Nomenclature TV Studio Lighting

A Committee Report, George H. Gill, Sr., *Subcommittee Chairman*

THE NINE DEFINITIONS presented here constitute a revision of terms published in this *Journal* in February 1955. Both the original report and this revision were drafted by the Television Studio Lighting Subcommittee on Nomenclature and widely circulated. The Committee welcomes suggestions and comments.

High-Key Lighting. A type of lighting which, applied to a scene, is intended to produce a picture having gradations falling primarily between gray and white; dark grays and blacks are present, but in very limited areas.

Low-Key Lighting. A type of lighting which, applied to a scene, is intended to produce a picture having gradations from middle gray to black, with comparatively limited areas of light grays and whites.

Key Light. The apparent principal source of directional illumination falling upon a subject or area.

Base Light. Uniform, diffuse illumination, sufficient for a television picture with adequate signal-to-noise ratio at desired lens aperture, and which may be supplemented by other lighting.

Fill Light. Supplementary illumination to reduce shadow or contrast range.

Cross Light. Illumination on the front of the subject from two directions at substantially equal and opposite angles with the optical axis of the camera.

Back Light. Illumination of the subject from behind to produce a highlight along its pictured edge.

Eye Light. Illumination to produce a specular reflection from the eyes (and teeth) without adding a significant increase in light to the subject.

Set Light. Separate illumination of background or set other than that provided for principal subjects or areas.

Submitted in draft on October 3, 1963, by George H. Gill, Sr., Century Lighting, Inc., 521 West 43rd St., New York, N.Y. 10036, and approved for publication on May 14, 1964.

Errata

Progress Report, May 1964 ***Journal*****, pp. 378–381**

The illustration which is Fig. 24 is not referred to in the text.

The text reference reading ***Fig. 24*** **should read** ***Fig. 25*** **and subsequent text references through** ***Fig. 29*** **should read through** ***Fig.*** **30.**

standards and recommended practices

Approved American Standards

Published here for your information are two American Standards approved on May 6, 1964 by the American Standards Association: PH22.90-1964, Method for Aperture Calibration of Motion-Picture Lenses, a revision of the 1953 standard, and a new proposal, PH22.107-1964, Dimensions of 8mm Motion-Picture Camera Spools (25-ft. Capacity). It should be pointed out the revision of PH22.90 is editorial in nature and the technical material has not been altered.

Inasmuch as compliance with American Standards is purely voluntary, these standards will become truly effective if very broad publicity is given to their existence. The ASA and the SMPTE would appreciate any personal influence to promote the use of these standards where such action is appropriate and proper. Copies of the standards may be obtained for a nominal fee from the American Standards Association, 10 East 40th Street, New York City, 10016.—*A.E.A.*

American Standard Method for Determining

Aperture Calibration of Motion-Picture Lenses

ASA
Reg. U.S. Pat. Off.
PH22.90-1964
Revision of
PH22.90-1953
* UDC 778.533.2:53.089

1. Scope

1.1 One purpose of this standard is to define the *f*- and *T*-numbers used to express the relative aperture of a photographic objective. A second purpose is to establish means for calibrating the diaphragms of objectives in both the *f*- and *T*-systems, with suitable tolerance specifications.

1.2 The photometric calibration of a lens diaphragm as contemplated by the *T*-system of diaphragm marking established by this specification is only one step in extending control for the purpose of producing photographic images of a desired density. The density of a photographic negative is dependent upon the illumination upon, and the reflectance of, the object photographed, the correctness of the diaphragm marking, the transmittance of the lens, the accuracy of timing of the exposure, the uniformity of the emulsion employed, and complete control of the processing. The output of a television camera tube, the response of a scanner, etc., are similarly dependent upon many independent variables. The application of the *T*-stop system is designed to improve the control as regards correctness of diaphragm marking and transmittance of the lens. The importance and need for this particular control increases as the control of the other factors enumerated is improved.

2. Definitions

2.1 *f*-Number

2.1.1 The *f*-number of a lens represents a true geometrical measure of the relative aperture.

2.1.2 For a lens having a circular aperture, which is perfectly corrected for spherical aberration and satisfies the sine condition, and which is also assumed to form an image in air of a very distant object, the *f*-number of the lens is defined by the equation:

$$f\text{-number} = \frac{f}{D} = \frac{1}{2 \sin \theta} \qquad (1)$$

where f is the focal length, θ is the semiangle of the cone subtended by the circular exit pupil of the lens at the point where the lens axis intersects the plane of the image of the assumed distant object, and the entrance pupil has a diameter, D.

2.1.3 If the entrance pupil is not circular, this relation becomes:

$$f\text{-number} = \frac{f}{D'} = \frac{f}{2}\sqrt{\frac{\pi}{A}} \qquad (2)$$

where f is the focal length, D' is the effective diameter of a noncircular entrance pupil, and A is the area of the entrance-pupil aperture.

2.1.4 If the aperture is circular, but the lens does not satisfy the sine condition, then f/D will not be equal to $1/(2 \sin \theta)$. In such a case, the *f*-number of the lens is to be defined by $1/(2 \sin \theta)$ rather than by the ratio f/D. This value is chosen because both the image illuminance and the depth of field of the lens depend directly on $\sin \theta$. In such a lens, then, the marked *f*-number will not be equal to the simple ratio of the focal length to the diameter of the entrance pupil.

