS OF THE PYROMETER FILAMENT AND THAT OF THE BACKGROUND IMAGE.

The condition usually assumed as holding in optical pyrometry is that the ratio of the brightness of the pyrometer filament to that of the background image formed in its plane is unity when there is an apparent brightness match. The present work shows this in general to be untrue. Actual determinations of this ratio which for brevity's sake we shall denote by k have been made. The method of doing this is theoretically simple. Three lamps whose filaments are represented here by 1, 2 and 3 were used, filament 1 being the pyrometer filament for which for a given entrance cone angle α , it was desirable to find k . With filaments 1 and 2 as pyrometer filament and background respectively, an apparent brightness match was obtained and their currents measured. Then, using these filaments successively as backgrounds, carrying the currents just determined, their brightnesses were compared with the aid of a pyrometer filament (filament 3) whose brightness-current relation had previously been determined as described above. Due consideration was of course necessarily given to the transmissions of the lens and of the individual lamp bulbs. Considerable difficulty is experienced experimentally in case filament l is small. This is due to the fact that it is very difficult to make pyrometer settings when the image of the background is small, as was the case with lamp l in most of our attempts to determine this ratio k . For the lamps used in obtaining the data presented in Fig. 2, we have determined with considerable care the corresponding values of k for an angle α equal to 0.0182 radians. These values of k have been used in locating the curves definitely in Fig. 2. Attention is once more called to the fact that the curves as platted actually represent the ratio of the brightness of the pyrometer filament to the brightness of the background image formed in its plane. In some instances as indicated the pyrometer filament is not as bright as the background image but in

general the pyrometer filament is seen to be considerably brighter. For the lamps *A* and *B* that were used the transmission of single thicknesses of the lamp bulbs was approximately 91 per cent. The transmission of the lens used was 77 per cent. It is readily seen that when the lamps *A* and *B* were used as pyrometer filaments for small values of the entrance cone angle α , in the neighborhood of 0.006 radians, the pyrometer filament was brighter than the filament used in the background itself, although the background was viewed through several more thicknesses of glass than was the pyrometer filament.

Some determinations of k made under conditions when angle α was of the order of 0.1 of a radian, indicated that, if the curves in Fig. 2 could be prolonged, they would finally become asymptotic to a value for the relative brightness in the neighborhood of 91 per cent. or 92 per cent. These measurements were attended with considerable difficulty, however, and should not be relied upon too fully. This k which represents the ratio of the brightness of the pyrometer filament to the brightness of the background image when they appear of equal brightness, as may be seen from the curves of Fig. 2, is dependent on the angle α , the diameter of the pyrometer filament and the character of the light used but apparently not to any appreciable extent upon the character of the material of the pyrometer filament.

It was of interest to find out in this connection whether the size of the background had an effect or not. It was thought sufficient to equate by the color match method as described by Hyde¹ the brightnesses of two very different-sized filaments of the same material which were to be used as backgrounds and then to compare their brightnesses with a given pyrometer filament. As two such backgrounds a 0.25 mm. and a 0.016 mm. tungsten filament were used. The two methods gave identical results. A trial with two other filaments not differing as widely in diameter gave like results. From this it may be concluded that k is independent of the size of the background, as one might naturally expect.

APPEARANCE OF A PYROMETER FILAMENT AS SEEN PROJECTED AGAINST THE BACKGROUND.

There are to be distinguished here three cases; 1st. When the entrance cone angle α is relatively large. 2d. When it is relatively small. 3d. When it is very small. In Fig. 4 we have given for such cases schematic diagrams illustrating certain apparent brightness variations in the neighborhood of the intersection of a 0.025 mm. tungsten pyrometer

¹ *Astrophys. Jour.*, 36, p. 89, 1912.

filament with the background image when the condition is fulfilled that the pyrometer filament shall disappear against the background image, in case the resolving power of the eyepiece is sufficiently small to permit of it. For simplicity the variation from Lambert's cosine law of the radiation from the pyrometer filament is here disregarded. The diagrams themselves, however, indicate what may be seen when, with the pyrometer lamp adjusted for such disappearance, we use an eyepiece arrangement with a considerably higher resolving power so that greater

