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SPECIFICATION OF THE TRANSPARENCY OF PAPER AND TRACING CLOTH

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INTRODUCTION

In response to the demands of several Government departments and of dealers in tracing cloth, the Bureau has developed and adopted a standard method for specifying the transparency of paper and tracing cloth.

The purposes of the present circular are to (1) state definitely the form of the specification, (2) explain its significance, (3) describe the apparatus and method of test, and (4) give general information and instructions to applicants for tests in terms of this specification.

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ESSENTIAL PRINCIPLE OF THE CONTRAST METHOD[1]

The essential principle of the contrast method of specifying transparency may be illustrated as follows:

If, in a diffusely lighted space, a black and white figure, such as Fig. 1, be covered with a sheet of translucent material, such as tracing cloth, in contact with the figure, the important optical result is a reduction of contrast. The black becomes gray and the white becomes less bright. This net result is the joint effect of two actions of the translucent material, viz, its reflection of light and its absorption. It seems obvious, however, that this net result is the thing of prime interest to the draftsman. It therefore appears reasonable to grade the transparency of tracing cloth by a measurement of this reduction of contrast. Having covered Fig. 1 with a piece of tracing cloth, we might, with a suitable

FIG. 1

photometer, measure the ratio of the brightness of the spot *B* to the brightness of the spot *W*. The value of this ratio will vary between zero and unity, being low for very transparent cloths and higher for less transparent ones. Anyone wishing to specify quantitatively the "transparency" of tracing cloth might accomplish his purpose by specifying a value of this ratio.[2]

CHOICE OF DEFINITE AND REPRODUCIBLE CONDITIONS

The crude specification above would, however, be of little value, because the conditions of measurement would not be readily and certainly reproducible. Another piece of white paper might not be so white; another ink spot might not be so black. It is necessary, then, to choose and define a reproducible black and white. It is also desirable to specify the conditions of illumination.

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[1] This principle has been employed by Sammet, of the Bureau of Chemistry, and by Nutting, of the Eastman Kodak Co., as well as by the Bureau of Standards. It is thought that the precise method described in this circular is more definite and reliable than the early methods used elsewhere. For a statement of the development of the method, see footnote 1 of a paper by Priest, Trans. Am. Cer. Soc., **17**; 1915.

[2] It should be noted, however, that this specification may not be entirely adequate, in that it does not take into account the impairment of visibility of fine lines due to the texture of the cloth. It may be necessary to deal with this aspect of the subject separately at a later time.

As standard white, a surface of magnesium oxide[3] is chosen; and as standard black, a black acetylene smoked surface in the bottom of a black-lined box.

The observed surface of the sample to be tested is illuminated by diffused light from all directions above, care being taken to have the illumination over the black equal to that over the white.

DESCRIPTION OF APPARATUS

The Photometer.—The ratio of brightness is measured by means of the Martens photometer. A section of this instrument in the line of sight is shown in Fig. 2. *O* is a lens; *W* is a Wollaston prism; *Z* is a biprism; *N* is a nicol prism capable of rotation about its long axis; *J* is an index attached to *N;* *K* is a circle divided in degrees (on it, angles of rotation of *N* may be read); *L* is a lens; *H* is the ocular for focusing on the edge of *Z*. For the complete theory of the instrument, the original paper by Martens must be consulted.[4] Suffice it here to say:

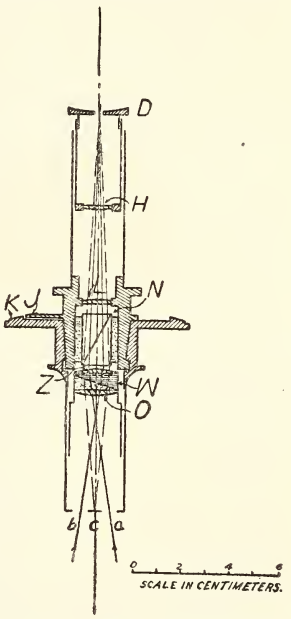

FIG. 2.—*Martens photometer.*

(*a*) One sees on looking into the photometer a divided photometric field, one half of which is illuminated by light coming from *a*, while the other half is illuminated by light coming from *b*.

(*b*) The field can be "matched;" that is, the two halves brought to equality of brightness by turning the nicol prism.

(*c*) The ratio of the brightness of a surface sending light into the photometer along *a* to the brightness of a surface sending light in along *b* can be computed as a function of the angles read on *K* when the two halves of the photometric field are matched.

