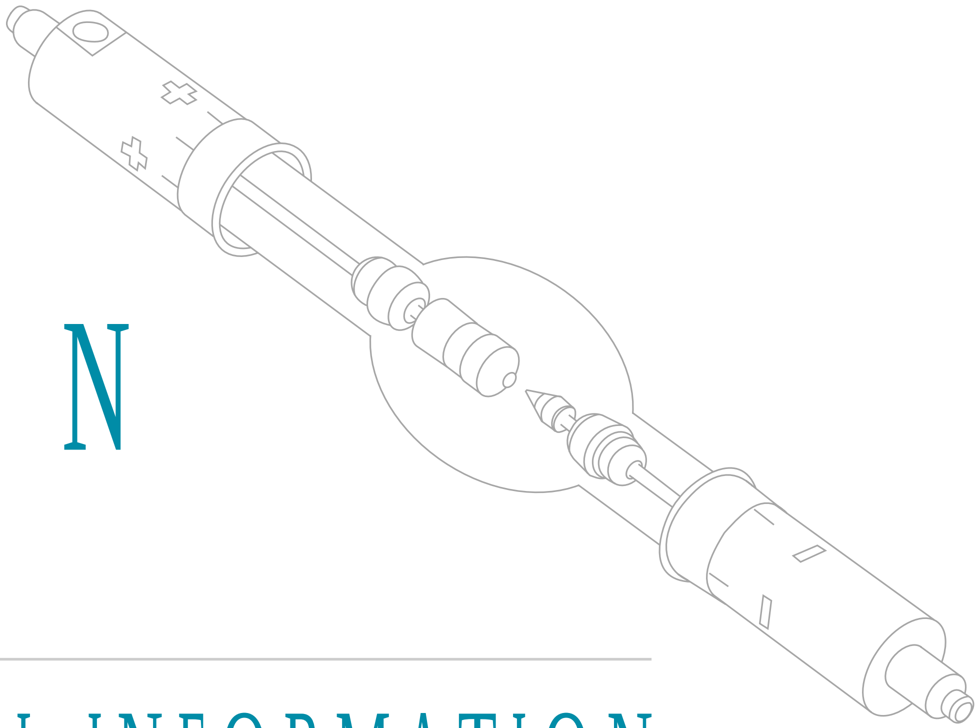
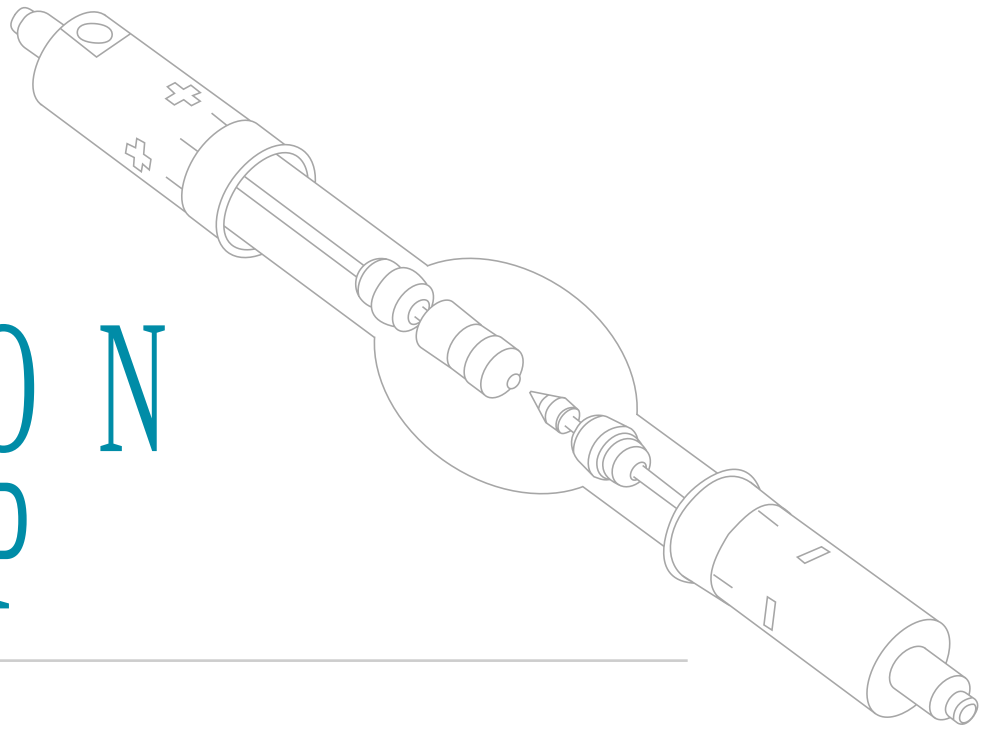


