

## Competencies

- History of incandescent lamp
- Tungsten-Halogen lamp design features and their operation
- Basic components of an incandescent lamp
- Filament design
- Bulb shapes
- Base design
- PAR lamp design
- Arc light sources
- Rated lamp life and factors that affect this rated life
- Safety precautions related to lamps
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## History of the Incandescent Lamp

The development of an adequate lighting design depends on a working knowledge of light sources and instrumentation. The basic light source we will use is incandescence light given off by a glowing filament.

There are two basic categories of incandescent lamps: the standard incandescent lamp and the tungsten-halogen lamp. Thomas Edison developed the standard incandescent lamp in 1879, and it really has not changed much over the past 100+ years.

The most common source of light used in performing arts today is the incandescent filament lamp. It is a gas-filled bulb containing a tungsten filament that emits light when an electrical current is passed through it. Tungsten is a metal that is relatively resistant to electrical flow. As a result, it will heat up and glow as electricity is applied to it.

## Tungsten-Halogen Lamps

The tungsten-halogen lamp (also called the “quartz lamp,” the “quartz-iodine lamp,” and abbreviated “T-H”) was developed in the 1950's and has become popular for television lighting. The development of the tungsten-halogen lamp has led to significant changes in the lighting industry. The most important has been the creation of smaller and more powerful

lighting instruments. Not only are the T-H lamps much more compact than standard lamps, but they also have a longer life and maintain initial intensity throughout their life-span.

The secret of this innovation is the halogen-family gas introduced into the bulb. In a normal incandescent lamp, as the tungsten filament burns, particles evaporate from the filament and deposit themselves on the cooler glass envelope. The result of this process is a gradual darkening of the bulb, and lessening of light output from the lamp. In the T-H lamps, however, the halogen gas gobble up the elusive tungsten particles and redeposits them at the hottest point within the bulb on the filament. The bulb ultimately fails because the particles are not redeposited evenly. Because the desired reaction between the tungsten particles and halogen gas requires a great deal of heat, the glass envelope is made smaller and constructed out of strong quartz glass.

The T-H lamp costs about twice as much as the standard lamp but it has twice the life and is efficient during its life span.

The biggest disadvantage of the T-H lamp is that the quartz glass envelope must NOT be touched by fingers. No matter how clean your hands happen to be, oil from your skin is deposited on the glass and will react with the quartz when heated. The result of this reaction weakens the envelope and may cause an explosion.

The tungsten filament is more fragile than the standard filament. NEVER jar an instrument with the lamp burning or still warm.

## Components of the Incandescent Lamp

The three important parts of an incandescent lamp are:

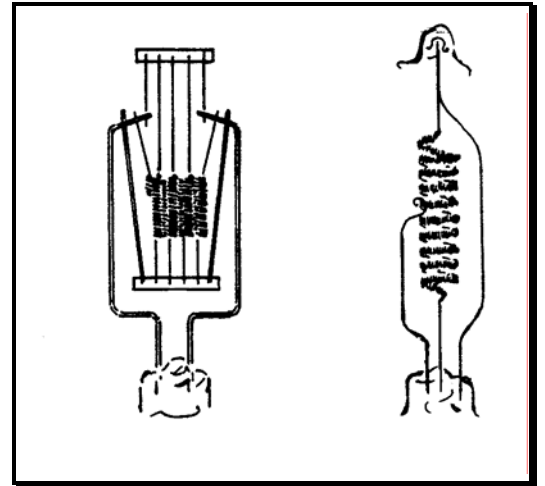
- **Filament** - Passes the current, yet offers enough resistance to effect the transfer of electrical energy into light and heat energy
- **Bulb** - The glass envelope that encloses the inert gas
- **Base** - Holds the lamp in position and make electrical contact

## Lamp Filaments

Since most lighting instruments use reflectors, the ideal lamp filament should be a “**point source**”. This is why filaments have been designed to be as compact as possible. To accomplish this and provide for a bright illumination, the filaments have been coiled and even double coiled.

