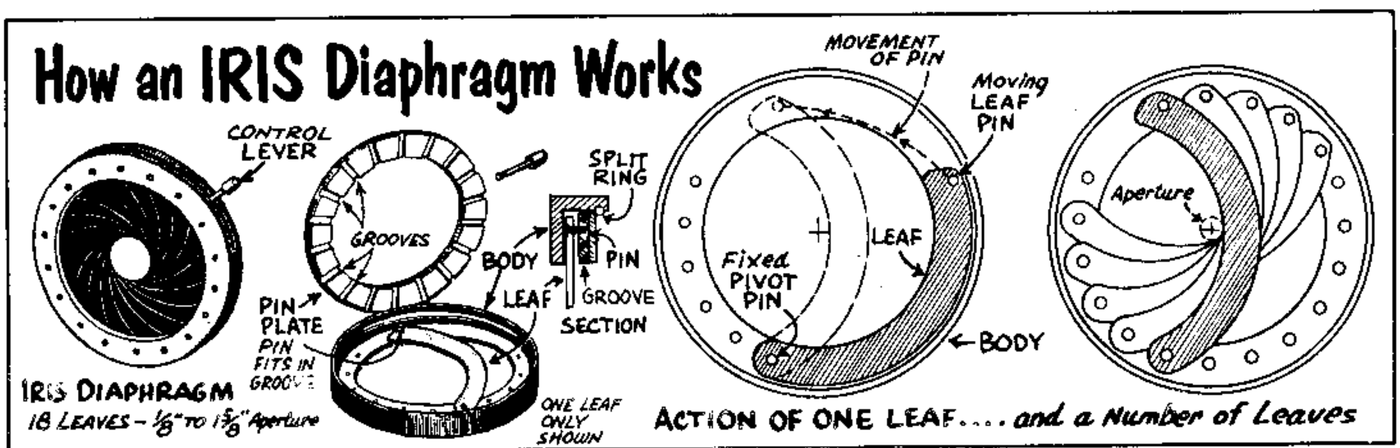
OPTICAL ENGINEERING NOTE #17:
IRIS DIAPHRAGMS AND OTHER APERTURES

An iris, diaphragm, aperture, or f/stop is an important part of any optical system to control the intensity of the light passing through the optic and also to control its aberrations. Conventional Wisdom states that a lens works best two or three stops down form its largest opening.

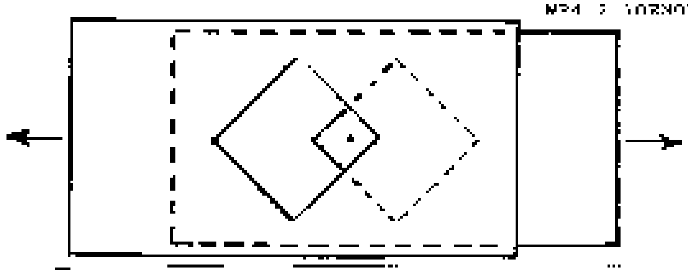
Joseph Nicephore Niepce is not only credited with the earliest surviving photograph, using his <u>heliographic process</u>, but he is also the inventor of the iris diaphragm in 1816, amongst other things. (See the **Photographic Inventors Handout, JOSEPH ISIDORE NIEPCE**.) His design used a series of overlapping leaves to approximate a circle; how close it gets depends on how many blades. His design is basically what is used today.

The mechanism controlling the movement of the blades is quite simple; one end of the blade is fixed on the housing in a pivot point, while the other end of the blade has a pin that fits in the rotating ring with the handle. The handled ring brings the inside of the arc blade towards the center of the circle.



Most cameras manufacturers try to get away with as few iris blades as possible. You may notice 5 or 6 bladed irises in the typical 35mm camera lens, and even as few as three in some cheaper items.