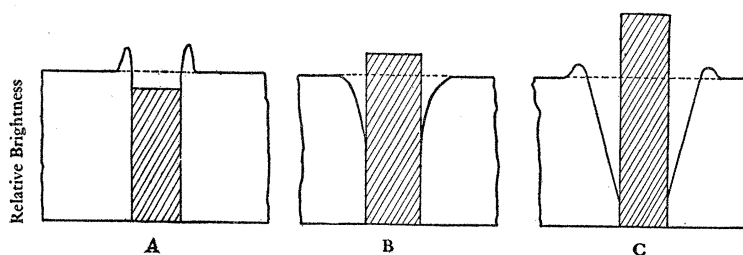


Fig. 4.

Distances along the background image. Schematic diagrams for illustrating certain apparent brightness variations in the neighborhood of the intersection of a 0.025 mm. tungsten pyrometer filament with the background image. Shaded portions represent the pyrometer filament; unshaded portions represent the image of the background. Case A, the entrance cone (angle α) relatively large—pyrometer filament less bright than background image; Case B, the entrance cone (angle α) relatively small—pyrometer filament brighter than background image; Case C, the entrance cone (angle α) relatively very small—pyrometer filament much brighter than background image.

detail may be seen. While the diagrams indicate the bright and dark bands which may be noticed as located just outside the confines of the pyrometer filament, the exactness of this method of representation should not be too strongly insisted upon. When the entrance cone is relatively large (case A) the pyrometer filament is less bright than the background image and, in case the resolving power of the eyepiece is sufficient, bright lines may be seen along the edges of the pyrometer filament. Of course these bright lines are quite disconcerting when one is attempting to make pyrometer settings.

In case a somewhat smaller cone angle α is used, these bright lines disappear so that even with an eyepiece of fairly high resolving power one does not have any trouble in obtaining a perfect disappearance of the pyrometer filament against the background image. The exact explanation of the dark bands noted in cases B and C and of the extra bright bands in case C are not at once apparent though we think they should also be ascribed to diffraction at the pyrometer filament. What has been said thus far as to the appearance of the pyrometer filament, refers strictly to a

tungsten pyrometer filament about 0.025 mm. in diameter. The general appearance when using larger pyrometer filaments are exactly similar so far as the eye can discern. However, in view of the results obtained on the ratio of the brightness of the pyrometer filament to the brightness of the background image (Fig. 2), the general description as to relative brightnesses for the three cases must here be modified, for the dark bands along the edges may be seen when the pyrometer filament is not as bright as the background image. The explanation which occurs to the writers is that the condition in such a case is somewhat similar to what has been represented above for case *C*, though the two outer bright bands are not observable. Such a condition may readily be correlated with the relative brightnesses observed. Of course, it is probable that with the 0.025 mm. pyrometer filament in case *B*, the extra bright bands of case *C* are also present though not observable.

This type of diffraction, in which the diffraction fringes are located in the plane of the diffracting edge, so far as the writers know has not been studied heretofore, seems to be an important type and to be well worth further study.

The fact that disappearance can be obtained under such conditions as have been described when an eyepiece with low resolving power is used, is due to the fact that the eye averages the brightness variations over a considerable angular range. Many times in our work we have been able to go from impossible working conditions to fairly satisfactory conditions by substituting for the eyepiece in use, one of lower resolving power.

SOME NECESSARY WORKING PRECAUTIONS.

In view of the results which have been obtained and the difficulties which have been experienced, certain conclusions are definitely reached regarding necessary working precautions. In case one wishes to compare various light sources, excepting possibly where the entrance cone angle α is comparatively large, that is of the order at least of 0.1 of a radian:

1. The sources to be studied should be used as backgrounds and not as pyrometer filaments.
2. A single pyrometer filament should be used throughout the inter-comparison.
3. The angles α and β should be definitely fixed. This can be best done by having limiting diaphragms at *C* and *E* which are at fixed distances from the pyrometer filament preferably as far away as possible. A commercial pyrometer of the Holborn-Kurlbaum type which we have in our laboratory possesses fixed diaphragms but they are in no sense limiting diaphragms.