Filaments have been designed for specific uses, such as providing equal light in all directions. Others are designed to provide light in only two directions; which is helpful when a reflector is used. The tungsten halogen lamp uses a filament that is double coiled and tends to be a bit longer and narrower than the standard incandescent filament.

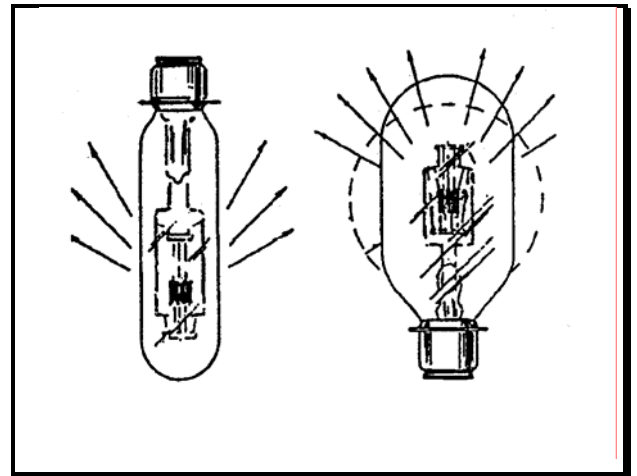
The light-center length (LCL) of a lamp is the distance from the center of the filament to some definite place in the base. With a screw-base lamp, the measurement is the contact button at the end of the base. It is important to know the LCL when a lamp is to be used in conjunction with a reflector or lens, for the center of the filament must be exactly aligned with the centers of such optical devices.



## Bulbs

The bulbs of standard incandescent lamps are made of ordinary glass, while the bulbs of tungsten-halogen lamps are made of the more heat-and pressure-resistant quartz glass. As a result, the standard incandescent bulb needs to be larger in order to dissipate the heat given off by the filament. The smaller envelope of the tungsten-halogen lamp has an important advantage over the standard incandescent lamp, for the size of the lighting instrument is often dictated by lamp size.

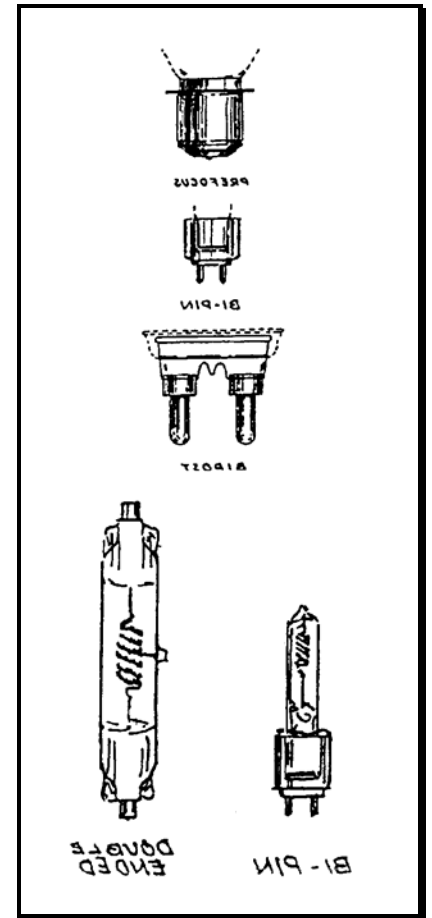
Bulbs come in various shapes, sizes and finishes. Lamps used in lighting instruments are usually either globe-shaped to permit the even dissipation of heat or tubular to allow the filament to be brought closer to some optical feature. Specific lamps have been designed to burn either base up or base down to dissipate heat. Lamps used in performing arts are usually made of clear glass, which is essential for any source used in an instrument with a reflector or lens.



## Lamp Bases

The electrical contact part of the base of the lamp is generally made of copper. The base may be any of several sizes and shapes. Bases also vary in type, with the common screw base found in household lamps being the simplest. It is often necessary to provide some sort of locking device so that the filament is correctly aligned. The pre-focus, bi-pin and bi-post bases have been developed for this purpose.

