ADJUSTING DEPTH-OF-FIELD — Part II

by Harold M. Merklinger
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In my first article ("Adjusting Depth of Field", *Shutterbug*, October 1991) I tried to raise the question of whether the tried-and-true wisdom on depth of field is still appropriate for today's high resolution films and lenses. The conclusion was that one could expect to achieve about seven times the resolution usually assumed in that wisdom. The standard rules for calculating depth of field can be adjusted to account for the higher resolution standard. But when one makes the changes, depth of field virtually vanishes. And that, in turn, does not square with my experience.

Setting the lens focus closer to infinity generally yields significant improvement in the resolution of distant subjects. Subjects well inside the calculated inner limit of depth of field, however, seem often to be imaged in a satisfactory manner. I also tried to debunk some of the myths associated with depth of field: things like the one-third rule, and the misleading apparent accuracy of depth of field tables.

In Part 2, I would like to explain why it is that subjects inside the calculated inner limit of depth of field can sometimes be rendered acceptably well in our images. It does not happen all the time. But it is quite possible to figure out when it will happen, and when it won't.

Before we launch into the main theme, though, please let me explain two errors in the October '91 article. Many readers noticed one of them; noone has yet reported the second. Figure 2, showing the depth of field and focusing scales for a 50 mm lens set at the hyperfocal distance for f/8, was not right. In order to make the diagram more compact, the layout people at Shutterbug cut my figure in two and rearranged the two scales! It's true! Ask our editor. Figure 1 of this article shows what that original Figure 2 should have looked like.

The other error was not strictly mine either, but I should have checked my facts first. I stated that for my 200 mm Micro-Nikkor, set at f/5.6 and focused at infinity, the depth of field table says the zone of acceptable sharpness extends from 1929.22 meters to infinity. It is true that the table I consulted (in a book on Nikkor lenses) said exactly that. But near as I can figure, that table is really for a 600 mm lens, not a 200 mm lens. When I calculate the number for myself, I get the distance to be 215 meters (about 700 feet)—just like the actual instruction book which came with the lens says. I should have checked the numbers.

The fact remains, however, that specifying any depth of field limit to three significant figures (never mind six) is usually excessive except in close-up photography. The effect simply is very seldom that critical—as we shall see.

Back to the main topic at hand. In Part 1 it was stated that our beautiful model—1929.22 meters in front of our lens (well, maybe 700 feet)—could walk significantly closer to the camera and we would not be able to see much difference in the image in the viewfinder. Or, in fact, in our prints. A lens focused at infinity has a unique characteristic. The ability of such a lens to resolve a particular subject is the same, no matter how distant the subject is from the lens. Our model could walk right up to our camera and our ability to discern her features would be essentially the same as if she were at thirty feet, a hundred feet or seven hundred feet. For the longer distances diffraction effects will cause some additional deterioration, of course.

The traditional methods for calculating depth of field concentrate on image sharpness. That is, things are measureed on the film. The image of a distant person is much smaller than that of a person close at hand. Measured in the image, a lens focused at infinity produces a sharper, more detailed image, more dots per millimeter, the farther the subject is from the camera. Measured relative to the subject, however, the case is quite different. If we can resolve the pupil in our model's eye when she is at 20 feet, we will still be able to see the pupil of her eye at a hundred feet, and probably also at 700 feet. We can also discern the pupil of her eye at ten feet or five feet. Her eye might fill the entire frame at close distances, but we'll still resolve the pupil. For the pictures taken close up, the image will not be as sharp as it could be if we were allowed to refocus, but it is still sharp enough to resolve the same features it resolved at greater distances.

The question is, then, how can we determine what any given lens will resolve in the object space? What details of the subject, what facial features, what size pebbles on the ground etc.? For a lens focused at infinity, the answer is dead simple. Look in the front of your lens and close down the diaphragm to the f-stop you are intending to use. The size of the diaphragm opening you see is the approximate size of objects which that lens will resolve when focused at infinity. If the working lens opening is something like three milli-

