CALCULATIONS FOR ENLARGEMENTS & REDUCTIONS

This handout is designed to help you learn to calculate *magnification (reproduction percent)* and exposure time when an original must be enlarged or reduced.

Magnification

If an original is 8″ wide and must be reproduced 4″ wide, the process camera or scanner must be set to reduce the size of the image. On a process camera, this involves moving the distances between the lens and copy and between the lens and film. On most process cameras, the copyboard and lensboard can be positioned according to graduated scales that indicate the percentage of enlargement or reduction. On some process cameras, the vacuum back and lens board are moved. On scanners, the reproduction size is set either through adjustment of the scanner or through the use of software controls. In any case, the percentage of enlargement or reduction is called *magnification.*

Magnification is calculated according to the following formula:

$$\text{Magnification} = \frac{\text{Reproduction size}}{\text{Original Size}}$$

Example 1: What is the magnification if a 3″ wide original is reproduced at 7″ wide?

$$\text{Magnification} = \frac{7}{3} = 2.33$$

The 2.33 must be represented in terms of percent. To find the corresponding percent, move the decimal point 2 places to the right. 2.33 is 233%.

Example 2: What is the magnification if a 10″ wide original is reproduced at 4″ wide?

$$\text{Magnification} = \frac{4}{10} = .40 = 40\%$$

Mathematically, the basic magnification formula can be expressed in several ways. These additional expressions allow you to calculate original size when reproduction size and magnification are known or reproduction size when you know magnification and original size.

$$M = \frac{R}{O} \qquad R = M \times O \qquad O = \frac{R}{M}$$

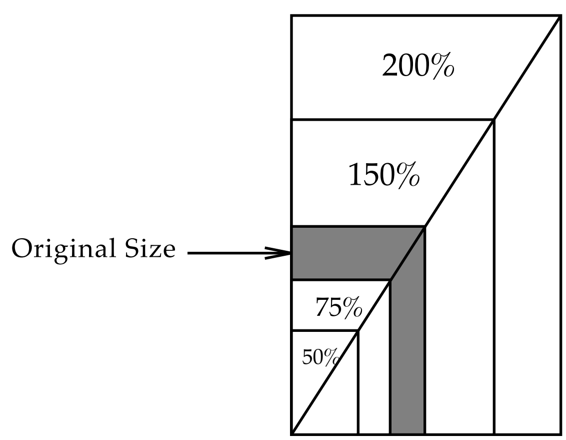
Example 3: What is the original size if the magnification is 150% and the reproduction size is 11″?

$$O = \frac{R}{M} = \frac{11}{1.50} = 7.3''$$

Example 4: What will the reproduction size be if the magnification is 80% and the original size is 9″?

$$R = (M \times O) = (.80 \times 9) = 7.2''$$

When enlarging or reducing images on a process camera, a change in the reproduction percent of the width will result in a corresponding (and proportional) change in the length. A good way to visualize the proportions of an enlarged or reduced image is to use the *diagonal line method* as shown below.



Desktop computers and high-end scanners can change widths and lengths of originals independently so that the final reproduction has proportions different than the original. Although this may be of some artistic value, its use should be limited because it distorts, and sometimes confuses, the intent of the original image.

Example 5: What will be the final length of an image reduced proportionately if the original is 8 X 10″ and the width of the reproduction is 3″?

$$\text{Magnification} = \frac{3}{8} = .38 = 38\%$$

$$R = (M \times O) = (.38 \times 10) = 3.8''$$

In this case, the final reproduction will be 3 x 3.8″.

Bellows extension

When making enlargements or reductions, the distance between the film and the lens must change. The closer the lens is to the film, the smaller the resultant image. The distance between the lens and the film is called *bellows extension* and is a very specific distance that depends upon the focal length of the lens.

If you set the process camera at 100%, measure the distance from the lens to the vacuum back, and divide that measurement by two, the result if the *focal length.* The focal length is usually engraved on the barrel of the lens. As an example, the Argyle camera has a focal length of 210 mm (± 8 1/4″). So, when the camera is set to 100%, the distance from the lens to the vacuum back is (2 x 210 mm) 420 mm. The bellows extension is calculated by dividing the distance between the vacuum back and the lens by the focal length of the lens. In this case 420/210 = 2, so the bellows extension is 2.