2.1.5 In terms of *f*-number, the basic equation for image illuminance becomes:

$$E = \pi t\, B/4(f\text{-number})^2 \qquad (3)$$

where B is the luminance of the object and t is the lens transmittance.

Approved May 6, 1964, by the American Standards Association, Incorporated
Sponsor: Society of Motion Picture and Television Engineers, Inc.

* Universal Decimal Classification

10 East 40th Street, New York, N. Y. 10016

Printed in USA
ASA1M664/1.00

2.2 Effective and Equivalent *f*-Number of a Lens Used at Finite Magnification

2.2.1 The effective *f*-number of a lens is that value which may be inserted into equation (3) to determine the image illuminance under the specific conditions in which the lens is used to form an image. It is defined as:

$$\text{Effective } f\text{-number} = \frac{1}{2 \sin \theta_m} \qquad (4)$$

where θ is the semiangle of the cone subtended by the circular exit pupil of the lens. θ_m changes as the magnification, m, increases. By "magnification" is meant the ratio of the transverse dimension of the image to that of the object.

2.2.2 For an infinitely thin lens, or for a thick lens in which the entrance and exit pupils coincide with the first and second principal planes, respectively, and in which the light beam is limited only by the iris diaphragm, the effective *f*-number will be related to the *f*-number by:

$$(\text{Effective } f\text{-number for magnification } m) = (f\text{-number})\,(1 + m) \qquad (5)$$

2.2.3 The Equivalent *f*-number is a quantity defined for those lenses that cannot be regarded as being "thin;" in such cases, the effective *f*-number at a finite magnification will not be equal to the infinity *f*-number multiplied by $(1 + m)$. Inasmuch as it has become routine to multiply the marked *f*-number of a lens by $(1 + m)$ in order to determine the effective *f*-number at a finite magnification, m, it is suggested that if a lens is designed to work at or near some particular finite magnification, m, the aperture markings should be engraved with the "equivalent *f*-number" defined by:

$$\text{Equivalent } f\text{-number} = \left[\frac{\text{Effective } f\text{-number at magnification } m}{1 + m}\right] \qquad (6)$$

2.3 *T*-Number

2.3.1 The *T*-number is a photometrically determined measure of the relative aperture of a lens adjusted to take proper account of the lens transmittance, so that the illuminance in the center of the lens field will be the same for all lenses at the same *T*-stop setting. This assumes that the object is an extended, uniform, completely diffusing (Lambertian) surface.

2.3.2 When lenses are marked in accordance with the *f*-system, the exposures made with different lenses at the same *f*-setting of the diaphragms may vary greatly, this variation arising from a variation in the number of component elements of the different lenses and from the large differences in the values of transmittance that exist between coated and uncoated lenses. The *T*-system defined in this section is a system of diaphragm graduation designed to compensate for this variation. With the *T*-system of graduation, the image illuminance in the center of the field is independent of the variations in lens structure enumerated above.

2.3.3 For a lens used with a distant object, the *T*-number is defined as the *f*-number of an ideal lens having 100-percent transmittance and a circular aperture, which would give the same central-image illuminance as the actual lens at the specified stop opening. Hence, for a lens with a circular aperture

$$T\text{-number} = \frac{f\text{-number}}{\sqrt{t}} \qquad (7)$$

and for a lens with an entrance pupil of any shape and area, A, the corresponding formula is:

$$T\text{-number} = \frac{f}{2}\sqrt{\frac{\pi}{tA}} \qquad (8)$$

2.3.4 In practice, however, it is expected that the normal procedure will be to re-engrave the diaphragm ring on the lens at a series of definite *T*-numbers, rather than to measure the *T*-numbers corresponding to each of the existing marked *f*-numbers.

2.3.5 Since the *T*-numbers are determined photometrically, they automatically take account of the size and shape of the aperture, the actual focal length of the lens, the lens transmittance, and any internally reflected stray light which may happen to strike the film at the center of the field (such as in a flare spot). It is implicit in the *T*-number system of aperture markings that the precision of lens calibration shall be high.

2.3.6 For a lens designed to be used at finite magnification, the equivalent *T*-number will correspond to the equivalent *f*-number defined by equation (6).

3. Symbols

3.1 *f*-number. Lenses calibrated according to the *f*-system should bear the designation "*f*/" or "*f*:" followed by the numerals (see American Standard Aperture Markings for Still Camera Lenses, PH3.33-1959).

3.2 *T*-number. Lenses calibrated according to *T*-stop system should bear the designation "*T*" or "*T*-" followed by the numerals.

4. Standard Series of Aperture Markings

4.1 The diaphragm ring of a lens shall be marked at every "whole stop" on either system. A whole stop is taken to represent an interval of double or half the image illuminance. In the *f*-system this corresponds to a ratio of $\sqrt{2}$ or $\sqrt{0.5}$ respectively in the diameter of a circular lens aperture.

4.2 These diaphragm markings shall be engraved on the lens as follows: 0.7, 1.0, 1.4, 2.0, 2.8, 4, 5.6, 8, 11, 16, 22, 32, 45, 64, 90, and 128. The maximum aperture of the lens shall be marked with its measured *f*-number stated to one decimal place. These recommendations are in accordance with American Standard Aperture Markings for Still Camera Lenses, PH3.33-1959. (Note that 22 is actually 22.6, and hence 23 would be better.)

4.3 In setting the lens aperture, it is assumed that the diaphragm ring will always be turned in the closing direction, and not in the opening direction, to eliminate backlash effects.