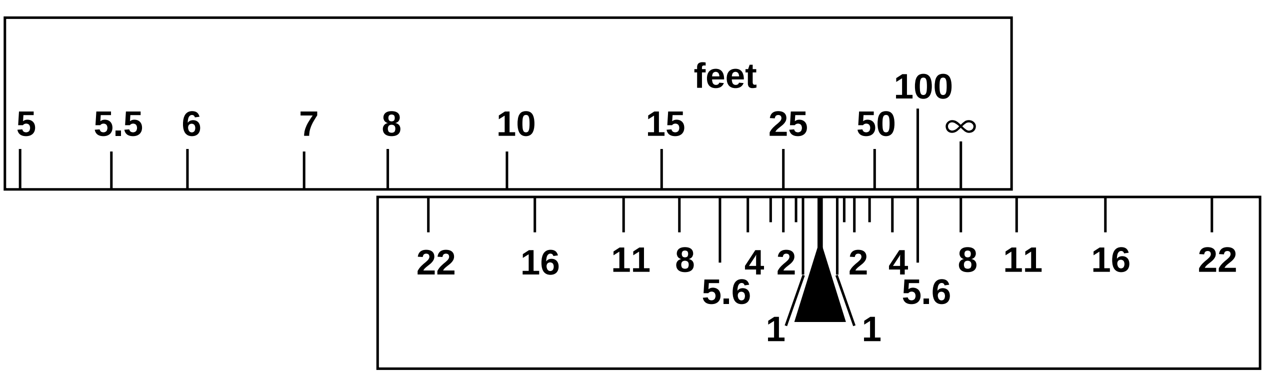

Figure 1: Here's what Figure 2 from my October '91 article should have looked like. These are the distance and depth of field scales for a 50 millimeter lens set at its hyperfocal distance for f/8.

Figure 2: Here are three pictures of my sister-in-law taken with three different lenses: a 24 mm, a 50 mm and a 100 mm, all focused at infinity. Each lens is set for a 6 mm diameter aperture. The results are all quite similar!

meters in diameter, we will be able to see the pupil in people's eyes. If the opening is larger, 25 millimeters for example, we might be able to measure the distance between the eyes, but that's about it.

As noted earlier, diffraction effects also limit resolution. We can indeed calculate what size an object must be if it is to be seen at all. We won't go into the details here, but I'll give an example. For a 50 millimeter lens set at f/10 (that is, for a 5 millimeter diaphragm opening) the smallest object which diffraction effects will permit us to see will have a characteristic size equal to about one-eight-thousandth of the distance from lens to subject. At 8,000 feet (about 1.6 miles) a 50 mm f/10 lens should be able to resolve an object one foot in diameter. Another way to express relative effects, might be as follows. From right in front of the lens to about a distance of 160 feet (50 meters), resolution will be limited by the size of the lens opening to objects 5 millimeters in diameter and larger. Diffraction is not a factor. Beyond 160 feet, diffraction effects take over and limit resolution to one-eight-thousandth of the distance from lens to subject. All of this is for lenses focused at infinity, of course. And lenses having the same physical or working diameter resolve the world in much the same way, regardless of their focal length.

To demonstrate the effect, I took several pictures of June using three different lenses, but all set to the same physical lens opening. And all were focused at infinity. The three lenses were a 24 mm f/4, a 50 mm f/8 and a 100 mm f/16. In each case that makes for a 4.5 millimeter diameter lens opening. Figure 2 shows some of the results. The signs she is holding show the lens focal length (on the viewer's left) and the distance (in meters) from which the picture was taken. The camera to subject distances were adjusted to keep the image magnification equal. Apart from a gradual decrease in contrast as lens focal length increases, I think you will agree that the three results are very much alike. That dot on her right cheek was put there deliberately to help judge sharpness effects. (It was really a black paper dot eight millimeters in diameter.)

When a lens is focused at infinity, it sees the world as though it had been painted with a brush that would just fit through the lens opening. The bigger the lens opening, the bigger the brush. The smaller the physical lens opening, the finer the brush. In Figure 3, I try to depict the ray geometry involved. The solid lines are intended to show the boundaries of a light ray bundle arriving at the lens from a small light source in the far distance. That light is focused to a tiny bright spot on the film. A small object closer to the camera, at distance D in this diagram, will be focused behind the film, as shown by the dashed lines. The small close object is registered on the film as a circle of light which is larger than it 'should' be. That is, the out-of-focus image is larger than would be a sharp image of the object obtained by stopping down the lens. The out-of-focus image is usually called the circle of confusion. If we were to measure its size and then work out how big the object *appears* to be, we find that the image size corresponds to that for an object at distance, D, the same size as the lens opening! And that fact remains true no matter what the distance, D, is. I know I haven't proved the point here. But trust me; I'm a photographer!

Sometimes it's easier to think of it in a different way. As Paul Rumsey, Shutterbug reader, observed: "Once you look at the camera as a slide projector and the object being photographed as a projection screen, it all becomes easy to visualize!" With the lens focused at infinity, a bright spot on the film would be focused into a parallel beam which shines a bright disk on any object in front of the lens. The size of that disk is the same as the aperture of the lens, no matter what the distance is.