On many early cameras the aperture was fixed, or the lens had to be disassembled to change the opening. A cheap and simple method of controlling the light throughput was designed by Waterhouse in 1857. His stops were nothing more than holes drilled in metal, placed in a slide in the lens mount. Stops like these control the light just as well as an iris, however it is not infinitely variable in size.

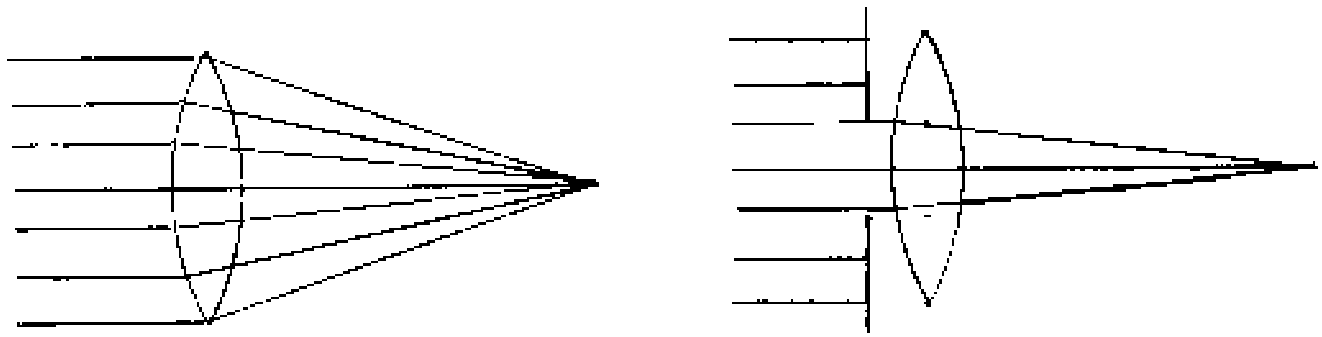


Polaroid SX-70s and the more current models use cat's-eye pupil shapes rather than circular ones. Light gathering power is dependent on surface area; it doesn't really matter if the shape is perfectly round or symmetric. The Polaroid engineers used this unconventional shape so that the auto-exposure mechanism can move through its range of intensities in a linearly fashion.

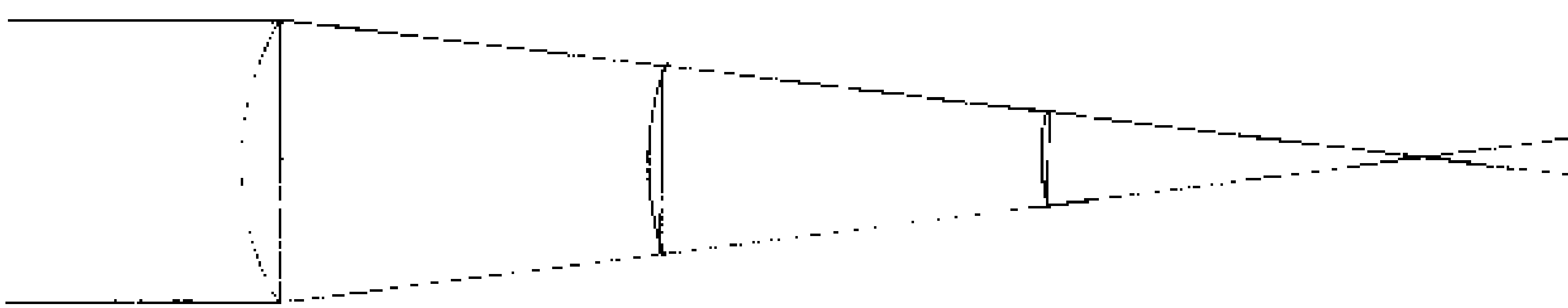
The location of the iris in a lens system is determined by its usefulness in eliminating aberrations. See the **Aberration Handout**.