If the camera is set to any size other than 100%, the film-to-lens distance will not be 420 mm, so the bellows extension will not be 2. To determine the bellows extension at magnifications other than 100%, use the following formula:

$$\text{Bellows Extension} = \text{Magnification} + 1$$

Example 6: What will the bellows extension be if an 8″ original is reduced to 3″?

$$BE = M + 1$$
$$BE = 3/8 + 1$$
$$BE = .375 + 1$$
$$BE = 1.375$$

To find the actual distance between the lens and the vacuum back, multiply the bellows extension by the focal length of the lens:

$$1.375 \times 210 \text{ mm} = 288.75 \text{ mm}$$

288.75 mm is less than the 420 mm lens-to-vacuum back distance that occurs when the camera is set to 100%. *Therefore, the lensboard will be closer to the film when reductions are made than when same-size reproductions are photographed.*

Example 7: What will the bellows extension be if a 2″ original is enlarged to 4″?

$$BE = M + 1$$
$$BE = 4/2 + 1$$
$$BE = 2 + 1$$
$$BE = 3$$

To find the actual distance between the lens and the vacuum back, multiply the bellows extension by the focal length of the lens:

$$3 \times 210 \text{ mm} = 630 \text{ mm}$$

630 mm is greater than the 420 mm lens-to-vacuum back distance that occurs when the camera is set to 100%. *Therefore, the lensboard will be farther away from the film when enlargements are made than when same-size reproductions are photographed.*

Copyboard extension

Similarly, the distance between the lens and the copyboard changes when enlargements or reductions are made. This distance is also dependent upon the focal length of the lens. When the camera is set to 100%, the copyboard extension, like the bellows extension, is two focal lengths. For the Argyle camera, 2 x 210 mm = 420 mm.

To find the copyboard extension for sizes other than 100%, use the following formula:

$$\text{Copyboard Extension} = \frac{1}{M} + 1$$

Example 8: What will the copyboard extension be if an 8″ original is reduced to 3″?

$$\text{Copyboard Extension} = \frac{1}{3/8} + 1$$

$$\text{Copyboard Extension} = \frac{1}{.375} + 1$$

$$\text{Copyboard Extension} = 2.67 + 1$$

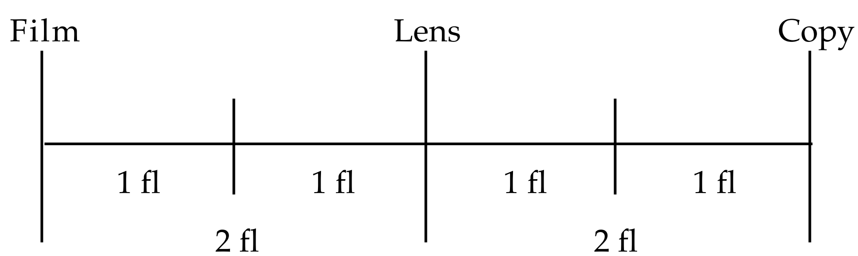
$$\text{Copyboard Extension} = 3.67$$

Like bellows extension, to find the actual distance between the lens and the copyboard, multiply the copyboard extension by the focal length of the lens:

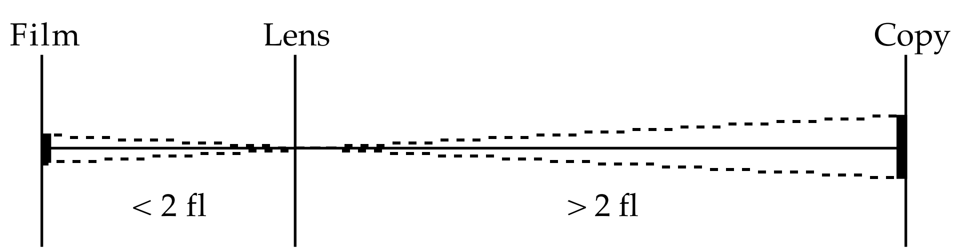
$$3.67 \times 210 \text{ mm} = 770.7 \text{ mm}$$