So, the bottom line runs something like this. In order to ensure that distant objects are imaged sharply, we must focus at the distance to the farthest object. Closer to the camera, resolution is limited to objects of roughly the size of the lens diaphragm opening. If the smallest objects in the scene being photographed are larger

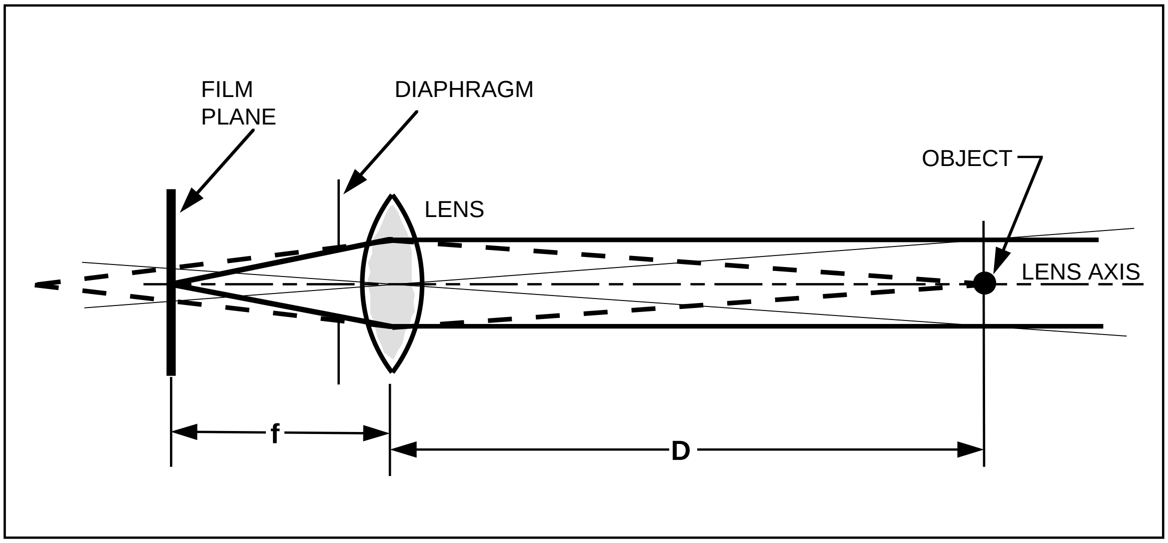

Figure 3: Here's the ray geometry for a lens focused at infinity. An object closer than infinity is focused behind the film. The out-of-focus image produced is larger than if the lens were stopped down further. The fine lines passing through the lens center show that the out-of-focus image corresponds to the sharp image of an object the same size as the effective lens aperture.

than that size, they will be recorded in the image. Objects smaller than the lens opening will be blurred out, no matter what the distance.

Before I understood these matters, I all too frequently focused my lens at its hyperfocal distance. The conventional rule, after all, is "to maximize depth of field, focus at the hyperfocal distance..." Let's suppose I am taking a scenic picture with important objects extending from three feet away to the far distance. I'm using a 50 mm lens, and need to use f/8 in order to permit a shutter speed short enough to stop the blurring of leaves, traffic, people etc. due to motion. According to Figure 1, the hyperfocal distance is about 32 feet, and the "inner limit of depth of field" is 16 feet. For those objects at three feet, changing the point of exact focus from 32 feet to infinity is not going to change things at all. For objects at three feet, 32 feet *is* effectively infinity. The sharpness of objects in the distance will improve noticeably by focusing at infinity, so I do it. If the objects in the foreground are five or six millimeters or so in size, I'm O. K. If the close-in objects are smaller than that and they are important, I have only one option. I must use a physically smaller aperture. Yet at the same time, I have to use f/8. The only solution is to use a shorter focal length lens. If I use a 35 mm lens, objects may be as small as 4 millimeters and show up distinctly in the image. A 24 mm lens would bring this down to 3 millimeters—about an eighth of an inch. Blades of grass should now be clearly visible; that's probably all I need.

In my experience, we humans are interested mostly in other humans. If we can recognize someone in a scenic landscape shot, we say, "Wow, what a sharp picture!" If the image of the person is too fuzzy to identify the person, we say "Could have been sharper." I have found that the magic number seems to lie in the three-to-five millimeter range. With that size lens opening, people are recognizable. With a ten millimeter opening, people are looking decidedly fuzzy. At 25 millimeters, we could probably not differentiate between some family members. At 200 millimeters, we aren't even sure those lumps are people.

Have you ever read that Ansel Adams often used a 300 mm lens set at f/64? Guess what! That corresponds to a lens opening measuring just under five millimeters in diameter!