5. Subdivision of a Whole Stop

5.1 If it is desired to subdivide a "whole stop" interval, reference may be made to a fraction, *S*, of a stop, defined so as to yield a ratio of image illuminance, *R*, equal to 2^S or $(0.5)^S$. Then, for any given illuminance-ratio, *R*, the corresponding fraction of a stop will be given by $S = (\log R)/(\log 2) = 3.32 \log R$. A few typical examples are given in Table 1.

Table 1. Fractional Stop Divisions

Fraction of a Stop (*S*)	Illuminance Ratio (*R*)
one-tenth	1.072 or 0.932
one-sixth	1.122 or 0.891
one-quarter	1.189 or 0.841
one-third	1.260 or 0.793
one-half	1.414 or 0.707
two-thirds	1.587 or 0.630
three-quarters	1.682 or 0.594
a whole stop	2.000 or 0.500

5.2 Each whole stop interval may be divided into three subdivisions by unnumbered dots or marks engraved at "thirds of a stop," namely: **0.71**, 0.79, 0.89, **1.00**, 1.12, 1.26, **1.4**, 1.6, 1.8, 2.0, 2.2, 2.5, **2.8**, 3.2, 3.6, **4.0**, 4.5, 5.0, **5.6**, 6.3, 7.1, **8.0**, 9.0, 10.1, **11.3**, 12.7, 14.3, **16**, 18, 20, **23**, 25, 28, **32**, . . .

5.3 The subdivision of a stop interval into thirds is consistent with

(1) The exposure meter markings stated in American Standard General-Purpose Photographic Exposure Meters (Photoelectric Type), PH2.12-1961

(2) The determination of the exposure index of films as stated in American Standard Method for Determining Speed of Photographic Negative Materials (Monochrome, Continuous-Tone), PH2.5-1960

(3) The calibration of filters in terms of density steps of 0.1; $^1/_3$ of a stop represents a logarithmic illuminance ratio equal to 0.1.

6. Accuracy of Marking

6.1 Lenses Marked According to the *f*-System

6.1.1 The maximum opening of a lens calibrated in accordance with the *f*-system shall be marked within an accuracy of ±12 percent of area, or ±6 percent of diameter.*

NOTE: Since in most factories a blanket calibration is generally used for the *f* apertures of a complete run of lenses of the same type, the smaller openings may be in error by as much as ±25 percent of area, or ±12 percent of diameter ($^1/_3$ of a stop), particularly in short focus lenses.

6.2 Lenses Marked According to the *T*-System

6.2.1 Each full-stop interval for a lens calibrated in accordance with the *T*-system shall be marked within an accuracy of $^1/_6$ of a stop (10 percent in illuminance or 5 percent in diameter).† This assumes that the diaphragm is always closed down to the desired aperture (not opened up from a smaller aperture) to eliminate backlash effects.

7. Procedure for Measurement of *f*-Numbers

7.1 Distant Object

7.1.1 The procedure for measuring the *f*-number of any lens having a circular diaphragm aperture is described in American Standard Methods of Designating and Measuring Apertures and Related Quantities Pertaining to Photographic Lenses, PH3.29-1958, Section 3.

7.1.2. If the entrance pupil is noncircular, it is necessary to measure its area, and then proceed as indicated.

7.2 Near Object

7.2.1 To measure the effective *f*-number of a lens when used with a near object, it is necessary to determine the angle θ in equation (4).

7.2.2 The effective *f*-number is defined by $1/(2 \sin \theta)$; and the equivalent *f*-number for engraving on the lens barrel will then be equal to the effective *f*-number divided by $(1 + m)$, where m is the magnification.

8. Photometric Calibration of a Lens by the *T*-Number System

8.1 General Requirements

8.1.1 Since *T*-stops are based on a measurement of the illuminance produced by the lens at the center of the field, it is first necessary to define the latter term. For the purpose of illuminance or flux measurement, the term "center of the field" shall be taken to mean a circular area approximately 3mm in diameter for 35mm or 16mm frames, or 1.5mm in diameter for 8mm frames, centered in the image frame.

8.1.2 The light used in making the determination shall be that emitted by a tungsten filament lamp operating between 2,900 and 3,200 K and the sensitivity characteristic

---

* In accordance with American Standard Focal Length Marking of Lenses, PH3.13-1958, the engraved focal length of lenses for still-picture photography must be within 4 percent of its true value, and, in accordance with American Standard Aperture Markings for Still Camera Lenses, PH3.33-1959, the measured diameter of the maximum entering beam shall be at least 95 percent of the quotient obtained by dividing the engraved focal length by the engraved *f*-number. Thus, by combining these tolerances we find the diameter of the maximum lens aperture may be in error by as much as 9 percent. This represents an error in area of 18 percent, or $^1/_4$ of a stop, which is felt to be unnecessarily large for motion-picture application. The tolerances for aperture marking for motion-picture objective lenses allow less latitude than that provided for still-picture camera lenses because of the stricter requirements in cinematography on the same continuous length of film using different lenses.

† Since 5 percent in diameter corresponds to 5 percent in *T*-numbers, a lens of aperture nominally *T*2 may be anywhere between *T*1.90 and *T*2.10. A lens nominally *T*4.5 may lie between *T*4.28 and *T*4.72, and a lens nominally *T*8 may lie anywhere between *T*7.6 and *T*8.4.

of the photoelectric receiver shall approximate that of ordinary panchromatic emulsion.* It is considered that these factors are not at all critical and no closer specification than this is necessary. Obviously, errors will arise if the lens has a strongly selective transmission, but such lenses would be undesirable for other reasons.