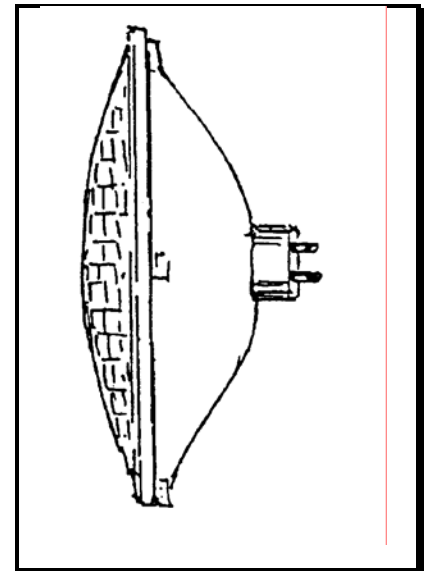
Most tungsten-halogen lamps have one of three types of bases. The bi-pin base slides straight into its socket and is held in place by a pressure plate. Excessive handling or jarring may cause this lamp to dislodge from its base, so care must be taken with instruments using the bi-pin lamp. The bayonet base has a twist lock action to ensure the filament is in the proper location. A locking mechanism holds the lamp firmly in place. The double-ended lamp is held in place by two spring-loaded metal contacts mounted so that they protrude through the reflector of an instrument. These lamps can be difficult to get properly seated. Care must therefore be taken not to damage either the contacts or the seal of the lamp base.



## PAR Lamps

PAR (parabolic aluminized reflector) lamps are essentially a self-contained lighting instrument. The glass envelope contains a parabolic-shaped reflector, either a standard incandescent filament or a small quartz lamp and a lens. PAR lamps are made of molded, heat-resistant glass and can be used outdoors without danger of cracking.

Automobile headlamps have used PAR-type lamps for many years, but rock-concert lighting introduced PAR lamps to performing arts production. Quartz PAR lamps are mounted in a very simple housing called PAR cans. They have the ability to throw a highly concentrated beam of light over a considerable distance. The light has a very distinctive quality because of its nearly parallel rays and its sheer intensity. The beam from a quartz PAR lamp is more ellipsoidal (oval) than round because of the filament shape and has a very soft and fuzzy edge, making it easy to blend one beam with another. The direction of the beam is changed by simply rotating the lamp within the PAR can housing. PAR lamps come in four different throw widths. The "64" designation indicates the diameter of the lamp. The diameter of the PAR 64 lamp is 8".



## Other Light Sources

The carbon-arc light source became popular in performing arts because of its intense and high color temperature light. Two copper-coated pencil-sized carbon rods are electrified and the carbon particles glow as they are dislodged from the rods. Gases produced by this burning are toxic and must be exhausted from the area. The carbon-arc is used mainly in follow-spots.

The main disadvantage of arc lighting sources is that they cannot be dimmed.

Another light source is the HMI unit. It produces a very high intensity light. The lighting instrument is very expensive and must be powered through a heavy ballast.

Fluorescent lamps are activated by passing current through a pressurized mercury vapor that charges a phosphorous coating on the inside of the tube causing the tube to glow.

Fluorescent lamps are rarely used in performing arts. Fluorescent instruments have recently been introduced for use in television lighting. They produce relatively little heat and a very soft light. Because the lamps tend to have a 60-cycle flicker, they can cause problems in television.

## Lamp Life

The rated life for most standard incandescent lamps is only 200 hours, while most T-H bulbs have over twice this rated life. A lamp's life may be shortened in a number of ways. If the lamp is not properly ventilated and operates at a high temperature, its life will be shortened. Rough handling can also cause premature failure. Most incandescent bulbs have been designed to operate either base up or base down. As a general rule, tubular bulbs should be burned base up and round bulbs should be burned base down.

Operating voltages can also affect bulb life. Burning a bulb at less than the rated voltage will cause the bulb to last longer, but the intensity of the bulb is also reduced. This lamp intensity is measured in lumens. As the lumen output is increased, lamp life is decreased.

## Safety and Light Sources

Please follow these simple rules when working with light sources:

- Always unplug a lighting instrument before moving it or replacing a bad bulb.
- Lamps are expensive, so be sure to treat them with care.
- Keep your fingers off quartz bulbs.
- The envelope of a burning lamp is very hot. Allow plenty of time for cool down.