WHY THOSE f/#'s

Figure Three shows the effect of stopping down the iris on the volume of light passing through the lens. The smaller volume of the more acutely angled cone of the stopped down lens forms a dimmer image.



Lenses of different diameters and focal lengths can deliver the same amount of light if they all form the same tip angle of the cone of convergent light, as shown in Figure Four.



The diameters and focal distances of the above lenses are proportional to each other, by the Geometric Rule of Similar Triangles, the bases and heights being the diameter and focal distances. Therefore the ratio of focal length to diameter is the same for all lenses, which is the named the f/#.

It is for this reason the f/numbering system was adopted to characterize the light-gathering power of an optical system, as an f/# of four collects the same amount of light into the image no matter what the focal length of the lens may be.

f/#'s

f/1	f/1.4	f/2	f/2.8	f/4	f/5.6	f/8	f/11	f/16
f/22	f/32	f/45	f/64	f/90	f/128	f/180	f/256	f/...

This is the typical set of f/#'s found on camera lenses, although this whole range is hardly ever utilized. There are inbetween numbers, as there could be any focal length/diameter ratio. The largest opening, typified by the lowest number of a lens is called its **speed**. For instance, a 50mm f/1.4 lens may come standard with a 35mm camera, and its f/#'s will range from 1.4 to 16, While a 210mm lens for view camera work will have stops from 5.6 to 90.

The light-gathering power of the lens is dependent upon the area of the circle formed by the aperture. To cut down the intensity of light by a factor of two, (to be able to reciprocate with the doubling and halving of shutter speed times on cameras), the area must be changed by a factor of two, which does not mean changing the diameter (or radius) by a factor of two but by a factor of the square root of two! The reader is asked to compute some examples to prove it to themselves.

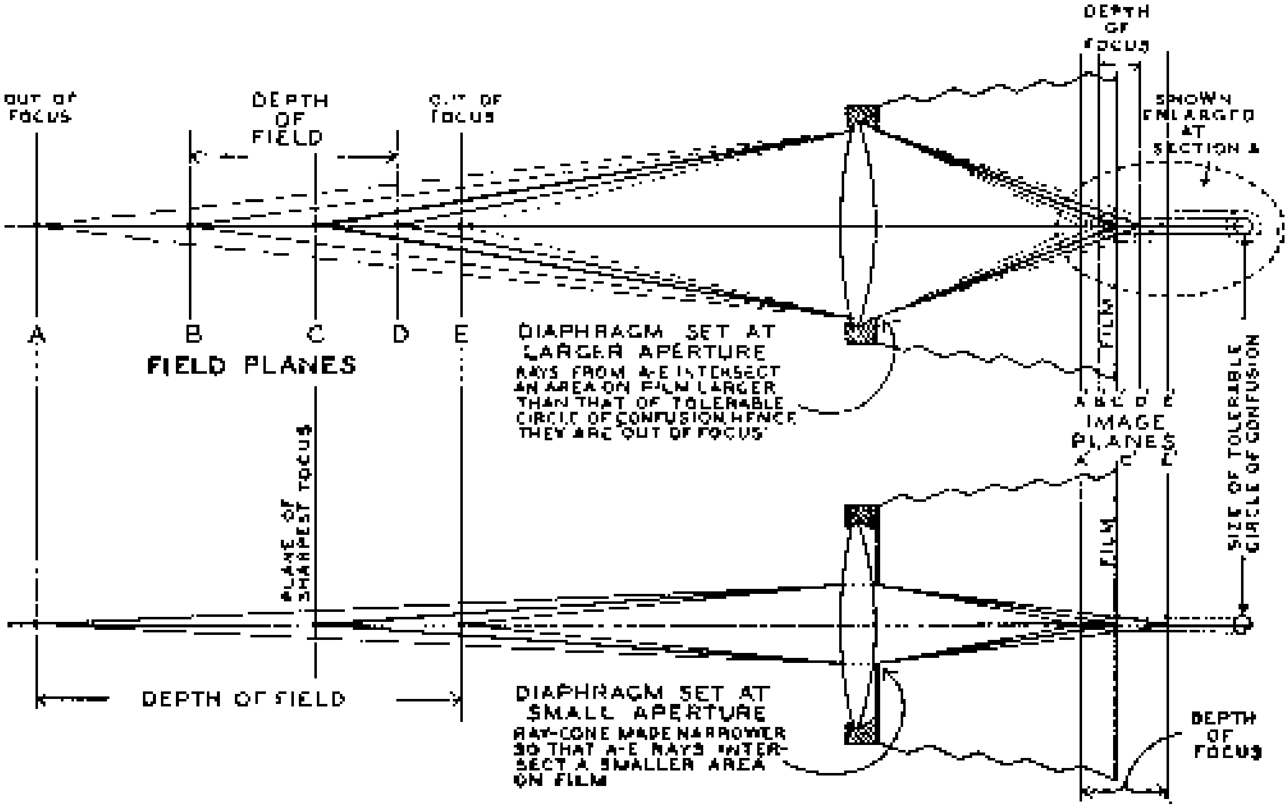
Oftentimes when photographing with bright light sources in the scene interesting rainbow patterns may appear. Close inspection may find images of the iris, often polygonal, with spectral projections emanating from the corners, caused by diffraction effects of the aperture.