8.1.3 The incident light shall fill a circular field whose angular diameter is no more than 10 degrees in excess of the diagonal of the intended angular field of the lens itself. During measurement, the light shall traverse the lens in the direction ordinarily employed in its use in the camera.

8.1.4 The lens should be carefully examined before calibration to ensure that there are no shiny regions in the barrel which would lead to flare or unwanted stray light, since this would vitiate the measurements badly. The lens surfaces should be clean.

8.2 Extended-Source Method of T-Stop Calibration (Distant Object)

8.2.1 This method of lens calibration has been described by Gardner[13] and Sachtleben,[9] the underlying theory being given by McRae.[4] It is based on filling the lens with light from an extended uniform source, and placing a metal plate in the focal plane of the lens with a 3mm hole (or 1.5mm hole for 8mm film) at its center. The light flux passing through the hole is measured by a photocell. This flux is then compared with the flux from the same source passing through the same hole from an open circular aperture of such a size and at such a distance from the plate that it subtends the desired angle, θ, where $\sin\theta = 1/(2T)$, T being the desired *T*-number. The greatest care is necessary to ensure that the extended source is really uniform, and also constant throughout the measurements. The open circular aperture is used as the "ideal lens with 100-percent transmittance" referred to in Section 2.3.3.

8.2.2 It should be noted that this procedure measures the *T*-number of the lens directly, regardless of whether or not the lens is aplanatic.

8.2.3 In practice, the reading of the photocell scale for each whole *T*-stop number is first determined by using a set of open apertures designed to provide known *T*-values at a convenient fixed working distance from the apertures; the plate with the 3mm hole limiting flux to the photocell is placed at this distance. The lens is then substituted for the open aperture, with the 3mm hole relocated accurately in its focal plane, and the iris of the lens is closed down until the measured flux produced by the lens is equal to that for each of the successive open-hole readings. The full *T*-stop positions are then marked on the diaphragm ring of the lens. The intermediate third-of-a-stop positions may be found with sufficient accuracy by inserting a neutral filter of 0.1 or 0.2 density behind each open aperture in turn and noting the corresponding photocell reading.

8.2.4 Suitable aperture dimensions for a distance of 50mm from aperture to plate are listed in Table 2. A single set of apertures is sufficient to calibrate lenses of all focal lengths, since the only factor involved is $\sin\theta$, and that is fixed by the aperture and working distance. The apertures should be bevelled to a sharp edge, and well blackened on both sides.

Table 2. Diameters of Calibration Apertures for a Working Distance of 50 mm

Desired *T*-number	Value of θ = Cosec^{-1} (2 × *T*-number), degrees	Diameter of Aperture = 100 tan θ, mm
0.5	90	∞
0.71	45	100
1.00	30	57.75
1.41	20.708	37.80
2.00	14.478	25.82
2.83	10.183	17.96
4.00	7.181	12.60
5.66	5.072	8.88
8.00	3.583	6.26
11.31	2.533	4.42
16.00	1.791	3.12
22.63	1.266	2.21
32.00	0.895	1.56

8.2.5 The extended source should be uniformly bright over its useful area to within ±3 percent. (This can be tested with a suitable telephotometer, or a small hole in an opaque screen can be moved around in front of the source, and any consequent variations in photocell reading noted.) The source conveniently may be a sheet of ground glass covering a hole in a white-lined box containing several lamps mounted around the hole and shielded so that no direct light from the lamp falls on the ground glass itself.

8.3 Collimated Source Method of Lens Calibration

8.3.1 This method has been described by Daily[11] and Townsley.[14] Light from a small source (a 5mm hole covered with opal glass and strongly illuminated from behind) is collimated by a well-corrected telescope objective, of a focal length at least three times the focal length of the lens to be tested, and of a sufficient aperture to fill the lens with light. This gives a collimated beam which will be focused by the lens to form a small disk of light in its focal plane, the diameter of which will be smaller than the prescribed 3mm limit.

8.3.2 For the comparison unit, an open aperture is used of diameter equal to the focal length of the lens divided by the desired *T*-number. This aperture is first mounted in front of an integrating sphere with the usual photocell, and the light from the collimator is allowed to enter the aperture. The aperture plate is now replaced by the lens, the iris diaphragm is closed down to give the same photocell reading, and the *T*-stop number is engraved on the iris ring. The intermediate thirds of stops can be added by using a neutral filter of 0.1 or 0.2 density, as described in Section 8.2.3.

8.3.3 If this method is used, the focal length of the lens must be measured separately, and a suitable set of open apertures must be constructed for use with each focal length encountered. However, one single set of fixed apertures may be used for all lenses, as described by Townsley.[14]

8.3.4 This procedure measures the *T*-number as the ratio of f/D, and the measurement is thus influenced by the state of correction of the lens in regard to spherical aberration and sine condition.

8.4 *T*-Stop Calibration at Finite Magnification

8.4.1 To use the extended-source method (see Section 8.2), it is only necessary to mount the metal plate at the desired image distance from the lens instead of placing it in the focal plane. The open apertures used for comparison must be calculated to have an opening corresponding to the desired equivalent *T*-number multiplied by $(1 + m)$. This is because the illuminance given by the lens is really being compared with the effective *T*-number of the open hole, but the engraving must be done at each standard step of the equivalent *T*-number (see Section 7.2.2).

