

# MOTION PICTURE CAMERAS AND LENSES

## THE CAMERA

Cameras are light-tight boxes that admit controlled light only through a lens, creating a series of individual frames as film is moved into place behind the lens. The film is held steady during exposure, and then advanced. Conceptually, motion picture cameras haven't changed for more than a century.

Some critical points:

- Film must be accurately placed, perfectly flat, and remain stationary during exposure for even, focused exposure to occur.
- The timing and accuracy of the aperture must be precise, especially for synchronous sound filmmaking. Even when sound isn't used, any variation in camera speed will affect exposure.
- The camera's moving parts must transport the film at virtually any speed required for the cinematographer's desired effect, without damaging the film.

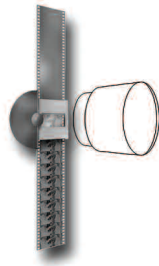


Edison's first movie camera accomplished these objectives. But comparing that camera to a contemporary model would be analogous to Ford's Model T and a Ferrari. Both are automobiles, but their capabilities and precision set them worlds apart. Yet each can be driven to the supermarket when necessary.



Because the basic film formats of 35 mm and 16 mm / Super 16 mm film are universal, a properly working older camera will likely suffice.

To look at the essential components of a motion picture camera, we'll follow the film's path through the camera:



### Lightproof housing

To prevent unintentional film fog, a camera body must be lightproof. Most cameras use a detachable lightproof magazine to hold large rolls of film; e.g., 400 feet for 16 mm or 1000 feet for 35 mm.

### Fixed or Variable-Speed Motor

Motors deliver precise frame rates. This drives the sprocketed wheels of the precision movement. On a more advanced camera the speed is displayed on a tachometer.

### Movement

The precision movement is directly linked to the rotation of the shutter, and manages the flow and timing of the film transport. The film undergoes two exposure cycle phases:

**Advancement**—moving the film from one frame to the next

**Registration**—holding the film rock steady during exposure

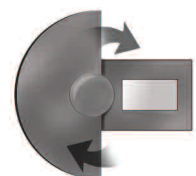
Advancement is controlled by a pull-down claw, which moves the frame that was just exposed beyond the gate, and brings the next frame to be exposed into position. Movement occurs when the shutter is closed.

Registration is controlled by the one or more registration pins that engage a perforation and hold the film steady for exposure. An alternate method uses magnets. Either way, registration is the opposite of movement. Because any film movement will result in a blurred image, it's critical that the film remain still during exposure.

## THE SHUTTER

A camera shutter controls the light reaching the film. The registration pins hold the film completely motionless when the shutter is open and exposure occurs. The shutter is closed when the camera advances the film to position the next frame for exposure.

In motion picture cameras, the most common shutter is a rotating disk with a section removed. The shutter opening is defined as the number of degrees that are removed from a 360-degree disk. A 180-degree shutter—one-half circle—is the most common. Motion picture film cameras have variable rates, but most expose film at 24 frames per second. A camera with a 180-degree shutter allows light to strike the film half the time.



Variable shutter-type motion picture cameras allow the shutter angle to be changed. Decreasing the shutter angle, from 180 to 90, reduces the shutter opening by half, and also halves the exposure time.

There are several reasons for changing the shutter angle:

- A small shutter angle results in a faster shutter speed. Action is stopped and seen clearly. Motion blur is avoided.
- The frequency of some flickering lights, such as older HMIs, require shooting at a 172 degree shutter angle to eliminate flicker.
- Using an electronically adjustable shutter in a ramping shot (where the frame rate changes during the shot) the shutter changes as the frame rate changes in order to compensate for the exposure effect of the speed changes.

## THE GATE

The gate is a metal plate that comes in contact with the film. Its rectangular aperture allows the image to fall only on the picture area of the film. The ratio of the width to the height is called the shooting aspect ratio.

### ***Formats: Gate and Movement***

The gate and the movement of a camera are two of the primary contributors to the film's format. The amount of film that moves through the camera is the same in the 16 mm and Super 16 mm formats, but the gate sizes are different.

In 35 mm cameras the gate and the movement differ. Most 35 mm format cameras advance the film 4 perfs at a time and expose the width of the film and a height of 4 perfs. The gate matches that size. Other camera formats move more or less film and have appropriately sized gates. A 3-perf camera system, for example, advances the film 3 perfs at a time and the gate aperture will only be 3 perfs high. It's important to note that the same 35 mm film is used in each camera; only the movement and camera gate aperture differ.

## THE VIEWING SYSTEM

A viewing system is required so the camera operator can monitor the area of the scene being photographed. There are two basic types of viewing systems: parallax and reflexive.

**Parallax** viewing systems consist of a rangefinder that is attached to the side of the camera. These are most often found on older film cameras. This viewing system does not display the same image that is being exposed through the lens.