4. The apparatus should be so adjusted that there is approximately axial symmetry.
5. The resolving power of the eyepiece should not be so great as to prevent the practical disappearance of the pyrometer filament against the background image.
6. The image of the background should be large in comparison with the pyrometer filament.
7. The magnifying power of the eyepiece should be sufficiently large so that no difficulty is experienced by the observer in fixing on the intersection and so that effects due to the eye's imperfections are largely eliminated.

It is interesting to note in this connection that the 40° difference in temperature, which as has been noted in the introduction was the starting point of the present paper, was apparently largely due to a failure to appreciate the importance of working precautions Nos. (6) and (7).

SOME DESIRABLE WORKING CONDITIONS.

1. It is obvious that the eyepiece should have as high a resolving power as possible but still with the condition that when the pyrometer lamp is balanced against the background there shall be disappearance. The ideal case is obtained when no matter how great the resolving power of the eyepiece neither bright nor dark bands may be seen at the edge of the pyrometer filament. This condition of disappearance depends upon the size of the pyrometer filament, upon the value of the angle α , and in case the deviations from Lambert's cosine law are not neglected upon the material of the pyrometer filament. Using pyrometer filaments of tungsten, the writers have roughly attempted to find these conditions. For a 0.050 mm. tungsten pyrometer filament using red light, a very satisfactory value for the entrance cone angle α was found to be 0.05 radian. Smaller pyrometer filaments require somewhat larger entrance cone angles, while larger pyrometer filaments require smaller entrance cone angles. This is not entirely in conformity with what would be deduced from Fig. 2, assuming that the most satisfactory value for α is that which corresponds to the condition that the pyrometer filament is very nearly of the same brightness as the background image when there is an apparent brightness match. This has been discussed above under the heading relating to the appearance of the pyrometer filament. It should not be forgotten, however, that for a considerable range on either side of such values, the disappearances will be very satisfactory, and that even when the disappearances are not satisfactory with a certain eyepiece very satisfactory disappearances may be obtained with eyepieces

of smaller resolving power. Sometimes, particularly when it is necessary to use a highly magnified background image, a small pyrometer filament is better than a large one, because for a given large magnification due to the eyepiece the bright or the dark bands will be less apparent for the smaller filament. This is due to the fact that for a given eyepiece resolving power the range of good disappearances for the smaller filament considerably overlaps that of the larger.

2. An eyepiece and eyepiece diaphragm combination which gives comparatively large clear images is of course desirable. A short focus objective lens for the eyepiece and as large an aperture as possible in the diaphragm are necessary to reduce to a minimum the diffraction of the light which occurs at the eyepiece diaphragm. Using light of short wave-length is advantageous here.

3. The pyrometer lamp is important. In general the writers have found filaments in either hairpin loops or single straight filaments mounted in spherical bulbs to be most satisfactory. In general in any particular problem the pyrometer filament should be considerably smaller than the filament of the background. In some cases carbon may be preferable to tungsten for pyrometer filaments. In other cases the reverse is true. Due to the deviations of the emissions from Lambert's cosine law as described by one of the writers¹ one might expect in general to be able to use carbon filaments advantageously when the entrance cone angle α is large and tungsten filaments when this angle is small. So far as the writers can see there is but little advantage of the one over the other based on the supposition that the relative change in brightness for a given relative change in current is greater for one type of filament than for the other. Whatever advantage there may be of this nature is apparently in favor of the untreated carbon filament and is of the order of 5 per cent. In case small angles of α are necessitated, there is no question but that it is much more desirable to have pyrometer filaments of tungsten than of carbon.

4. For the sake of ease of adjustment particularly in obtaining axial symmetry, it is very desirable to have the diaphragm *C* one with a variable aperture.

5. In cases where high accuracy is demanded, a gain may be made in case the brightnesses permit, by using light of the shorter wave-lengths. Not only are some diffraction effects eliminated but also an actual gain is experienced due to the fact that, while for both red and blue light the least relative change in brightness which is just detectable is about the same, the relative change in brightness for a given small change in temperature is the greater for the shorter wave-length light.

