# National Institute of Standards & Technology

# Certificate

## Standard Reference Material® 1010a

### Microcopy Resolution Test Charts

### (ISO Test Chart No. 2)

This Standard Reference Material (SRM) is intended to be used to determine the resolving power of microcopy systems in the photographic industry. It was designed to meet the general requirements for ISO Test Chart No. 2, as described in ISO 3334: 1989 [1]. This SRM consists of five identical charts with 26 patterns printed on white photographic paper with a glossy surface. Each chart is nominally 90 mm wide by 113 mm high.

**Test Chart Pattern Description:** The patterns consist of black bars on a white background, the length of the bars are 24 times their width, and the bars and spaces are of equal width. The patterns range in spatial frequency from 1 cycle/mm to 18 cycles/mm. Each pattern is made up of two groups of five parallel bars; the bars in the two groups are oriented perpendicular to one another. The number associated with each pattern is the number of cycles/mm on that pattern.

**Expiration of Certification:** The certification of this SRM is deemed to be indefinite within the stated tolerances, provided the SRM is stored and handled in accordance with the instructions given in this certificate.

**NIST Measurement Technique:** All SRM 1010a test charts were made from one master negative. Originally, 25 % of the test charts in the lot were individually evaluated for horizontal and vertical observation measurement by a measuring microscope and reflectance densitometer. In 1998, measurements were made on five randomly chosen SRM units from remaining stock. Line width, line length, space width, and relative density were remeasured using a custom air bearing supported X-Y coordinate machine, using a ultra-high precision microscope and laser interferometer positioning stage. X-Y coordinate accuracy of the system was greater than 40 nm. Measurements were also checked using a standard measuring microscope and using the X-Y coordinate machine in manual mode with a calibrated graticle.

**Measurement Results Relative to ISO 3334: 1989 Specifications:** Relative density exceeded the specified 85 % lower limit for all patterns. Spatial frequency error of four full cycles was less than the 3 % specified for all patterns. Line length was within the specified range for all patterns. The spatial frequencies 1.0 through 5.0 and 10 through 18, are within the specified tolerance. For spatial frequencies 5.6 through 9.0, the tolerances are exceeded by a maximum of 0.03, see Table 1.

The technical and support aspects involved in the issuance of this SRM and the revision of this certificate were coordinated through the Standard Reference Materials Program by R.J. Gettings.

Gaithersburg, MD 20899
Certificate Issue Date: 6 October 1998*

Thomas E. Gills, Chief
Standard Reference Materials Program

12 Jun 78 (original certificate date); 21 Jun 82 (editorial); 1 Jun 90 (editorial)
*This revision reports increased accuracy. This certificate replaces all previous SRM 1010a certificates.

Original optical examinations and measurements leading to certification were made by L.E. Fink of the NIST Radiometric Physics Division. Current measurements leading to the analysis of measurement uncertainty where performed by J. B. Fowler of the NIST Optical Technology Division (formerly, Radiometric Physics Division).

**Storage and Handling:** To extend lifetime, test charts must be stored away from ultraviolet light, excessive temperature, and humidity. After use, return the chart to the bag provided or to one that provides similar or better protection.

**Instructions for Use:** The useful reduction ratio of a microcopying camera is limited by the nature of the material to be copied, the resolving power of the lens, the resolving power of the photographic material, accuracy of focusing, vibration, and systematic relative motion of the optical image with respect to the photographic material. The resolving power of a system in cycles/mm is the number of the pattern resolved in an image multiplied by the inverse of the reduction ratio.

To measure the resolving power of the microcopying system, photograph the charts in the same manner as documents. The charts are placed at the center and the corners of the camera field of view. The corner charts should be oriented so that one group of bars is directed toward the center of the field. Additional charts may be placed at the center of the long side or anywhere in the field at the user's discretion. Examine the processed film images with a microscope using a magnification from 1/3 to 1 times the number of cycles/mm of the resolving power to be observed. For example, to view an image from a system with resolving power of 100 cycles/mm, the magnification should be between 30 X and 100 X.

If the camera is slightly out of focus, the copy of the chart may have more or less than five bars in some groups. This is "spurious resolution" and is sometimes accompanied by failure to resolve at one spatial frequency when apparent resolution occurs at a higher frequency. If there is no evidence of spurious resolution, find the smallest pattern in which the bars can be counted with reasonable assurance. For example, if the finest resolved pattern is marked "4.0" and the reduction ratio is 1:29, the resolving power is 116 cycles/mm.

Away from the center of the field, the resolution of bars directed toward the center is often not equal to the resolution perpendicular to that direction because of lens aberrations. If the patterns perpendicular to one another are not equally resolved at the center of the field, one should suspect camera vibration or other image motion with respect to the film.

The resolution required to copy type depends on the size of type, the reduction ratio, and the quality of reproduction required. For most practical purposes, R, the resolving power in cycles/mm; e, the height in millimeters of the lower case "e" in the type to be copied; r, the inverse of the reduction ratio; and q, an arbitrary "quality index" are related by the following equation:

$$R = \frac{qr}{e}.$$

For excellent copy, in which the details of type are clearly defined, q must be eight or more. If q is assigned a value of five, the copy may be read without difficulty although serifs and fine details of type are not clear. If q is three, the copy may be difficult to read with the letters e, c, and o being partly closed.

As a general "rule of thumb," the resolving power of a lens-film combination R is related to the resolving power of lens $r_1$ and the resolving power of the film $r_2$ by the following equation:

$$\frac{1}{R} = \frac{1}{r_1} + \frac{1}{r_2}.$$

The resolving power of a lens is limited by the wave nature of light. The maximum resolving power of the lens depends on the wavelength of light, the form of the patterns observed, and the condition of observation. The maximum axial resolving power, A (expressed in cycles/mm), of a lens at various wavelengths can be obtained by using Rayleigh's criterion [2], $A = \frac{1\,000\,000}{1.22\, b \lambda}$, where b is the f-number and λ is the wavelength in nm.

For example, if the wavelength of the system's illumination is 546 nm and the f-number of the lens being used is 4.0, the maximum axial resolving power of the lens would be 375 cycles/mm. As suggested by this relationship, most lenses have their highest resolving power at full aperture, but the image contrast is generally more satisfactory if the aperture is closed one or two steps from full aperture.

Minor excursions from the ISO 3334: 1989 requirement were detected when using the X-Y coordinate machine. These are listed below, but are so small that they are undetectable when using the SRM in accordance with ISO 3334:1989.

Table 1. Excursions from ISO 3334: 1989 Tolerance

| Spatial Frequency | ISO 3334: 1989 Tolerance | NIST Measurement |
|---|---|---|
| 5.6 | 0.95-1.05 | 1.055 |
| 6.3 | 0.95-1.05 | 1.058 |
| 7.1 | 0.95-1.05 | 1.042 |
| 8.0 | 0.95-1.05 | 1.076 |
| 9.0 | 0.95-1.05 | 1.08 |

REFERENCES


[1] ISO 3334:1989 Micrographics - ISO Resolution Test Chart No. 2 - Description and Use.

[2] Smith, W. J., *Modern Optical Engineering - Design of Optical Systems,* McGraw-Hill, Inc., 1966.


*Users of this SRM should ensure that the certificate in their possession is current. This can be accomplished by contacting the SRM Program at: Telephone (301) 975-6776 (select "Certificates"), Fax (301) 926-4751, e-mail srminfo@nist.gov, or via the Internet http://ts.nist.gov/srm.*