PHOTOGRAPHIC OBJECTIVES #4: MACROPHOTOGRAPHIC LENSES, BELLOWS, EXTENSION TUBES AND SUPPLEMENTARY CLOSE UP ATTACHMENTS

The screw thread mechanisms of most photographic lenses focus close enough to fill their format's image area with the most favorite photographic subject, head and shoulders of a person, which is a magnification of about 1/8th. To focus on an object closer than that, the image distance needs to be increased.

Spacers that fit between the camera body and the lens for most manufacturer's mounts are available to move the lens further from the image plane. By increasing the image distance, the object distance decreases, allowing the photographer to move in closer for a larger image of a smaller object.

As an example, Mamiya offers three extension tubes for the 645 camera: 11.8, 23.6 and 35.4 mm. Using the simple lens formula the working distance of the 80 mm normal lens (this distance is the longest object distance of the combination with the prime lens focused at infinity) can be calculated.

The 80 mm normal lens focuses from infinity on down to 700 mm with its built-in screw thread. At infinity, the image distance is 80 mm, as this is the definition of focal length. Solving the simple lens formula for image distance when object distance is 700 mm yields 90 mm. This gives a change in image distance of 10 mm to when the object distance goes from infinity down to 700 mm. This can be verified by measuring the extension of the lens as it is focused through these extremes of its range.

Adding the 11.8 mm extension tube gives us image distances of 91.8 for far, 101.8 for near, giving an object distance range from 622 mm to 370 mm, with magnifications of .14 to .28. (Magnification of .14 means a 100 mm sized object becomes a 14 mm sized image at the film plane.)

Running the numbers for the 23.6 mm extension tube, the image distance range extends from 103.6 to 113.6 mm, object distances of 351 to 270 mm respectively, with .30 to .42 times magnification.

Similarly for the 35.4 mm extension tube, image distance varies from 115.4 to 125.4 mm, object distance from 260 to 220 mm, magnification from .44 to .56 X.

With all three tubes stacked together, for a combined extension of 70.8 mm, plus the 10 mm that the lens racks out itself, the image distances grow from 150.8 to 160.8, the latter being twice the focal length which means the object distance is also twice the focal length for exact 1:1 object/image size! With the lens focused at its retracted infinity position the magnification is still a decent .88.

The math for using other combinations of these tubes, or in conjunction with other lenses, is, as they say in the math books, an exercise left to the reader[1]. The basic rule of thumb is that more extension lets the photographer move in closer, and the effect of the tubes is greater on shorter focal length lenses. There may be some odd combinations that don't work mechanically, or perhaps vignetting will occur, where the image is smaller than the film format, making dark corners.

These **extension tubes** or **rings** don't introduce any more optical elements into the image forming path, so the only aberrations that show up are due to the prime lens itself. Lenses can be designed to work perfectly at one conjugate distance, and performance deteriorates at other distances. Typical camera lenses are designed to work best at long object distances. Whatever happens outside this range is not necessarily a priority of the lens designer, and the addition of the extension rings to decrease object distance may show surprising image degradation.

There are lenses that are designed to work at close distances, called **macrophotographic objectives,** or **macro** for short. The conjugate distance their performance is peaked for is 1:1 life size or thereabouts, yet still deliver acceptable images in the far field.

In order for the lens to work from near to far the focusing mechanism must have a rather long screw thread arrangement. For 1:1 imaging, the lens must be extended to twice its focal length from the image plane, and in the case of the Mamiya 120 mm macro lens, this would be 240 mm, about 9½"! Just another reason why these lenses are so expensive.

A **bellows attachment** allows continuously variable image distances as opposed to the jumps of the extension rings. When collapsed to its shortest dimension, the mounting hardware adds 40 to 60 mm to the image distance, so a typical camera lens mounted on the bellows loses its ability to focus on infinity. The focusing range starts at a decent magnification, perhaps .5 or .75, and then with the bellows racked out fully the magnification might grow to 3 or 4 times life size with a normal lens in position!

There are some lenses in a camera system that do not have a focusing thread but rely upon being used solely on the bellows. These **bellows lenses** are usually the same optical system that comes packaged in the macro lens with its focusing mount. It adds an old-fashioned view camera feel to a roll film body. To feel even more retro, there

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[1] Or you can go to Mamiya.com for the particulars. If I would have went there first, I wouldn't have had to do the math! But my numbers match up to theirs quite nicely!

may not be a mechanical or electronic linkage to the lens from the camera body, so all exposure adjustments might have to be made totally manually.

On the better bellows the camera and lens mounts might move on the rails independently. Moving either one of them can deliver the proper focus. Even more deluxe are provisions to move the whole bellows and camera assembly as a unit on the tripod. Focusing could be done by moving the whole system at once, changing the object distance, which preserves the magnification ratio.