8.4.2 The collimated source method cannot be used to calibrate a lens at finite magnification.

---

* A suitable cell is one having an S-3 surface, combined with a Corning Glass Filter No. 9780 about 2.5mm thick.

References

General

1. A. C. Hardy, "The distribution of light in optical systems," *J. Frank. Inst.*, *208*: 773–791, Dec. 1929.

2. A. C. Hardy and F. Perrin, *Principles of Optics*, McGraw-Hill Book Co., New York, 1932, p. 411.

3. L. C. Martin, *Applied Optics*, Vol. 2, Pitman, London, 1932, p. 210.

4. D. B. McRae, "The measurement of transmission and contrast in optical instruments," *J. Opt. Soc. Am.*, *33*: 229–243, Apr. 1943.

Lens Calibration

5. G. W. Moffitt, "Determining photographic absorption of lenses," *J. Opt. Soc. Am.*, *4*: 83–90, May 1920.

6. J. Hrdlicka, "Measuring the effective illumination of photographic objectives," *Jour. SMPE*, *14*: 531–553, May 1930.

7. D. B. Clark and G. Laube, "Twentieth Century camera and accessories," *Jour. SMPE*, *36*: 50–64, Jan. 1941; also U.S. Patent 2,334,906 (filed Sept. 1940, issued Nov. 1943).

8. E. W. Silvertooth, "Stop calibration of photographic objectives," *Jour. SMPE,* 39: 119–122, Aug. 1942.

9. L. T. Sachtleben, "Method of calibrating lenses," U.S. Patent 2,419,421 (filed May 1944, issued Apr. 1947). (Note: This patent is held by RCA, which has expressed willingness to grant a paid-up license for a nominal fee. See *Jour. SMPTE, 56:* 691–692, June 1951.)

10. E. Berlant, "A system of lens stop calibration of transmission," *Jour. SMPE, 46:* 17–25, Jan. 1946.

11. C. R. Daily, "A lens calibrating system," *Jour. SMPE, 46:* 343–356, May 1946.

12. A. E. Murray, "The photometric calibration of lens apertures," *Jour. SMPE, 47:* 142–151, Aug. 1946.

13. I. C. Gardner, "Compensation of the aperture *ratio markings of a photographic lens for absorption,* reflection and vignetting losses," *Jour. SMPE, 49:* 96–110, Aug. 1947; also *J. Res. Nat. Bur. Stand., 38:* 643–650, June 1947 (Research Paper RP 1803).

14. M. G. Townsley, "An instrument for photometric calibration of lens iris scales," *Jour. SMPE, 49:* 111–122, Aug. 1947.

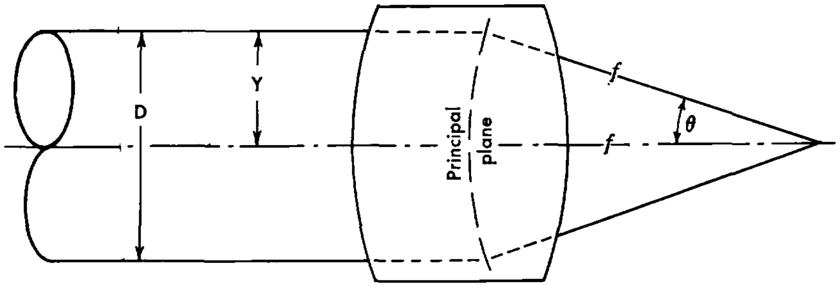
15. F. G. Back, "A simplified method for the precision calibration of effective *f*-steps," *Jour. SMPE, 49:* 122–130, Aug. 1947.

16. F. E. Washer, "Errors in calibrations of the *f* numbers," *Jour. SMPE, 51:* 242–260, Sept. 1948; also *J. Res. Nat. Bur. Stand., 41:* 301–313, Oct. 1948 (Research Paper RP 1927).

17. A. E. Murray, "Diffuse and collimated *T*-numbers," *Jour. SMPTE, 56:* 79–85, Jan. 1951.

APPENDIX

(This Appendix is not a part of American Standard Aperture Calibration of Motion-Picture Lenses, PH22.90–1964, but is included to facilitate its use.)



A1. Theory of Image Illuminance

A1.1 The illuminance produced at a point on the axis of a lens by a uniform plane extended to the Lambertian surface, when the lens has a circular aperture, is given by:

$$E = \pi t\, B \sin^2 \theta \qquad (9)$$

where *E* is the illuminance in lumens per unit of area; *t* is the lens transmittance, expressed as the ratio of emerging flux to entering flux for a beam sufficiently narrow to pass through the lens without obstruction by the lens mount; *B* is the object luminance in candles per square unit; and *θ* is the semiangle of the cone subtended by the circular exit pupil of the lens at the axial point under consideration.

A1.2 If the lens can be assumed to be aplanatic, that is, to be free from spherical aberration and to satisfy the sine condition, and if the object is very distant, then the value of sin *θ* will be given by:

$$\sin\theta = \frac{Y}{f} \qquad (10)$$

where *Y* is the semidiameter of the circular entrance pupil of the lens and *f* is the focal length. The validity of this equation may be seen by reference to the diagram, remembering that, in a lens having the type of correction assumed in this paragraph, the principal planes of Gauss are in reality portions of spheres centered about the axial object and image points, respectively.