XENON LAMP

TECHNICAL INFORMATION



XENON LAMP

DESIGN

Lighting Technologies International™

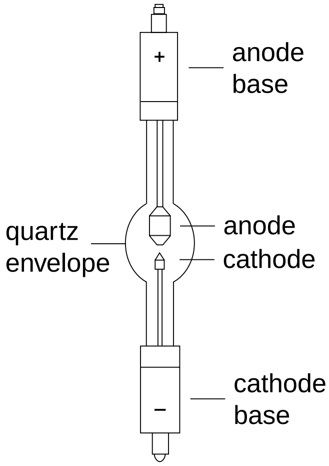
GENERAL DESCRIPTION OF XENON LAMPS

Xenon lamps from the LTI family of specialty discharge light sources lead the way in providing high-technology solutions to many markets. Whether for cinemas, video projection, or stage and studio applications, LTI's xenon lamps are designed for use in the industry's most technologically advanced equipment — they provide an almost perfect point source of light.

LTI's xenon lamps are specifically designed for DC operation, bringing longer life, enhanced stability, and instant ignition to any application. Xenon lamps have a color temperature of approximately 6000˚K, which matches the spectral distribution of the sun. This is essentially "white" light, which remains constant throughout the life of the lamp. The high color representation index (CRI>9) ensures that color properties are constant throughout the life of the lamp.

The following information is intended to be a practical guide to give a basic overview of xenon lamps, from design to operating parameters to lamp behavior to care & handling. Common problems are discussed and solutions offered. With an understanding of this information, users will gain optimum performance from their xenon lamps.

LAMP DESIGN AND TERMINOLOGY



Bulb

Xenon lamps from LTI consist of a spherical or ellipsoidal envelope made of quartz glass, which can withstand high thermal loads and high internal pressure. For ultimate image quality, only the highest-grade clear fused silica quartz is used. It is typically doped, although not visible to the human eye, to absorb harmful UV radiation generated during operation. The operating pressures are tens of atmospheres at times, with surface temperatures exceeding 600˚C.

Electrodes

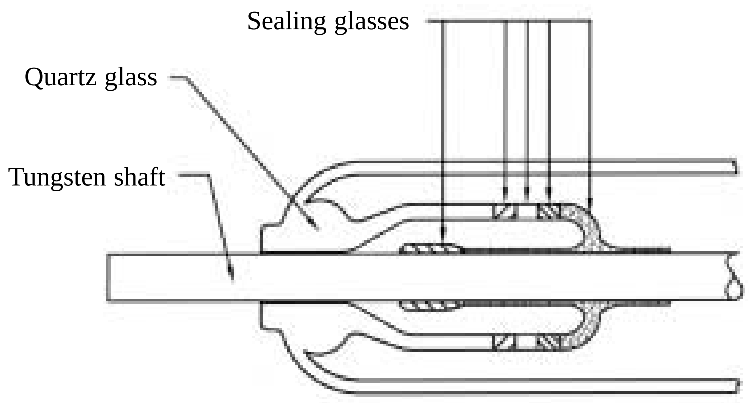
Electrodes in LTI's xenon lamps are made of tungsten; this is the only metal with a sufficiently high melting temperature and sufficient vapor pressure at elevated temperatures to be used for electrodes. Compact arc lamps require solid tungsten electrodes because of their high wattage concentration and correspondingly high plasma temperatures within the short arc gap directly between the electrodes.

The smaller, pointed electrode is called the cathode, which supplies the current to the lamp and facilitates the emission of electrons. To supply a sufficient amount of electrodes, the cathode material is doped with thorium. The optimum operating temperature of the cathode tip is approximately 2000˚C. To obtain this precise operating temperature, the cathode tip is pointed and in many cases has a groove on the pointed tip to act as a heat choke. This heat choke causes the tip to run at a higher temperature. This configuration of the cathode tip allows for a very high concentration of light from the cathode tip and a very stable arc.