770.7 mm is more than the 420 mm copyboard extension when the camera is set to 100%, so *the copyboard is farther away from the lens for reductions than for same-size reproductions.*

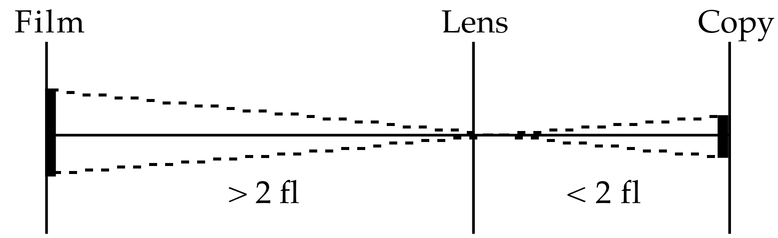
Relationship between bellows extension and copyboard extension for same-size, reductions and enlargements



same-size



reduction



enlargement

Camera extension (camera ratio)

Camera extension, also called camera ratio, is the number of times the diameter of the aperture falls into the bellows extension. This gives an indication of the strength of the light reaching the film: the higher the camera extension, the weaker the light reaching the film.

Camera extension is found using this formula:

Camera extension = bellows extension x *f:*stop

Example 9: What will the camera extension be if a 10″ original is reproduced at 14″ on *f:*22?

Camera extension = bellows extension x *f:*stop
Camera extension = (M + 1) x 22
Camera extension = [(14/10) + 1] x 22
Camera extension = (2.4) x 22
Camera extension = 52.8

Example 10: What will the camera extension be if a reproduction is made same-size on *f:*22?

Camera extension = bellows extension x *f:*stop
Camera extension = (1 + 1) x 22
Camera extension = (2) x 22
Camera extension = 44

Example 11: What will the camera extension be if a 20″ original is reduced to 10″ on *f:*22?

Camera extension = bellows extension x *f:*stop
Camera extension = (M + 1) x 22
Camera extension = (1.5) x 22
Camera extension = 33

Note that the camera extension number is larger for enlargements than for same-size. Also note that the camera extension number is smaller for reductions than for same-size and that the camera extension is smaller for reductions than enlargements. Recalling that the higher the camera extension number the weaker the light reaching the film, enlargements provide the film with weaker light than same-size or reductions. Conversely, reductions provide the film with stronger light than same-size or enlargements. Obviously, in order to maintain proper film exposure and density, the exposure time must be changed to compensate for the varying strength of the light reaching the film when making enlargements or reductions.

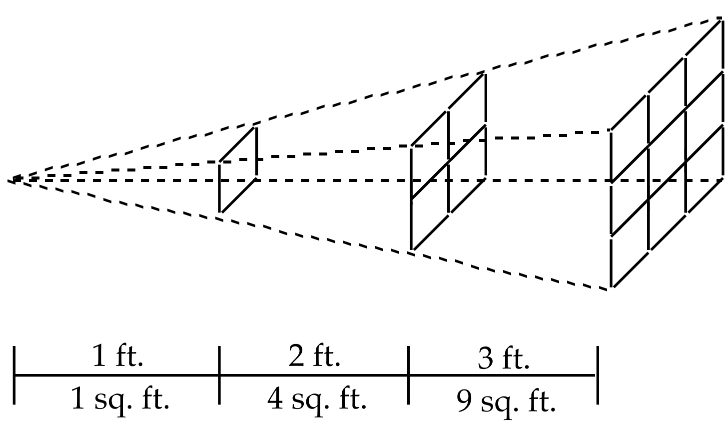
Calculating exposure for enlargements and reductions

Because the strength of the light reaching the film varies when enlargements or reductions are made, as demonstrated by varying camera extension numbers, exposure adjustments are necessary to maintain proper film density. There are two ways to make this adjustment:

- Increase or decrease exposure time as necessary;
- Open or close the aperture of the lens (to admit more or less light) using the *equivalent stop* method.