A1.3 If the lens aperture is not circular, which will often occur when the iris is partly closed, the angle *θ* has no meaning. In such a case, we may define the effective diameter, *D′*, of the entrance pupil in terms of its area, *A*, by:

$$A = \frac{\pi D'^2}{4} \qquad (11)$$

therefore

$$D' = 2\sqrt{\frac{A}{\pi}} \qquad (12)$$

A1.4 For an aplanatic lens, we may now replace sin *θ* by *D′*/2*f*, and the image illuminance equation (9) becomes:

$$E = \pi t B(D'/2f)^2$$

therefore by equation (12) we find:

$$E = t\, BA/f^2 \qquad (13)$$

A2. Notes on the Measurement of *f*-Number

A2.1 If the entrance pupil is noncircular, it is necessary to measure its area. This may be done conveniently by mounting a point source of light, such as a small hole in front of a lamp bulb or a 2-watt zirconium lamp, at the rear focal point of the lens, and allowing the light beam which emerges from the front of the lens to fall upon a piece of photographic material. After processing, the recorded area is measured with a planimeter and applied in equation (2). If the lens is too small for this procedure to be employed, it may be placed in a suitable telecentric projector working at a known magnification (a workshop profile projector is suitable). The back of the test lens should be toward the source of light. The entrance pupil will then be projected onto the screen of the projector at a known magnification, at which time its area can be determined with a planimeter.

A2.2 To measure the effective *f*-number of a lens when used with a near object, it is necessary to determine the angle, *θ*, in equation (4). This may be done by using a point source of light at the correct axial object position, and measuring the diameter of the emerging beam at two widely separated planes a known distance apart. A simple computation will enable the semi-cone angle, *θ*, to be determined.

A3. Notes on the Measurement of *T*-Number

A3.1 The photocell may conveniently be used with a simple direct-current amplifier.* Care must be taken to ensure that the photocell sensitivity and the line voltage do not change between making readings on the open aperture and on the lens itself. To guard against this, some convenient turret arrangement is desirable, with the lens on one side and the open aperture on the other so that the two may be interchanged and compared immediately with each other by merely turning the turret.

A3.2 In the *collimated source method* of *T*-stop calibration, in order to guard against drift and line-voltage variations which might occur between the readings on the comparison aperture and on the lens, it is convenient to leave the known standard aperture in place in front of the sphere, and to insert the lens into the beam in such a position that the little image of the source falls wholly within the standard aperture. The meter reading should then remain the same no matter whether the lens is in or out of the beam. A second plate with a 3mm aperture should be placed over the comparison aperture while the lens is in place to stop any stray light which may be reflected from the interior of the lens.

A4. Corner-to-Center Illuminance Ratios

A4.1 In the specifications of this standard and in the prescribed methods of measurement, the values apply only to that point at the center of the image field of the lens. It is usual for the image illuminance to fall off with distance from this center of the image. In the precise photometric calibration of the *T*-stops of a lens, it is sometimes important to know what illumination differences will exist at other points in the image.

A4.2 Having calibrated the stop markings of the lens on the *T*-system by one of the methods described, the observer may, if desired, determine, in addition, the ratio of corner illuminance to center illuminance, at full aperture and preferably at other apertures also. For this purpose, the 3mm (or $1^1/_2$mm) hole shall be used first at the center of the field and then moved outward until its rim is touching the top and side limits of the camera gate.

These distances are shown below.

Gate, mm	Radial Shift of Hole, mm
35 (16.03 x 22.05)	11.5
16 (7.47 x 10.41)	4.5
8 (3.51 x 4.80)	2.0

A4.2.1 To measure the corner-to-corner illuminance ratio using the extended source method of calibration, *the lens is set in position and the 3mm hole and the* photosensitive receptor are displaced laterally by the desired amount. The photocell reading is noted at axial and corner positions, and the corresponding light ratio found from a calibration curve of the receptor.

A4.2.2 The corner-to-center ratio at any desired aperture can be conveniently determined, using the collimated source method of calibration, by simply *rotating the lens through the desired field angle, φ,* and comparing the photosensitive receptor reading with its value for the lens axis. The light-flux ratio can then be read off a calibration curve for the photocell system, and converted to the desired corner-to-center illumination ratio by multiplying it by $\cos^4 \phi$. (Note that this procedure will be correct only in the absence of distortion, but no motion-picture lens is likely to have enough distortion to cause any significant error.)

---

* Suitable systems are the "Electronic Photometer" model 500 (Photovolt Corp., 95 Madison Ave., New York, N.Y.), and the "Magnephot" (W. M. Welch Scientific Co., 1515 Sedgwick St., Chicago, Ill.). It is felt that a photo-voltaic cell, although desirable for reasons of simplicity, has insufficient sensitivity for accurate determinations of the smaller apertures unless a galvanometer of exceptionally high sensitivity is employed.

American Standard Dimensions of

8mm Motion-Picture Camera Spools (25-ft Capacity)

ASA
Reg. U.S. Pat. Off.

PH22.107–1964

* UDC 778.533.4

1. Scope

1.1 The dimensions shown in this standard are for 8mm motion-picture film spools with a nominal capacity of 25 ft. These spools are used in cameras of the type in which each roll of film is passed through the camera twice for exposure in accordance with American Standard 8mm Motion-Picture Film, Usage in Camera, PH22.21-1953. The spindle holes in the spool are shown with splines which are intended to assist in assuring correct orientation of the spool in the camera.

1.2 This standard does not specify the relative orientation of the splines in the two spindle holes (or of the core slot).

