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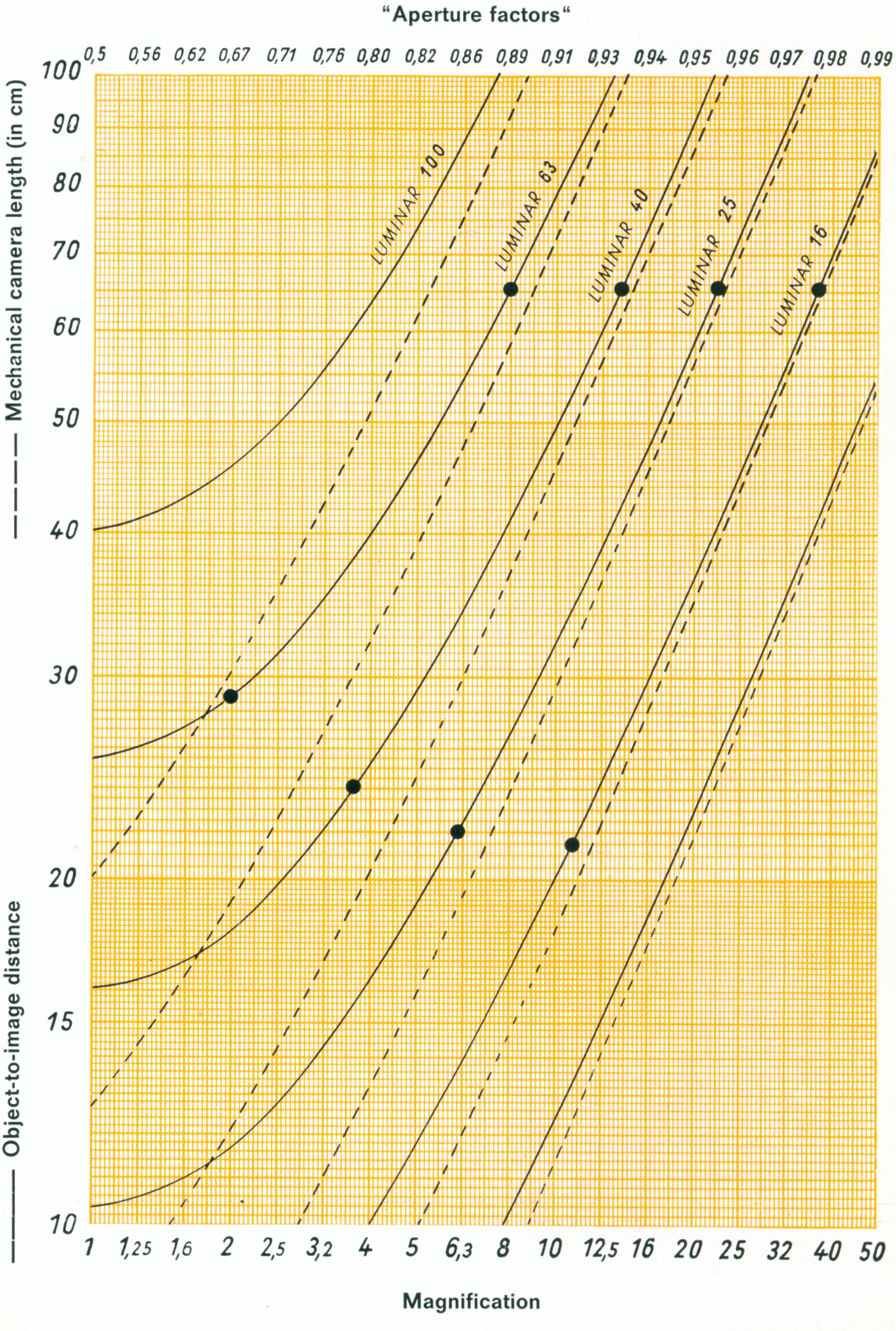
CARL ZEISS

Photomacrography with LUMINAR Lenses

Magnifications obtainable with a bellows-type camera



"Aperture factors"
0,5 0,56 0,62 0,67 0,71 0,76 0,80 0,82 0,86 0,89 0,91 0,93 0,94 0,95 0,96 0,97 0,98 0,99
– – – – Mechanical camera length (in cm)
—— Object-to-image distance
100 90 80 70 60 50 40 30 20 15 10
LUMINAR 100
LUMINAR 63
LUMINAR 40
LUMINAR 25
LUMINAR 16
1 1,25 1,6 2 2,5 3,2 4 5 6,3 8 10 12,5 16 20 25 32 40 50
Magnification

$$M = \frac{k}{f}$$

According to this formula, the **magnification** in photomacrography depends on the focal length f of the objective and the optical camera length k. The latter is the distance between the image (film or plate) and the image-side focal point of the objective. Since the location of this focal point is generally not known, it is practically impossible to determine the optical camera length. It is, therefore, necessary to use an easily measurable length for determining the magnification. As such we may choose the mechanical camera length $b=k+f$, the distance between the principal plane of the objective and the image, or – better still – the object-to-image distance which can easily be measured with accuracy. The relationships between mechanical camera length, or object-to-image distance – for an objective of a given focal length – and the magnification are shown in the graph on the opposite page.

