OPTICAL ENGINEERING NOTE #4
OPTIMAL PINHOLE SIZES FOR PHOTOGRAPHY

Just what is the optimum size of pinhole for photography? A variety of sources supply a variety of answers. For instance, Johnson* gives

"diameter of hole = $\frac{\text{square root of d}}{120}$

Eq.1

where d is the distance of the plate from the pinhole in inches and 120 a factor depending on the diameter of the diffraction disc given by a small hole."

Notice that 120 is a fudge factor for units in inches. To change d in millimeters to inches requires dividing it by 25.4. But d is under the square root radical (if my computer had a radical graphic), and then so as to not upset the balance of the equation, the denominator must also be divided by the same quantity, the square root of 25.4, which for all practical purposes is 5, so Equation 1 becomes:

diameter of hole = $\frac{\text{square root of d}}{24}$

Eq.2

This looks like the formula in the basic photographic textbooks**,

D = $\frac{\text{square root of f}}{28}$

f for focal length = d above Eq.3

which is their metric formula, converted from their inch one which has 141 as the denominator. Where those coefficients came from is not mentioned, except that they discuss "A basic formula that takes into account the wavelength of light is D = square root (2.5 * wavelength * f)...Various sources do not agree on the constant used in the formula, and the 2.5 constant used above represents an average value." Eq.4

(For a more complete discussion see the **Handout**, **AIRY'S DISC**.)

A focal length of 100 mm was chosen for the camera to complement the lens test***, using the same objects. Equations 2, 3 and 4 give 416, 366, and 354 microns. Precision pinholes were purchased from Optimation**** in the stock sizes of 200, 400, and 800 microns. Exposures were made under the same conditions as ***, and since the 400 micron pinhole is f/250 (100mm divided by .4mm), the duration of the exposure dose was bracketed about four minutes with this aperture! 800 microns = f/125, one minute being the central exposure, and the f/500 two hundred micron pinhole's range was 2, 4, 8, 16, and 32 minutes of photon collecting!

Another experiment involving this set of pinholes was to shoot an undiverged laser beam at them, with the hole 100 mm from a piece of high resolution photographic film (Kodak Technical Pan Film again). The diffraction pattern, which is the limiting factor of resolution, becomes visible at higher exposures.

OBSERVE the slides to see which pinhole image is the sharpest. Was it the predicted one? Is it a significant difference or hard to say?

How do the pinhole images stack up next to the single lens element images?

Sketch what a diffraction pattern through a pinhole looks like. Are all the bands equally spaced?

Do the diffraction patterns increase or decrease in diameter as the pinhole size gets smaller?

REFERENCES

*. B. K. Johnson, OPTICS AND OPTICAL INSTRUMENTS, Dover Publications, New York, 1960, (a reprint of the second edition of Practical Optics, The Hatton Press, Ltd., 1947), p. 112.

**. Leslie Stroebel, et al., Bbasic Photographic Materials and Processes, Focal Press, Boston, 1990, p.135, for instance.

***. See the previous **OPTICAL ENGINEERING NOTE, #4, THE GREAT 100mm LENS EXPERIMENT**.

****. Manufacturer of precise yet inexpensive ($24) pinholes: OPTIMATION, INC., BURR-FREE MICROHOLE DIVISION, 8025 South Willow Street, Building 1, Suite 101, Manchester, NH 03103, 603-623-2800

The following file, OptPinholeSizeIllus, (a whopping 20 Megabytes!) shows the results of these experiments.

800 micron

200 micron

400 micron

105 mm Nikkor