2. Operation in Camera

2.1 When the spool is on the supply spindle, the flange with the 3-splined spindle hole, flange A (Fig. 1), shall be on the left-hand side (as seen from the lens).

2.2 The half of the film adjacent to the flange with the 3-splined hole, when the spool is on the supply spindle, shall be in line with the camera lens.

2.3 When the spool is on the take-up spindle, the flange with the 4-splined spindle hole, flange B (Fig. 3), shall be on the lefthand side (as seen from the lens).

2.4 When the loaded camera is viewed from the side, with the lens to the left, both the supply and take-up spools shall rotate in a clockwise direction.

3. Dimensions

3.1 The dimensions shall be as given in the figures and table.

3.2 If rivet heads or other fastening devices extend beyond the outer surface of the flange, they shall lie within the zone indicated by diameters K and L (Fig. 3). It is not intended that this standard prescribe the nature or number of these fastening devices.

3.3 Dimension H_1 (Fig. 2) is the space between the flanges outside the core. It is measured from a point on the inner surface of one flange to the corresponding point on the opposite flange. The measurement shall be made with an instrument which does not distort the flanges.

3.4 Dimension H_2 (Figs. 2, 4) is the space between the flanges just inside the core. This space shall be sufficient to permit maximum width film of 0.630 in. (16.00mm) to fit freely into the film slot. The space between the inner surfaces of the splines, Dimension H_3 (Fig. 4), within a diameter of 0.384 in. (9.75mm), Dimension D (Figs. 1, 3), shall not be less than 0.622 in. (15.80mm).

3.5 Dimension J_1 (Fig. 4) is the overall thickness of the spool within a 0.615-in. (15.62-mm) diameter zone at the center of each flange.

3.6 When the spool is rotated on an accurate, tight-fitting spindle, the maximum outward deviation from the *intended plane of rotation* for any point on the flange outside the 0.615-in. (15.62mm) diameter zone shall not exceed 0.015 in. (0.38mm). This 0.015-in. (0.38mm) tolerance includes fastening devices, variations in flange thickness, flatness and lateral runout of the flanges.

Approved May 6, 1964, by the American Standards Association, Incorporated
Sponsor: Society of Motion Picture and Television Engineers, Inc.

* Universal Decimal Classification

Printed in USA
ASA1M664/60

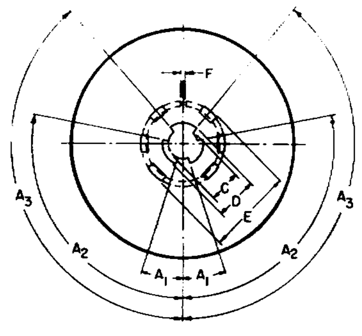


Fig. 1

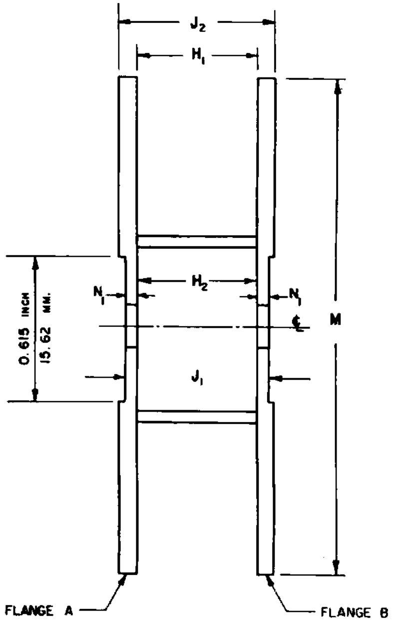


Fig. 2

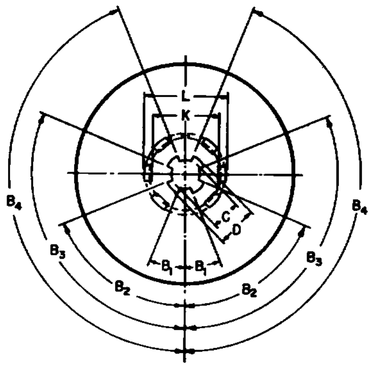


Fig. 3

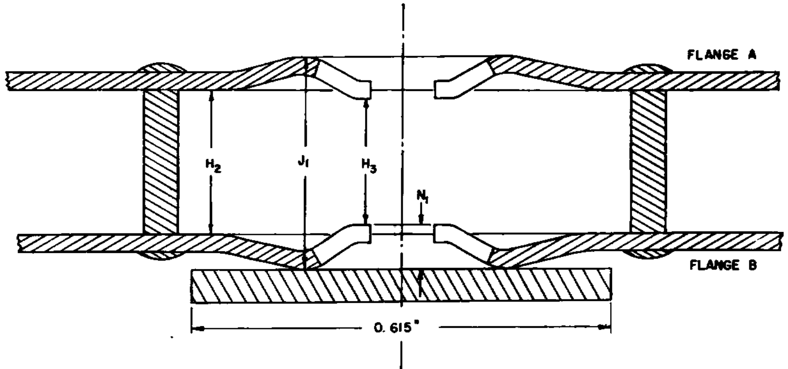
Dimensions	Degrees	Dimensions	Inches	Millimeters
A_1	$19\,{}^{1}/_{4} \pm 1$	C (bore for spindle)	0.288 + 0.007 − 0.004	7.32 + 0.18 − 0.10
A_2	$100\,{}^{3}/_{4} \pm 1$	D	0.384 min	9.75 min
		E (core diameter)	0.750 ± 0.015	19.05 ± 0.38
A_3	$139\,{}^{1}/_{4}$ [illegible] 1	F	0.035 ± 0.020	0.89 ± 0.51
		H_1 (see 3.3)	0.631 min	16.03 min
		H_2 (see 3.4)	0.630 min	16.00 min
B_1	$19\,{}^{1}/_{4} \pm 1$	H_3 (see 3.4)	0.622 min	15.80 min
		J_1 (see 3.5)	0.720 ± 0.020	18.29 ± 0.51
B_2	$70\,{}^{3}/_{4} \pm 1$	J_2 (see 3.7)	0.760 max	19.30 max
		K (see 3.2)	0.615 min	15.62 min
B_3	$109\,{}^{1}/_{4} \pm 1$	L (see 3.2)	0.812 max	20.62 max
		M	2.031 ± 0.015	51.59 ± 0.38
B_4	$160\,{}^{3}/_{4} \pm 1$	N_1 (see 3.9)	0.038 min	0.97 min
		N_2 (see A4)	0.025 min	0.64 min