Magnifications are plotted on the abscissa and the values are indicated at the lower edge of the graph in proportional increments (standard magnifications). The difference between two values is 25 % (or a factor of 1.25). The mechanical camera length or the object-to-image distance can be read off the ordinate. The guide line representing the object-to-image distance is solid, that for the mechanical camera length is broken.

LUMINARS are photomacrographic objectives, i. e., objectives for low-power photomacrography, corrected for image distances from 10 cm to 100 cm.

As with photographic lenses, the light-collecting power of the LUMINARS is measured in terms of the aperture ratio (diameter of entrance pupil D : focal length f) rather than the numerical aperture used in microscopy. The aperture can be stopped down in order to increase the depth of focus.

The graduations on the diaphragm scale are not aperture ratios because such values (which correspond to the definition D : f) apply only if the object is located in the object-side focal plane and the image in the image-side focal plane. Instead, the diaphragm scale of the LUMINARS indicates exposure factors, with the aid of which it is easy to compute, from a given exposure time and diaphragm setting (at a certain magnification), a new exposure time for another diaphragm setting.

Example:

Magnification 8×; diaphragm setting 2; determined exposure time: 3 seconds.
What is the exposure time for a diaphragm setting of 15? The multiplying factor is $15:2 \approx 8$, so that the exposure time in this case is 24 seconds (or 8 times the original 3-seconds exposure).

LUMINARS

Diaphragm setting	16 mm		25 mm		40 mm 63 mm		100 mm	
	Aperture ratio	Numerical aperture	Aperture ratio	Numerical aperture	Aperture ratio	Numerical aperture	Aperture ratio	Numerical aperture
1	f/2.5	0.2	f/3.5	0.14	f/4.5	0.11	f/6.3	0.08
2	f/3.5	0.14	f/5	0.10	f/6.3	0.08	f/9	0.057
4	f/5	0.10	f/7	0.07	f/9	0.055	f/12.5	0.04
8	f/7	0.07	f/10	0.053	f/12.5	0.04	f/18	0.028
15	f/10	0.052	f/14	0.036	f/18	0.028	f/25	0.02
30	f/14	0.036	f/20	0.027	f/25	0.020	f/36	0.015

In the field of photomacrography (magnifications from 1 × to approx. 20 ×), the effective aperture ratio is always smaller than the aperture ratio engraved on a photographic lens which – as was mentioned above – applies only when the object is located in the focal plane. The reduction factors applicable to the different magnifications are indicated along the top edge of the graph under the heading "aperture factors". The values of the aperture ratios indicated in the table (over-leaf) or the corresponding numerical apertures must thus be multiplied by these "aperture factors" in order to determine the effective aperture ratio or the effective numerical aperture for the corresponding magnifications.

The following values can be determined **with the aid of the graph:**

1. Determination of the magnification (when the image has been focused with a given LUMINAR):

Measure object-to-image distance (or mechanical camera length). Locate the measured value on the ordinate on the left side of the graph. Follow the line horizontally to the right until it intersects with the solid (or broken) line of the given LUMINAR. From the point of intersection go down vertically and read off the magnification at the bottom of the graph.

Example: LUMINAR of 40 mm focal length; object-to-image distance measured: 40 cm (mechanical camera length 36 cm); magnification determined: 8×.

2. Determination of object-to-image distance (or mechanical camera length) in order to reach a given magnification for the LUMINAR used:

Find the given magnification on the abscissa at the bottom of the graph. Then follow the vertical line upwards to its intersection with the guide line representing the object-to-image distance (or mechanical camera length) of the objective used. At the left of the graph read off the object-to-image distance (or mechanical camera length) to be set.

Example: LUMINAR of 25 mm focal length, desired magnification 16×. Object-to-image distance to be set: 46 cm (mechanical camera length 43.6 cm).

3. Determination of the magnifications that can be obtained with a certain LUMINAR and a bellows-type camera:

Determine minimum and maximum object-to image distances. Then find the magnifications corresponding to each of these values as described under 1. and enter these limits on the graph. It is thus possible to determine at a single glance which LUMINAR is best suited for obtaining a particular scale of reproduction.

Example: Dots plotted on the graph.

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G 41-455-e

Printed in Germany

RZ VI 68 UOO