**Reflexive** viewing systems display the image that is being seen through the lens. Just as in SLR cameras, the motion picture camera uses a mirror or prism to redirect the light collected by the lens to the operator's viewing system. In this way, the camera person sees the actual image that the film "sees."

Reflexive viewing is accomplished in two ways:

A **prism** is placed in front of the gate and splits any light coming through the lens; the light continues toward the film and into the eyepiece. This system, unfortunately, places one more optical element between light and the film, and this can negatively affect resolution and the amount of light reaching the film.

Most modern cameras use a **shutter mirror**. The mirror is placed on the back of the shutter at an angle that reflects light coming through the lens to the eyepiece. When the shutter is closed the mirror reflects all light transmitted by the lens upward into the viewfinder. This system has less negative effect on exposure and image quality.

### **Video Tap**

Most modern cameras have a video tap or video assist that is used to show a video representation of what is seen in the viewfinder. This is accomplished by splitting the light that is sent to the viewfinder by the shutter mirror or prism.

### **Footage counter**

The footage counter indicates the amount of unexposed film left in the camera. This is usually a dial that indicates how many feet have been exposed from the start of the roll.

### **Camera Code**

Today's more advanced cameras record time code data directly onto the film. This allows the post house to synchronize the sound automatically.

## **THE LENS**

A light-tight box with film in it doesn't require a lens to expose film—even a pinhole camera can capture an image. But a lens can gather more light than a pinhole. A lens can focus and clarify. It's the tool we use to define our image.

Scientists and photographers have studied the lens since the early Twentieth Century. Few will describe any lens as technically perfect, although a lens' unique optical characteristics make it the best choice for a particular shoot.

Lens function is complex. We know that since all visible objects reflect light rays in all directions, we must gather as many rays as possible and get them to our film without distortion. Simple lenses use a single convex glass element positioned so that the light rays from the subject are bent towards and converge at the film. By carefully placing the lens relative to the film, we successfully record an image.

An iris is an aperture of variable size used to control the intensity of light falling on film. The iris control is usually calibrated in f-stops or T-stops. A change of one f-stop or T-stop is equivalent to doubling or halving the intensity of light falling on the film. T-stops are more accurate because they factor for light loss through the lens glasses.

T-stops are calculated by measuring the actual amount of light traveling through the lens and therefore allow for light loss through the lens glasses and are, therefore, more accurate. F-stops are a mathematical estimation of light that will travel through the film aperture.



Simple lenses have a limited ability to focus light. Optical distortions can result when light rays enter from the lens perimeter; those rays have to travel farther to reach the film and will be less focused. To a limited degree we can solve this problem by narrowing the glass width; the resulting loss in light, however, makes the lens “slower.” For each additional stop of light passage in a given lens, the design becomes more complex—the geometric correction becomes more extreme.

Standard, wide-angle, telephoto, and zoom lenses include the ability to adjust focus and iris. Some lenses include a second element, positioned between the first element and the film. Its concave surface compensates for the distortion of the first element. Each element introduces distortion, typically resulting in internal reflection, or flare. The distance between these elements and the precise grind of the glass is critical, and these factors add significant cost to the lens.

An aperture controls the quantity of light passing through a lens. The best lenses perform well at every aperture setting. As such, the precision of the lens must be consistent at every point within each glass element.

Dr. Max Berek of Leitz established image quality standards before 1914 by capturing “miniature” still photographs on 35 mm film. His “circle of confusion” defined the measure of permissible out-of-focus quality in a ten-inch paper photograph. Though modified, this concept endures.

Color is probably the most complex factor in lens design. Because each color has a specific wavelength measured in nanometers, a particular shade has a unique wavelength. Blue objects and red objects will focus in different places on a film frame, whether the film is black-and-white or color. Getting all colors to converge on a single plane despite their different lengths is fundamental to lens design. In 1938 Kodak pioneered the concept of making glass lenses with exotic types of rare-earth elements and cementing them together in each element to correct the aberration.

Zoom lenses were developed later. A good zoom lens must address each of the potential pitfalls while offering the utility of variable focal length. In motion picture applications, the light transmission, sharpness and individual color focus must remain unchanged despite the focal length change within a shot.

## **Focal Length and Focus**

Lenses are identified by their focal length in millimeters and maximum aperture in f-stops (e.g., 50 mm/f1.4 lens). The focal length is defined as the distance from the optical center of the lens to the film plane. The f-stop is calculated from the dimensions of the lens.

## **Focal Length and Angle of View**

The focal length of a lens determines the angle of view, or perspective, seen through the lens. Normal lenses provide a perspective that approximates human vision.

Lenses that are shorter than normal provide a wider angle of view—they are wide-angle lenses. Lenses that are longer than normal provide a narrower point of view and magnify the subject—they are telephoto lenses. Wide-angle lenses make background objects appear further away; telephoto lenses compress distance and make the background appear closer. Thus, moving the camera toward a subject (as in a dolly move) results in a look that is very different from a scene captured by zooming the lens from a stationary camera position. The apparent separation from the background, making objects relatively smaller, makes camera movement less noticeable. Thus, using wider lenses for hand-held scenes is preferable.