The Complete Apparatus.—The complete apparatus is shown in section in Fig. 3 and in perspective in Fig. 4. In Fig. 3 it is

[3] Prepared by deposit of the "smoke" from burning magnesium ribbon. In this way a beautiful, clean, smooth, reproducible mat white surface is easily obtained. The white smoke is readily deposited on a fine ground surface held a few inches above the burning ribbon. Repeated trials should give identical surfaces. Holding the glass too near the flame will not give good surfaces. The deposit should be made so thick that an increase in thickness does not increase its reflecting power. In order to avoid the necessity of very thick deposits, the plate on which the deposit is made should be white and of high reflecting power (chalk, magnesium carbonate, milk glass). The operator should protect his eyes by dark yellow glasses, as the magnesium flame is injurious.

[4] Phys. Z's., **1**, p. 299; 1900.

shown with the line of sight, *AB*, horizontal. However, the apparatus may be turned about the axis, *CD*, to bring the line of sight to any desired angle. *EFGH* is a white-lined box; *KL* is the standard white surface; *MN* is the black cavity; 1, 2, 3, 4, 5, and 6 are lamps; *OQ*, *RS* are diffusion screens. If paper or cloth is being examined, the sample is placed in the clip *TU*. If a plate of glass is being examined, the sample *XY* is placed in the slide *HZ*. The slide, as well as the clip, may be slid in and out from the top of the box. *VW* is the photometer; *I* and *J* are black spots to prevent direct reflection of light from the sample into the photometer; *C* and *D* are supports.

Ventilation of the lamp boxes is provided by holes in the top and bottom, screened so as not to let light through. The photometer may be rotated about the axis, *AB*, so as to reverse the field, and stops are provided 180° apart.

Precautions in Designing Apparatus.—Those intending to construct apparatus similar to that described in this circular are cautioned to test by actual practice the correctness of the position and of the size of the black hole *XN* and of the magnesia surface *KL* (Fig. 3), with reference to the photometer to be used. Both halves of the photometric field should be perfectly uniform in brightness over their entire surfaces, and, when matched, the dividing line should disappear along its entire length simultaneously.

The number of 25-watt tungsten lamps shown in Fig. 3 gives more intensity than is usually needed.

The clip *TU* should be constructed in such a way that the sample is held perfectly flat; otherwise the photometric field will not be uniform and the precision of setting will be poor.

METHOD OF MEASUREMENT

The illumination of the surface covering the black hole must equal that of the surface covering the standard white. This is tested as follows:

(*a*) Both the hole and the white surface are covered by a uniform opaque mat white plate.

(*b*) The photometer is turned so that one-half the field is illuminated by light from the part of the white plate over the hole, while the other half is illuminated by the part over the standard white.

(*c*) The two halves of the photometric field are matched.

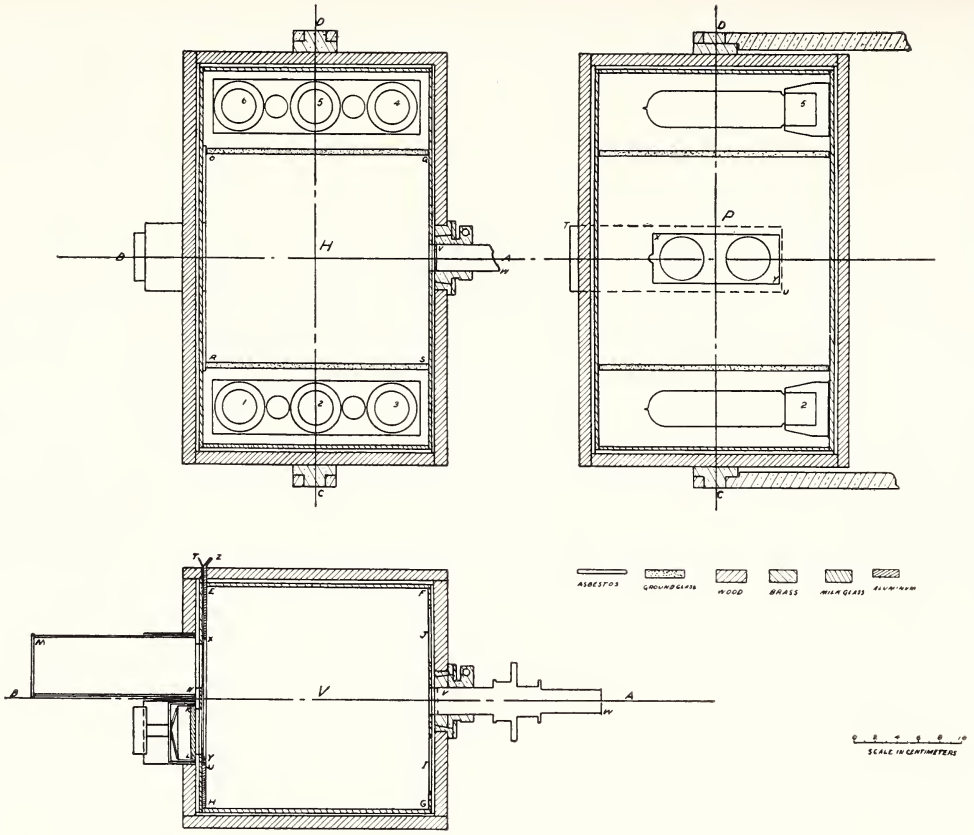

FIG. 3.—*Bureau of Standards apparatus for testing transparency of paper or tracing cloth*