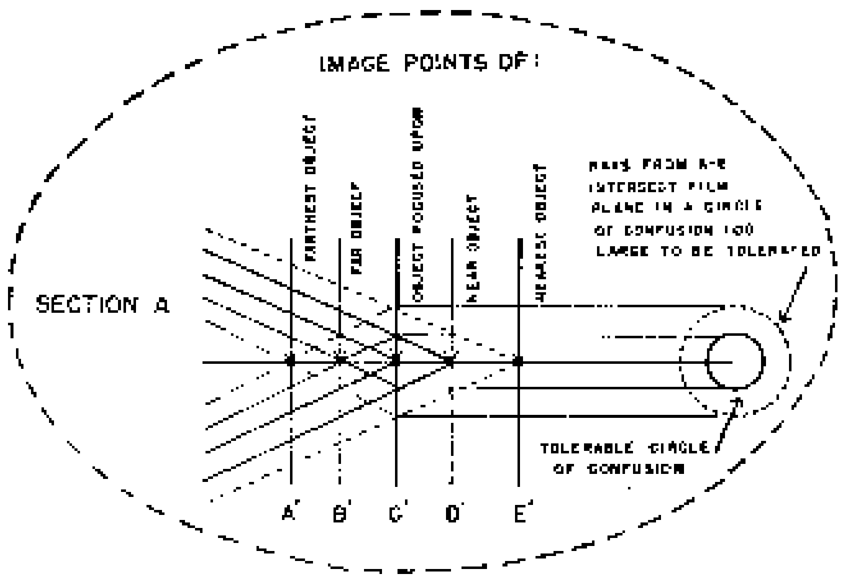
Diaphragms are useful for getting rid of junk around laser beams, and controlling illumination in microscopes. They are hardly ever used in projection lenses, but are important in photographic enlargers.

Bare irises are available from the **MAJOR OPTICAL MANUFACTURERS**[1], **MMK Surplus**, and sometimes found in bins at **American Science & Surplus**, and **Darkroom Aids**.

1. See the **Handout, SOURCES**.

Figure Five shows the component parts of a large broken diaphragm; these were shed when this thing hit the floor. As a mechanism this size costs about a hundred dollars to replace. The individual stamped spring steel blades have a graceful arc shape; when they overlap each other they make a twenty-sided polygon.





If the focused object distance is u, the focal length of the lens is F, the diameter of the lens aperture is A, and the "circle of confusion" on the film (which is a circle so small as to be indistinguishable from a point) is c', then the near and far depths of field are given by:

(*Continued on following page*)