The anode, the larger electrode, receives electrons emitted by the cathode. Once the electrons penetrate the anode face, the resulting energy is converted to heat, most of which radiates away. The large, cylindrical shape of the anode helps to keep the temperature low by radiating the heat from the anode surface. LTI's anode material is specially treated to ensure long life with minimal melting or change in the anode shape.

Seal
Every xenon lamp from LTI has two hermetic seals that form an airtight connection for the electric current between the inside and outside of the lamp. Since tungsten is a metal and has a much different coefficient of expansion than the quartz envelope, the two materials cannot be sealed directly to each other – they would crack and not make an airtight seal.

The most reliable type of seal used in lamps to make the transition from tungsten to quartz is the graded seal. With this seal, a series of different types of glass are placed around the tungsten rod that is attached to the electrodes. These different types of glass have different expansion characteristics: glass with a similar expansion property to tungsten is placed onto the tungsten rod, and a glass with properties similar to those of quartz is placed next to the quartz envelope. Between these two types of glass, other glasses are used to form a gradual transition between them.



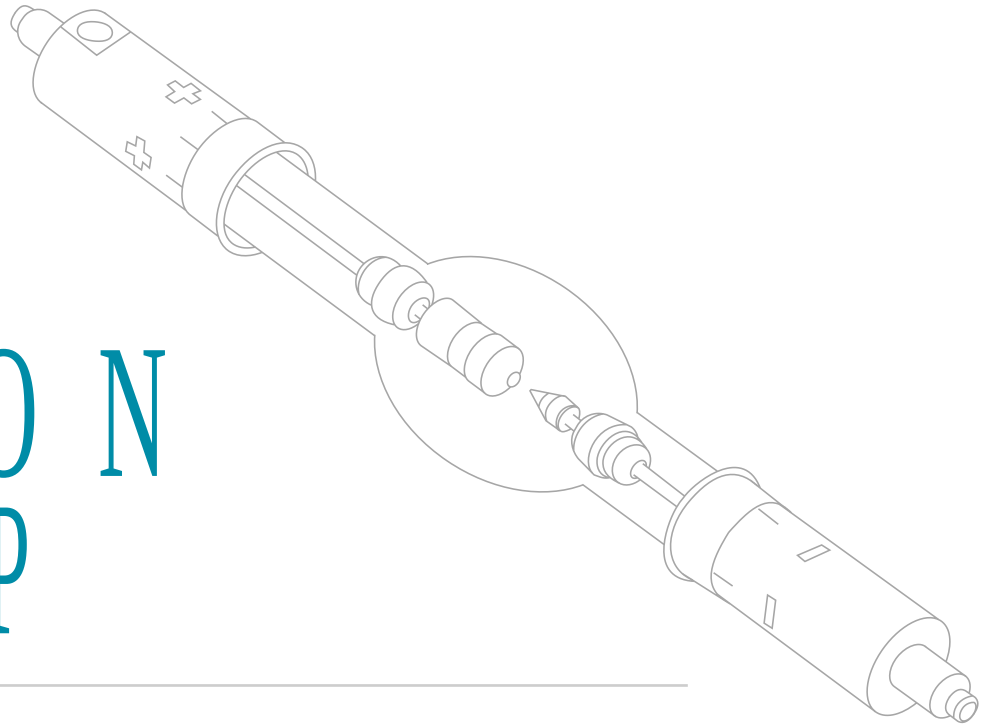
Graded Seal

Base
The two diametrically opposed cylindrical extensions, or bases, serve to mechanically support the xenon lamps during system installation, as well as to provide a means for electrical connection. Inside the ferrule, or base, is a flexible lead wire that eliminates any possibility of stress or strain between the electrode shaft and the ferrule. The ferrules are attached to the quartz envelope using a unique carbon-graphite tape and passivated compression ring. For installation, the ferrules either have a threaded pin, cable, or non-threaded pin. All of LTI's ferrules are nickel-plated to ensure good electrical contact, thermal contact, and to prevent oxidation. The ferrules have polarity cutouts to assist in installation and to facilitate cooling. A metal pin or cable, or a combination of these, is attached to one or both bases.

Ignition wire
The ignition wire, which runs between both ends of a xenon lamp, helps to ignite the lamp. The pure nickel wire is thin and helps initiate the discharge of the lamp. The purpose of the ignition wire is to create an electric field within the envelope that helps to stimulate the ionization of electrons and a partial flow of electrons.