As an example, the correct lens to film distance is set for 1:1 magnification. Then the whole unit is moved closer or further from the object unit it is in focus, and not changing the image size.

A problem that occurs with either the tubes or the bellows devices is that the exposure needs to be compensated. The f/number of a lens is defined as the ratio of the image distance divided by the diameter of the lens. Usually this speed number is calculated when the lens is focused at infinity. This is the closest that the lens ever gets to the image plane, and yields the lowest f/number.

As the lens is focused on closer objects, the image distance increases, which yields an increasingly larger f/number for a given aperture size. For instance, with an 80 mm lens set at f/8 the aperture's diameter is 10 mm when it's focused at infinity. (Image distance = focal length at infinite object distance.) When the lens is focused at its closest, 700 mm, image distance is 90 mm, so the 10 mm aperture which was rated at f/8 now becomes f/9, which is less than 80% of the original intensity, or a third of a stop! By the time you focus down to 1:1 life size with this lens, the image distance is twice the focal length, 160 mm, so the 10 mm aperture now is a measly f/16! A loss of two stops!

A through the lens light meter may or may not automatically compensate for this effect, depending on whether or not the mechanical and electrical connections from the camera body to the lens are preserved. The less expensive devices probably don't, so compensation may have to be done manually in the stop down metering mode.

Light meters that look at the film while it is exposing to determine the exposure time will automatically take care of this problem. But if you are using an incident light meter at the subject plane to determine exposure for flash or flood light there will be a need to take into account the lens extension.

Exposure milestones along the way are at infinity, no compensation; at .4 reproduction ratio (100 mm object reduced to 40 mm image) one full stop compensation; at 1:1 ratio two stops. When the image is tripled life size 4 stops are necessary to compensate, and after that you are intruding into the range of microscopes.

Because it is harder to keep the aberrations under control near the unit magnification mark, macro lenses are usually of moderate speed, like f/3.5 – 4. F/2.8 is speedy for a macro.

At high magnification, depth of field for a given f/stop becomes quite shallow. The minimum f/stop is down at 22 or even 32. Be prepared for long exposure times when doing close-ups!

When non-macro lenses are used in the close up mode with bellows, especially at greater than 1:1 ratios, the preferred mounting orientation is with what is normally the output side of the lens (film side) towards the object. This is necessary because lenses are designed to work in certain focusing regions, with a normal lens doing its duty with a large object distance and a short image distance. But when the image distance becomes greater than the object distance at high magnifications, those roles are reversed and so is the lens orientation.

A different tact to moving in close is to add a supplementary lens on the front of the prime lens of the camera. They are positive lenses, and the action starts when the object is placed one focal length from the lens.

An object placed one focal length from the lens will have rays that come out parallel; Case 4, **IMAGE AT INFINITY CONJUGATE DISTANCE** in OPTICAL ENGINEERING NOTE #9 earlier in this Chapter. To capture this image formed at infinity, the prime lens is focused at infinity. As the combination is moved closer to the object to make it bigger, this close up lens moves into a Case 5 situation, **NEGATIVE CONJUGATE DISTANCE**, producing a magnified virtual image, and the prime lens needs to follow focus until it runs out of adjustment.

The close-up attachment lenses usually give their focal length not in mm but in diopters like the eye doctors. The focal length can be found by dividing the diopter number into 1000 (mm in a meter.) A #2 (500 mm) works well, picking up with its furthest focus at 500 mm, about where the close focusing ends with a typical 50 mm normal lens on a 35 mm camera. Other diopters are available, with a #10 being the strongest that can be found.

With the #2 CU Lens screwed on to a 50 mm normal lens, the closest focus is at 500 mm, and the magnification ratio is the ratio of the focal lengths, 50/500, or .1. The close focus is dictated by the close focus of the prime 50 mm lens, 600 mm. The camera is moved close enough to the object so that the close up lens forms a virtual image at 600 mm. For this image distance, the object distance is 270 mm. The

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magnification of the object by way of the close up lens is 2.2 X life size.

But following that image is the prime lens focused at 600 mm, which provides a 1/11 life size image, so the combined magnification is 1/11 X 2.2 = .2 life size, twice of the unaided lens, still respectable!

The disadvantage of using a supplementary closeup lens is the introduction of aberrations from the attachment. Stopping down and not putting important subjects in the periphery of the frame helps. The beauty of it is that all mechanical and electronic connections from the body to the lens are preserved, and there is no f/stop compensation necessary. This is one must have accessory, as it takes up next to no space in the camera bag without lightening the wallet too much!

An even cheaper but quick and dirty technique to move in close to an object is to take the lens off the camera, and hold its front element against the body! It is kind of a corollary to the notion a few paragraphs above of using the normal lens backwards on the bellows attachment. The range of focusing distances and magnifications are limited, but it still can help in a pinch!