(Large scale blue print can be furnished on application)

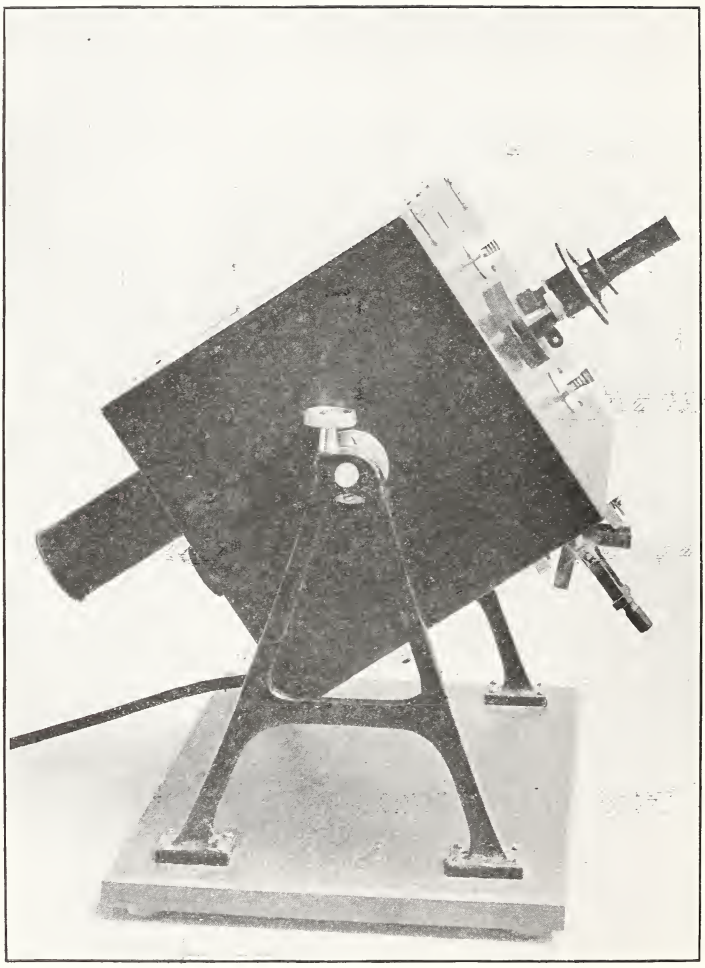

FIG. 4.—*Bureau of Standards apparatus for testing transparency of paper or tracing cloth*

(*d*) The whole photometer is turned about AB through 180°. If the condition of equal illumination is satisfied, the two halves of the field will still be matched.

The sample is placed in the clip TU so that part of it covers the black hole and part of it the white surface.[5]

The photometer is set so that the light from the part over the black hole illuminates the half of the photometric field which is extinguished for the position of the nicol which reads zero on the circle K. The two halves of the photometric field are matched by turning the nicol N. The angle θ_1 is read (index J on circle K). The photometer is rotated through 180° about axis AB. The two halves of the photometric field are again matched, and corresponding angle θ_2 is read. (Use only values of θ_1 and θ_2 falling between 0° and 90°.)

Then,

$$\frac{B}{W} = \cot \theta_1 \tan \theta_2$$

where B = brightness over the black hole
and W = brightness over the white spot.

This ratio, $\frac{B}{W}$, has been called the contrast ratio.[6] It varies between zero and unity, larger values indicating less transparency.

COMPUTATION

The indicated operation is most readily performed by a special slide rule designed at the Bureau for this purpose;[7] but may be easily made by use of ordinary trigonometry tables.

ACCURACY

Precision.—The average deviation of a single observation from a mean of 10 observations is about 0.7 per cent. Different mean values also differ on the average by about this amount, but mean values are occasionally obtained, even under the best conditions, which differ by as much as 1.5 per cent. This is, of course, common to all photometric methods. Thus, if tests are carefully made, the results may be considered reliable to about 1 per cent.