The *intended plane of rotation* is defined as a plane perpendicular to the axis of the spindle and coincident with the surface of a flat support centered on the spindle axis and having a diameter of 0.395 in. (10.03mm).

3.7 Dimension J_2 (Fig. 2) is the overall thickness of the spool *outside* the 0.615-in. (15.62-mm) zone which is centered on each flange. J_2 is a composite dimension covering all of the spool characteristics described in 3.6.

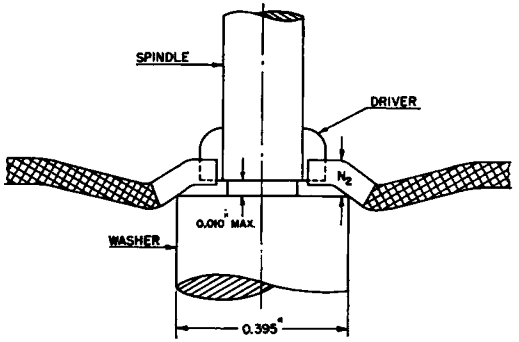
3.8 Dimension F (Fig. 1) specifies the width of the slot in the core for attaching the end of the film.

3.9 Dimension N_1 (Fig. 4) is the effective thickness of the 4-splined webs which engage most camera drivers. It is measured from a plane perpendicular to the axis of the spindle and coincident with the surface of a flat support having a diameter of 0.615 in. (15.62mm).



ENLARGED SECTION FOR DIMENSION N_1

Fig. 4



SPINDLE AND SPOOL RELATIONSHIPS

Fig. 5

APPENDIX

(This Appendix is not a part of American Standard Dimensions of 8mm Motion-Picture Camera Spools (25-ft Capacity), PH22.107–1964, but is included to facilitate its use.)

A1. Figure 2 is in the nature of a "space diagram;" that is, its outside dimensions represent the space that was reliably available for film spools in all 8mm cameras on the market at the time this standard was drafted. Film spools will not necessarily look much like this diagram, but there should be no operational interference between a film spool and a current 8mm motion-picture camera so long as the spools are manufactured with dimensions that fall within the indicated limits. Since the maximum value of H_1 (Fig. 2) does not affect the interchangeability of the spool, no limit is specified. However, the maximum is an important quality characteristic and it is expected that every spool manufacturer will hold H_1 within the narrowest limits that his design and manufacturing process permits.

A2. The angular dimensions and tolerances for the width of the tongues in the splined spindle holes are in accord with current practice for new spools and with the requirements of existing cameras. However, there are in existence and use spools of older design with tongues slightly wider by 1° to 2° on each edge of each tongue.

A3. Camera spindles should allow for a radius of not more than 0.015 in. (0.38mm) at each corner of each tongue.

A4. Figures 4 and 5 represent special case examples of how the needs of certain dimensions critical to proper performance in some cameras can be met by appropriate shaping or embossing of the spool stock if spools are made of a thin-gage material (much less than 0.040 in.). For a number of years, the effective thickness of the 4-splined webs which engage most camera drivers, Dimension N_1 (Fig. 4), was the stock thickness, nominally 0.040 in. (1.02mm). Recently, spools have been made from thinner materials which require embossing to maintain Dimension J_1 (Fig. 4) and to enable the splines to engage the camera drivers, some of which have a clearance approaching 0.025 in. (0.64mm).

As outlined in 3.9, Dimension N_1 (Fig. 4) is normally measured to a flat support having a diameter of 0.615 in. (15.62mm). Many cameras have spool support washers with diameters considerably less than 0.615 in. (15.62mm). In order to assure proper operation with such cameras, the dimension from the inside of the 4-splined flange to the plane of a flat support 0.395 in. (10.03mm) in diameter centered on the flange, Dimension N_2 (Fig. 5), shall be at least 0.025 in. (0.64mm).

The enlarged section for Dimension N_1 (Fig. 4) illustrates one method of shaping the splines in the 4-splined flange so they will engage the camera driving spindle when the flange thickness is less than 0.025 in. (0.64mm).

Camera spindles engaging the 4-splined flange of the spool should not have a gap greater than 0.010 in. (0.25mm) between the bottom of the spindle driving spline and the top of the spindle shoulder or washer that supports the spool.

It is recommended that, in newly designed cameras, the diameter of the supporting spindle shoulder or washer be not less than 0.500 in. (12.70mm) and no greater than 0.615 in. (15.62mm).