Varying exposure time

When light travels, it spreads out equally in all directions as illustrated below.



The drawing illustrates that light spreads out in a squared relationship to the distance it travels:

1 ft travel = 1^2 ft. = 1 sq. ft. 2 ft travel = 2^2 ft. = 4 sq. ft.

3 ft travel = 3^2 ft. = 9 sq. ft. 4 ft travel = 4^2 ft. = 16 sq. ft.

If the light travels three feet and spreads across nine square feet, the light reaching each square foot is only one-ninth as strong as the light travelling only one foot. This relationship is called the *Inverse Square Law of Light.* This law is stated:

> *This intensity of light is inversely proportional to the square of the distance it travels.*

This can also be expressed in an equation as:

$$\text{Intensity} = 1/D^2$$

When exposing enlargements or reductions, the distance between film and lens, as expressed by the camera extension, changes the strength of the light reaching the film. The camera extension varies according to the bellows extension, while the strength of the light reaching the film varies according to the inverse-square law.

To find the equivalent exposure to properly expose film when making enlargements or reductions, use the following formula:

$$\text{Equivalent exposure time} = \frac{(\text{new bellows extension})^2}{(\text{bellows extension at 100\%})^2} \times \text{exposure time at 100\%}$$

Example 12: What will the equivalent exposure time be if an original is reproduced at 200% of its original size and the exposure time at 100% is 20 seconds?

$$\text{EET} = \frac{(M + 1)^2}{(2)^2} \times 20 \text{ seconds}$$

$$\text{EET} = \frac{(2 + 1)^2}{(2)^2} \times 20 \text{ seconds}$$

$$\text{EET} = \frac{(3)^2}{(2)^2} \times 20 \text{ seconds}$$

$$\text{EET} = (9/4) \times 20 \text{ seconds}$$

$$\text{EET} = 45 \text{ seconds}$$

Example 13: What will the equivalent exposure time be if an original is reduced to 40% of its original size and the exposure time at 100% is 50 seconds?

$$EET = \frac{(M + 1)^2}{(2)^2} \times 50 \text{ seconds}$$

$$EET = \frac{(.40 + 1)^2}{(2)^2} \times 50 \text{ seconds}$$

$$EET = (1.96/4) \times 50 \text{ seconds}$$

$$EET = 24.5 \text{ seconds}$$

As shown by the examples above, exposure time must be increased when enlargements are made. For reductions, exposure time must be reduced. These relationships correspond to the previous statements concerning camera extension:

- *Enlargements = higher camera extension number = weaker light = more exposure time*
- *Reductions = lower camera extension number = stronger light = less exposure time*

Equivalent-stop method

Instead of increasing or decreasing exposure time, the lens aperture can be opened to let more light in or closed to let in less light. The amount of opening or closing is called *equivalent stop.* Equivalent stops are shown on one line of the *f:*stop indicator on the Argyle camera.

To calculate the equivalent stop, use the following formula:

$$\text{Equivalent stop} = \frac{\text{(camera extension at 100\%)}}{\text{(bellows extension at enlargement or reduction)}}$$

Example 14: What will the equivalent stop be if an 8″ original is reduced to 4″ on *f:*22?

$$\text{Equivalent stop} = \frac{\text{(camera extension at 100\%)}}{\text{(bellows extension at enlargement or reduction)}}$$

$$\text{Equivalent stop} = \frac{\text{(bellows extension at 100\%)} \times 22}{(M + 1)}$$

$$\text{Equivalent stop} = \frac{2 \times 22}{1.5}$$

Equivalent stop = 44/1.5

Equivalent stop = *f*:29

In the case of adjustable apertures with *f*:stop indicators and pointers, like the lens on the Argyle camera, these calculations have already been done and are shown as magnification numbers on the *f*:stop scales. Using the problem from example 14 above, if you set the magnification on the *f*:22 scale to 50% using the pointer (the reproduction percent in example 14) and observe the location of the pointer on the equivalent stop scale, you will see that it points to *f*:29.

Some cameras have no *f*:stop scales. When using those cameras, either equivalent stop or equivalent exposure time must be calculated.