## Intensity Measurement

Light is measured in footcandles - the amount of illumination provided to an object that is one foot from the flame of a candle. A light meter is used to measure footcandles.

Another scale to define the amount of illumination is Lux. A Lux is approximately 1/10 of a footcandle.

Falloff is the amount of decrease in illumination as an object is moved away from the source. The formula for determining falloff is  $1/d^2$  (d=distance). Falloff at 2 feet is 1/4 and 3 feet is 1/9, so you can see there is a rapid falloff as the distance increases. Outdoors, there is no falloff of the sunlight.

The cameras we use require a minimum of 50 footcandles for proper operation.

## Color Temperature

We tend to think of the light emitted from an ordinary lamp as being white, but the fact that so-called white light is relative, and the actual color of light given off by sources can vary from a warm red to a cold blue. The method we have to identify the color makeup of any light source is called color temperature and its measurement is in Kelvin (k) degrees. The measurement is made using a meter called a spectrophotometer. The Kelvin temperature is important to you because the standard bulb will fall into the 2,800 to 3,000 degree range. Television lighting standards require a 3,200-degree source. If a standard household bulb is used, it gives off a red glow. Most fluorescent lamps operate over 5,000 degrees K. and provide a very bluish cast. As a general rule, the higher temperature, the cooler (bluer) the light. Dimming a lamp decreases the color temperature significantly.

Light Source	Temperature
Candle flame	1,900°K
Sunrise	2,000°K
Sunset	2,000°K
100-Watt household lamp	2,865°K
Studio lamp	3,200°K
Photoflood	3,400°K
Sunlight early A.M. or late P.M.	4,200°K
Sunlight	5,800°K
Overcast sky	6,000°K
Summer sun and blue sky	6,500°K
Clear skylight	12,000-20,000°K

## Reflection and Refraction

When a beam of light passing through air encounters anything in its path, three things can happen. The light may be:

- Absorbed
- Refracted (Bent)
- Reflected

All lighting instruments use reflectors to increase the efficiency of a light source and sometimes a lens to gather and redirect light from the source.

## Reflection of Light

The law of specular reflection explains what happens to a light beam when it strikes a smooth, shiny surface, such as a mirror. It is reflected at an angle equal to the angle at which it is struck, but in the opposite direction. The angle of incidence is equal to the angle of reflection. If the reflector is not mirror-like, the reflected light will be defused.

## Reflectors

Lighting instruments use one of three reflector types or shapes:

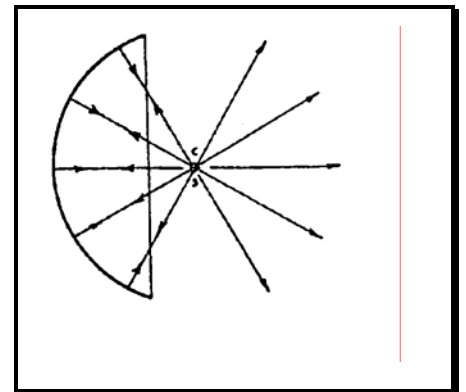
- Spherical - Fresnel-type spotlight
- Parabolic - PAR-type lamps
- Ellipsoidal - Ellipsoidal reflector spotlights (ERS)

The shape of the reflector determines exactly how it redirects light from a source.

## Spherical Reflectors

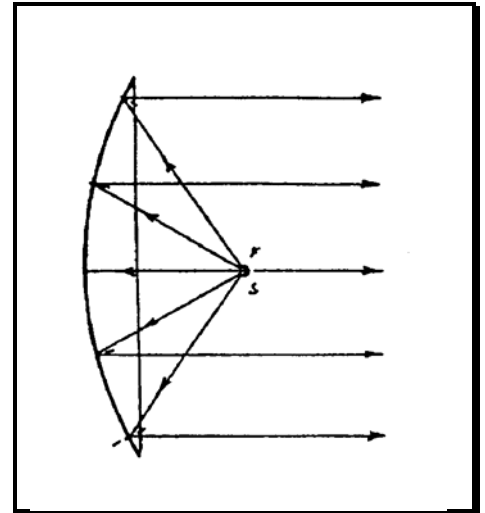
If a polished metal piece is made into a reflector in the form of a part of a sphere, and a source of light is placed at the center of the curvature of this form, each ray of light that strikes the reflecting surface will do so squarely. It will be returned through the source.

