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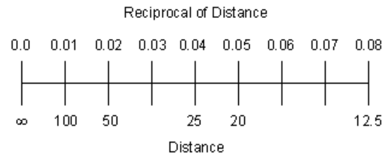
The Theory of Depth of Field Scales

A lot of information about depth of field and hyperfocal distance as applied to photography can be found elsewhere by searching the internet. This document only explains the mathematical theory underlying a depth of field scale.

The distance scale is a linear plot of the reciprocal of distance:



It can be seen here, for example, that 25 feet is twice as far from infinity on the scale as 50 feet, because the reciprocal of 25 (1/25) is 2 times the reciprocal of 50 (1/50). The reason for using a reciprocal scale is developed below.

Begin with the equations for hyperfocal distance, near distance, and far distance from Greenleaf (1950):

Hyperfocal distance:	$H = \frac{f^2}{Nc} + f$	[1]
Near distance:	$D_n = \frac{s(H-f)}{H+s-2f}$	[2]
Far distance:	$D_f = \frac{s(H-f)}{H-s}$	[3]

where:

H	is the hyperfocal distance
f	is the lens focal length
s	is the focus distance
D_n	is the near distance for acceptable sharpness
D_f	is the far distance for acceptable sharpness
N	is the f/number
c	is the circle of confusion

By summing the reciprocals of the near and far distances (the reciprocals of equations [2] and [3]), it is seen that:

$$\frac{1}{D_n} + \frac{1}{D_f} = \frac{2}{s} \quad \text{or} \quad \frac{1}{D_n} - \frac{1}{s} = \frac{1}{s} - \frac{1}{D_f}$$

It follows that:

$$\frac{1}{D_n} - \frac{1}{s} = \frac{H+s-2f}{s(H-f)} - \frac{(H-f)}{s(H-f)} = \frac{(s-f)}{s(H-f)} = \frac{(s-f)}{s\left(\frac{f^2}{Nc}\right)}$$

And, when the focal length f is much less than the focus distance s, it is seen that:

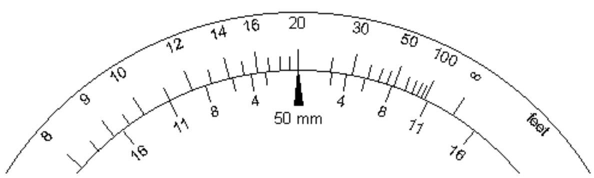
$$\frac{(s-f)}{s\left(\frac{f^2}{Nc}\right)} \approx \frac{s}{s\left(\frac{f^2}{Nc}\right)} = \frac{Nc}{f^2}$$

Thus, given a circle of confusion c for a lens with focal length f set to aperture N, the quantities:

$$\frac{1}{D_n} - \frac{1}{s} \quad \text{and} \quad \frac{1}{s} - \frac{1}{D_f} \quad \text{and} \quad \frac{Nc}{f^2}$$

are constant and equal. The constant equality provides the foundation for plotting the aperture marks on a depth of field scale.

When the reciprocal of distance is plotted on a scale, the marks for near and far distance for a given aperture are equally spaced on either side of the focus mark. The spacing of the aperture marks is also constant, regardless of where the focus mark is positioned on the scale. An example of a depth of field scale with aperture marks is shown below.



References:

1. Greenleaf, Allen R., *Photographic Optics*, The MacMillan Company, New York, 1950, pp. 25-27.
2. Bennett, Robert L., "The Construction of a Depth of Focus Calculator", *American Photography*, American Photographic Publishing Company, Boston, February 1940, pp. 114-118.