¹ A. G. Worthing, *Astrophys. Jour.*, 36, 345, 1912.

EFFECTS OF PRESENT RESULTS ON PREVIOUS WORK.

It seems natural in this connection to consider what effect the present work may have on the results of other investigations where the Holborn-Kurlbaum optical pyrometer principle has been used. An inspection of the literature shows that writers in general have not specified carefully the conditions under which their pyrometers have been used. Because of this we restrict our comments to papers with which we have been personally connected and to papers which have been issued from this laboratory.

1st. In a paper on "A Study of the Energy Losses in Electric Incandescent Lamps" by Hyde, Cady and Worthing,¹ the lamps studied were used as pyrometer lamps. Since the results on a single lamp used as a pyrometer lamp were complete in themselves, the method was free from error, and the results are undoubtedly of the right magnitude.

2d. In a paper entitled "Measurements of Intrinsic Brightness by a New Method," by Ives and Luckiesh,² the various sources were used as pyrometer filaments. The arrangement of the apparatus and the method employed in obtaining the brightness in which the pyrometer filament and the image of the background were assumed to be the same at a brightness match, were such that certain corrections to their results are necessary. The values obtained in most instances should be reduced by about 7 or 8 per cent. Most of them are probably relatively correct.

3d. A paper on the "Radiant Efficiency of Incandescent Filaments," by W. E. Forsythe,³ is open to the same objection. The temperatures which were obtained were probably too high by about 1 per cent. A redetermination of these temperatures is to be undertaken in the near future in this laboratory.

4th. In a paper on "On the Deviation from Lambert's Cosine Law of the Emission from Tungsten and Carbon at Glowing Temperatures," by A. G. Worthing,⁴ the method used was correct in principle.

5th. A paper "The Relation Between Black Body and True Temperatures for Tungsten, Tantalum, Molybdenum, and Carbon, and the Temperature Variation of their Reflecting Power," by C. E. Mendenhall and W. E. Forsythe,⁵ the results are free from serious error due to diffraction.

SUMMARY.

1. Errors due to diffraction at the filament of the pyrometer lamp of the light from the background have been discovered in connection with

¹ Trans. of Illum. Eng. Soc. (U. S.), 6, p. 238, 1911; Illum. Eng. (London), 4, p. 389, 1911.

² Elec. World, 57, p. 438, 1911.

³ PHYS. REV., 34, p. 333, 1912.

⁴ Astro. Jour., 36, p. 345, 1912.

⁵ Astro. Jour., 37, p. 380, 1913.

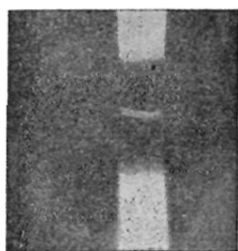
the Holborn-Kurlbaum optical pyrometer. In some cases in measuring brightnesses errors as great as 60 per cent. may occur, though in temperature measurements the corresponding errors would be much less.

2. Determinations have been made of the ratio of the brightness of the pyrometer filament to the brightness of the image of the background formed in the same plane. The use of large filaments as pyrometer filaments and large angles for the entrance cone angle α tend toward making the pyrometer filament less bright than the background image when an apparent match is obtained, conversely small filaments and small angles for the entrance cone angle α tend toward making the pyrometer filament brighter than the background image for an apparent brightness match.

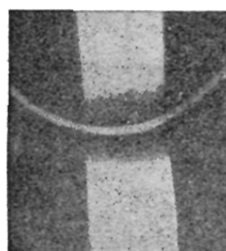
3. Some necessary working precautions and some desirable working conditions for high accuracy have been considered, and may be found incorporated under appropriate subheadings of this paper.

4. The effects of the present results on certain published works have been considered.

NELA RESEARCH LABORATORY,
NATIONAL LAMP WORKS OF GENERAL ELECTRIC CO.,
NELA PARK, CLEVELAND, OHIO,
March, 1914.



a



b

Fig. 3.

Photographs showing apparent brightness of pyromètre filament due to light from the background diffracted by it. *a*, pyrometer filament cold; *b*, pyrometer filament made luminous by a small current.