## FOCUS

Three important concepts are used in discussions of lens focus: the Circle of Confusion, Depth of Field and Hyperfocal Distance.

### Circle of Confusion

In its simplest definition, circle of confusion is the measure of a permissible out-of-focus quality in a photograph. For instance, a photographic image of a point source of light is not a true point, but a small patch of light. Though, to our eye, it appears like a point. If other point sources were photographed closer or farther away, they might appear as a larger light patch or circle. Circles, that are smaller than 1/1000 inch “confuse” our eye and they appear as points in focus.

Which circle of confusion you use depends on the gauge of the film stock and the lens quality. When using sharper lenses with contrasty lighting, you might use a 1/1000 or 1/2000 inch. Lenses of lower quality or when using effects filters, it is possible to use a larger circle of confusion, such as 1/500 inch.

Depth of field tables use the circle of confusion as part of the calculation.

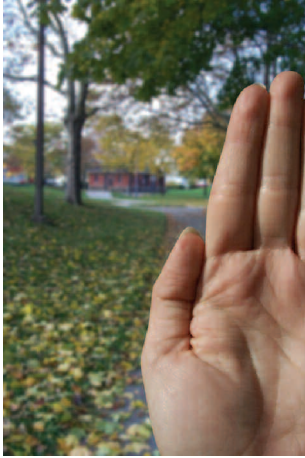
### Depth of Field

Depth of field is the area between the closest and farthest points from the camera that are in acceptable focus. When the focus is set at a given distance, there is a range in front of and behind that distance which remains in focus. The cinematographer must understand how to calculate the depth of field for a given shot, and how to expand and shrink that depth of field, as necessary.

Film systems provide control over depth of field. The naturally shallow depth of field can be easily manipulated to create the look you want. Depth of field is used as a creative tool. In many scenes, there is so much depth of field for the viewer, that it is sometimes difficult to isolate where the audience should be looking. By using depth of field to control the image, you can isolate the character from the background.

There are several ways to determine depth of field:

- Depth of field tables.
- Manual calculators, which allow the user to approximate a depth of field by lining up the parameters on a type of slide rule.
- Computer software can calculate depth of field.
- “Smart lens” devices on some newer cameras show the depth of field directly on a small display mounted next to the lens.



### PARAMETERS THAT AFFECT DEPTH OF FIELD

- Format size or target size
- Aperture
- Focal length
- Distance from camera

To REDUCE the depth of field:

- Use a larger format
- Use a wider aperture
- Use a longer focal length
- Reduce the focus distance (move closer)

Controlling the depth of field helps tell the story by allowing the viewer to focus on key elements of the scene. A large or wide depth of field (deep focus) is used to show the entire scene in focus. By opening the aperture, moving further back, and using a longer lens, the depth of field narrows, and the background and surrounding elements fall out of focus. This effect can dramatize a scene by calling attention to a lone sharp subject, rendering everything behind and in front of that object soft. This effect is often called Differential Focusing.

### Hyperfocal Distance

Hyperfocal distance can be interpreted as the closest focus distance at which both objects at infinity and closer objects are in focus.

Focusing at this point provides the maximum depth of field for specific lens and T-stop combinations. When focused on the hyperfocal distance, the depth of field extends from one-half the hyperfocal distance to infinity.

35 mm CAMERA DEPTH-OF-FIELD and HYPERFOCAL DISTANCE										
LENS FOCAL LENGTH: 50 mm				CIRCLE OF CONFUSION = .001" (1/1000")						
F/stop	f/1.4	f/2	f/2.8	f/4	f/5.6	f/8	f/11	f/16	f/22	f/32
Hyperfocal Distance	230.7'	161.5'	115.3'	80.7'	57.7'	40.4'	29.4'	20.2'	14.7'	10.1

**Example:**

If you were shooting 35 mm film with a 50 mm lens at f/11 and you focused at the hyperfocal distance of 30 ft. (as determined from chart above), your depth-of-field would be from 1/2 the hyperfocal distance (15 ft.) to infinity.

***Double System Diligence***

By its very nature, film cameras are part of this ensemble known as double system. One system, the camera, registers the picture element of the story, while the other system, the sound recorder, handles the sound.

The apparent nuisance of slating and syncing is more than offset by the convenience of working without being tethered by cables and the advantage of state-of-the-art quality in each stand-alone system. Still, we need to resolve the issue of mating sound to picture. The matter is greatly simplified by our ability to name each frame of film.

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“The film, the cameras, they go  
anywhere. I’ve taken them to the  
Sahara. I’ve taken them to the  
Himalayas. I’ve taken them  
everywhere.”

—*Pascal Wyn, Production Director*

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