A few Comments on the Bellows Extension Factor

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(bellows4a.doc)

We all use light meters to determine proper exposures for photography. Some of us use meters that are built into the camera, meters that see the same light that the film will see. But for those who use field cameras or view cameras, with a meter that is separate from the camera itself, the exposure indicated by use of the light meter is valid and will give a “proper” exposure when the camera is focused on infinity. If the focus is not at infinity, an exposure correction is often necessary. This article provides a convenient and reliable method to quickly determine the appropriate exposure correction.

At the infinity focus position, the ground glass (or film plane) is located at a distance from the lens equal to the focal length of the lens. At that position, for the correct shutter speed and f-stop setting for a given ISO-rated film, the film receives the appropriate amount of light for each square inch of the film to properly expose it if we follow the recommendation of the light meter (and the scene has a typical average grey tonality). But, if we move the film further from the lens (as we do when we focus on something that is closer than infinity), and we don’t change the shutter speed or the f-stop setting, the film will receive less light per square inch when it is at its new position further from the lens and it will be underexposed. We must adjust for this new position of the film plane and we can readily do that by adjusting the shutter speed or the f-stop, but we need a bit of guidance to do that properly. One way is with lots of experience, enough experience so that the required corrections become so automatic that we don’t even think about them. A second way is to do a numerical computation in the field and use the result of that computation. Another way is to do all the possibly relevant calculations in advance and put them in an easily accessible form, a form that removes guess-work and results in a proper exposure. We will take this third approach here.

But, to begin, let us take a minute or two to understand why we need to make this correction. In the figure below, we have sketched a side view of the position of the film plane in the back of a camera for a situation where, for example, a camera has been focused at infinity. The scene is to the left and the film to the right. The straight line paths of light that reach the extremities of the film (the top and bottom of the sheet of film that is viewed edgewise), are shown as two solid lines. Where the solid lines cross at a point represents the position of the lens on the front of the camera. All the light between the two solid lines strikes the film. We have shown the path the light would take beyond the film (if the film and back of the camera were not present) as dashed lines and have shown the light ray that hits the center of the film as a horizontal dashed line.
Now, if we move the film further from the lens (to focus on something closer to
the camera than before), some of the light from the field of view of the lens that
previously hit the film and helped to expose it will miss the film. Since the size of the
sheet of film has not changed, if the film was previously properly exposed, when we
move the film it will be underexposed because it will not get enough light. This situation
is shown in the figure below where the film is further from the lens that it was previously.

Figure 1: Illustration of a field camera focused on a scene at infinity

So, if the film plane is moved further back, as is necessary to focus on something
closer than infinity, and there is no change in the aperture or the shutter speed, the film
will receive less light than is necessary to properly expose the film. Thus, the exposure
time and/or lens opening must be increased to compensate. For any lens, the amount of
compensation required depends on the new position of the lens relative to the position of
the lens for infinity focus. Light meters that are not “through the lens” provide an f-stop
and shutter speed combination in anticipation of focus at infinity (and uniform 18% grey
in the scene). If the camera is not focused on infinity (or close to it) we need a correction
for the meter reading to get proper exposure.

The required exposure correction depends in a relatively simply way on the new
distance between the film plane and the lens compared with the old distance between the
film plane and the lens when the focus was at infinity. This correction factor is
traditionally termed the bellows correction factor, or the bellows extension factor, the
bellows factor, or simply the exposure factor. Although we will not dwell on the
mathematics, the relationship is that the exposure factor is given by the ratio of the square
of the new lens to film plane distance to the square of the old lens to film plane distance.
This can be readily computed in the field, but doing this in advance and keeping a plot of
the results handy makes things a bit more convenient when in the field. The proper correction factors (called exposure factor in the plot) for several lenses with focal lengths from 90 mm to 305 mm are shown in the plot below as a function of the distance between the center of the lens and the position of the film plane (ground glass).

**Figure 3**: Exposure factors as a function of the lens center to film plane distance for a range of lenses of focal length from 90 mm to 305 mm, as might be commonly used for photography with a 4 x 5 camera.

To use the figure, one measures the distance from the ground glass to the lens and reads the correction factor from the plot. So, all that is required in the field is a ruler and a copy of the plot. As an example, suppose we are using a lens with a focal length of 150 mm. For such a lens, the infinity focus has the film plane at a distance that is 150 mm (i.e. 5.91 inches) from the center of the lens. For this situation the 150 mm line meets the lens to film plane distance axis at 5.91 inches and the exposure factor is 1.0 since no correction is needed. Next, if we focus on an object in a scene that is closer to the camera, there will be a new, larger, distance between the film plane and the center of the lens. For example, suppose the new position of the film plane is 9 inches from the center of the lens. In this case, making reference to the figure, we read the correction factor by
moving along the line labeled by 150 mm until we reach a point directly above the distance of 9 inches. We then read from that point (on the 150 mm line) horizontally back to the left and find the exposure factor to be about 2.3. This means that we must admit 2.3 times the amount of light anticipated by the light meter to get a proper exposure. So, if the original shutter speed was 1/30 sec at, say, f/16, we need to increase the exposure. And, we need make the exposure a bit more than double what the meter reading gave us. Since shutter speeds are discrete, we may not be able to correct this perfectly by shutter speed alone, and that is the case in this example. So, in this case, with a factor of 2.3 we shift the shutter speed by a factor of two to 1/15 sec and we shift the aperture a bit more open, say from f/16 to almost half-way between f/16 and f/11. This gets us close to the required correction of 2.3, close enough for a good exposure. If we were to make no correction, the film would be underexposed by more than one stop. (An exposure factor of 2 represents a factor of two in the amount of light, i.e. one stop, or in other words, one zone.)

As noted at the beginning, many cameras have exposure meters that account for this correction. And, it is the case that for small format cameras the changes in distance between the lens and the film plane are often rather small. But, for those who use field or view cameras, the use of a plot like this helps to avoid exposure errors in the field and is very convenient.