[5] The sample must not touch the magnesia, but must be so near that a further decrease in distance does not affect the ratio $\frac{B}{W}$ to be measured. In this apparatus, less than 2 mm. was found suitable.

[6] This term has been used for some time in this connection by Nutting, of the Eastman Kodak Co., as well as by the Bureau of Standards.

[7] Made to order by Keuffel & Esser, Hoboken, N. J.

Reproducibility.—(*a*) The results do not depend upon the exact amount nor upon the exact degree of diffusion of the illumination. The white-lined box is merely a convenience; its exact reproduction is not a part of the specification.

(*b*) It is not necessary to use the Martens photometer. Check results have been obtained using the Bechstein photometer,[8] an instrument entirely different from the Martens in principle and construction.

(*c*) The reproducibility of the magnesia surfaces within the uncertainty of observation has been demonstrated by repeated trials.

(*d*) The constancy of the same film for several days has been experimentally demonstrated.[9]

STANDARD FORM OF SPECIFICATION

For the convenience of those desiring to employ this method of specifying transparency, the following form of specification is suggested:

The contrast ratio referred to a black cavity and a magnesia surface and determined by the method described in Bureau of Standards Circular No. 63 shall be [*not*][10] *less than* —.

GENERAL INFORMATION RELATIVE TO THE TRANSPARENCY OF TRACING CLOTH

In considering the specification of the transparency of tracing cloth, the following facts should be taken into account:

1. The contrast ratio (as determined above) for cloths commonly considered satisfactory is about 0.35.

2. Very high-grade transparent cloth may have a contrast ratio as low as 0.20.

3. Pieces of cloth generally are not uniform to within the accuracy of measurement. The contrast ratio may vary as much as 0.04 from spot to spot in the same piece.

4. The contrast ratio varies with the age of the sample, usually increasing, indicating diminishing transparency. Samples have been observed to change from about 0.36 to 0.44 in five months. In one or two good samples a very small increase in transparency has been observed.

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[8] Ztr. Instrkde., 27, p. 178; 1907.

[9] It has been observed by Nutting and Jones (Trans. Ill. Eng. Soc., 9, p. 596) that the reflecting power of freshly calcined magnesia decreased 2 or 3 per cent in a day or a few days. Experiment has shown that this is not true for our films.

[10] If high transparency is desired, omit "not." If low transparancy (opaque print papers, etc.) is desired, use "not."

INSTRUCTIONS TO APPLICANTS FOR TESTS

Application.—All applications for tests must be made in writing addressed "Bureau of Standards, Washington, D. C." The applicants should enumerate the pieces sent, giving the identification marks of each, and should state explicitly the tests desired (see schedule at end of circular), and the portions of the piece from which the samples are to be cut. If a time test is desired, the length of time should be stated, and if more than a one-sample test is desired, the number and location of each sample should be stated.

Shipping Directions.—It is exceedingly important that the pieces of tracing cloth or paper reach the Bureau perfectly flat, smooth, clean, and dry. Care should be taken in packing not to touch the pieces with the fingers in any part where a measurement is desired. The surface is ruined by the moisture from the skin. A wrinkle causes a shadow in the photometric field and should be avoided. It is advisable to place the piece to be tested between two layers of the same cloth. If packed flat, enough protection should be used to keep the piece from bending during transit. If rolled, care should be taken that it is done so as to permit flattening again without difficulty or injury to the sample.

The standard sample size is 4 by 12 cm. For uniformity test, ample cloth or paper should be sent to obtain the desired number of perfect samples from different parts. The Bureau assumes no responsibility for samples in transit; and no sample will be tested which does not arrive in apparently perfect condition. No pieces will be returned unless specifically requested.

Remittances.—Fees in accordance with the accompanying schedule should be sent with the request, or promptly upon receipt of bill. Department regulations prohibit the issuance of reports before the fees due thereon have been received. Remittances may be made by money order or by check drawn to the order of the Secretary of Commerce.

SCHEDULE OF TESTS

In this schedule a sample is understood to be a piece 4 by 12 cm, the centers of the spots over black and white being about 6 cm apart.

Description of test	Fee schedule	Fee
One sample in one position, giving mean value of contrast ratio computed from five observations each of Θ_1 and Θ_2	47i	$2.50
Duplicate of above, reversing black and white for same sample to test uniformity	47i-1	1.50
Test of uniformity of large piece, by measurements on a number of samples from same large piece. For five or more samples, per sample	47j	2.00
Test of change of contrast ratio with age. Sample to be preserved at the Bureau under conditions agreed upon by the applicant and the Bureau and repeat determinations made from time to time over such period as desired. Per each determination of five observations	47k	2.00

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Director.

Approved:
WILLIAM C. REDFIELD,
Secretary.

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