It is necessary for the source (filament) to be located precisely in relation to the reflector. Although it is not doubled, the efficiency of a light source in combination with a spherical reflector is increased significantly.



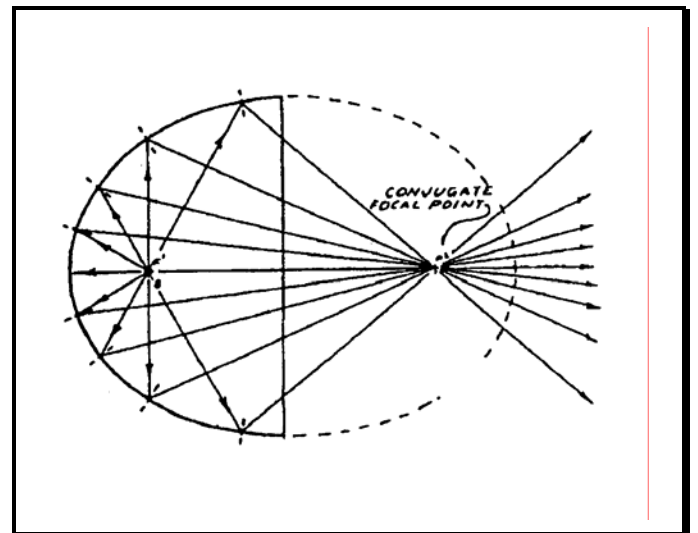
## Parabolic Reflectors

The nature of a parabolic reflector is such that if a light source is placed at its focal center, all rays that strike the reflective surface will emerge parallel to one another. This will give a concentration of light in a tight beam.



## Ellipsoidal Reflectors

The ellipsoidal reflector is more efficient than either the spherical or parabolic reflectors. By mathematical definition, an ellipsoid has two focal points. When a reflector is constructed in the form a half an ellipsoid and a source is placed at the focal point at that end, all rays of light that strike the reflector will be diverted through the second or conjugate focal point. The result is that an enormous percentage of light from the source is directed in a manner that makes it easily usable.

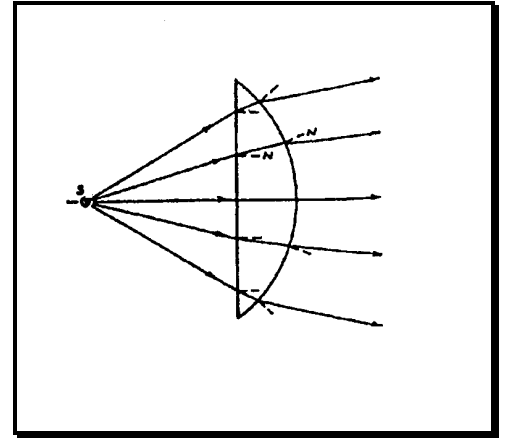


## Refraction

Refraction is a phenomenon observed by anyone who looks into a pool of water and notices how a straight stick will seem to bend sharply as it passes beneath the surface. The law of refraction states that when a ray of light passes into a denser medium, it is bent toward a perpendicular drawn to the surface at the point of entry. When it reemerges into the less dense medium, it is bent away from the perpendicular drawn from that point.

## Plano-Convex Lens

If two surfaces of a sheet of glass are parallel, the path of an emerging ray will be parallel but slightly offset. If they are not parallel, they will take a different angle. This is the principle of all lenses. The simplest lens is the plano-convex lens, with one flat side and one outward curved surface.



## Fresnel Lens

The thick glass of the lens has a tendency to crack, because of excessive heat from the source. The Fresnel (Fir'nel) lens has the curved surface cut back to reduce mass.