Filling
Xenon lamps from LTI are filled with 99.99% pure xenon gas. In order to ensure high performance and long lamp life, the gas must meet stringent purity standards, and thus must contain virtually no impurities. Xenon delivers the important advantage of producing an essentially continuous spectrum of visible light at 6000˚K.

Xenon lamps are filled to a positive pressure between 4 and 10 atmospheres; this pressure rises dramatically during operation due to the increase in lamp temperature.



XENON LAMP

PHOTOMETRIC CHARACTERISTICS

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PHOTOMETRIC CHARACTERISTICS

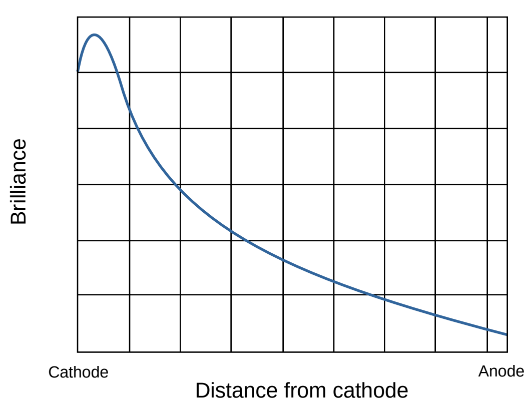
Luminous efficacy and luminous flux

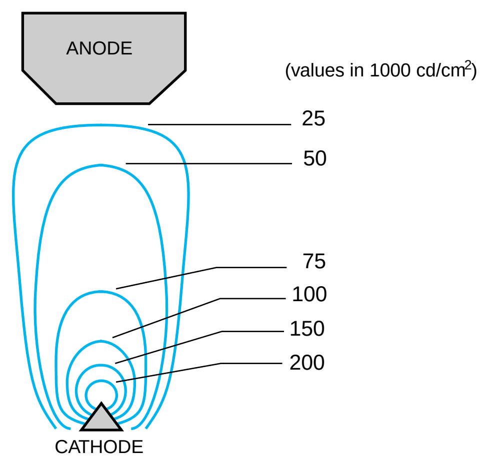
An average LTI xenon lamp converts about 80% of the electrical power put into the lamp into radiation. The other 20% is lost through heat conduction and radiation. Of the 80% that is converted to radiation, about 60% is used in the arc itself. This means about 48% of the actual electrical input is used in the arc. LTI's xenon lamps display high luminous efficacy; generally, the higher the lamp voltage, the higher the luminous efficacy. Electrode gap also has some effect on luminous efficacy – lamps with a longer electrode gap have a higher luminous efficacy.

When the electric current is increased, the luminous flux also increases proportionately with the current to a power of approximately one-and-a-half. The result is an increase in efficiency due to the simultaneous increase in lamp voltage.

Brilliance

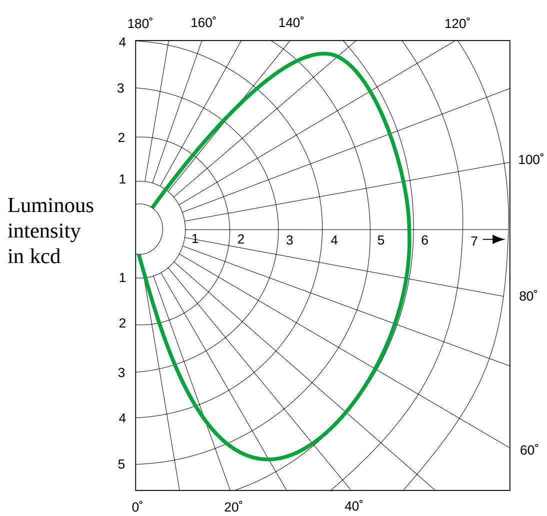
Brilliance of a xenon lamp is greatest at the cathode; it decreases rapidly as it nears the anode. Brilliance distribution in the arc of a typical xenon lamp can be viewed in the following charts:





Distribution of luminous intensity

Another important factor when examining xenon lamps is the typical distribution of luminous intensity. This is especially important in the design of optical systems that use LTI xenon short arc lamps. Most of the radiation originates near the cathode, since this is the root of the arc, as shown in the following diagram:

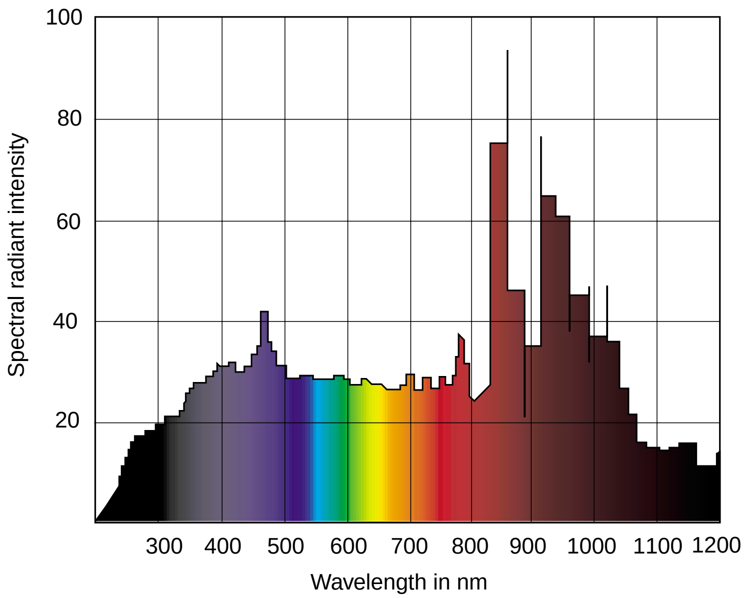


Spectrum and color properties

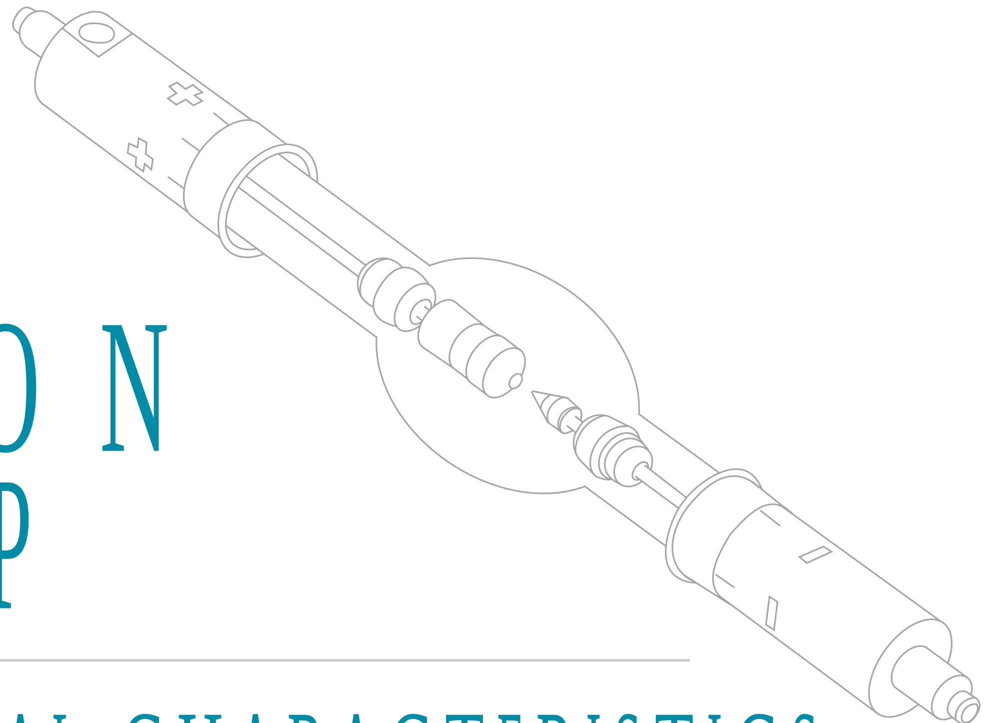
Unique spectral color properties make xenon lamps attractive for use in many applications. Xenon lamps have a daylight color temperature of 6000˚K, closely matching the spectral distribution of the sun (380 to 780 nm). This is essentially "white" light, which remains constant throughout the life of the lamp. Xenon also delivers the important advantage of producing an essentially continuous spectrum of visible light; this is reflected in a high CRI, or color representation index. This ensures that color properties are constant throughout lamp life.

The color temperature of xenon lamps is independent of warm-up time, lamp type, wattage, lamp voltage, lamp current, and operating hours of the lamp.

The spectral distribution shown in the chart below is typical of a xenon lamp from LTI. Note that approximately 6% of the power used is emitted in the form of UV radiation below 380 nm.



XENON LAMP



ELECTRICAL CHARACTERISTICS

Lighting Technologies International™

ELECTRICAL CHARACTERISTICS

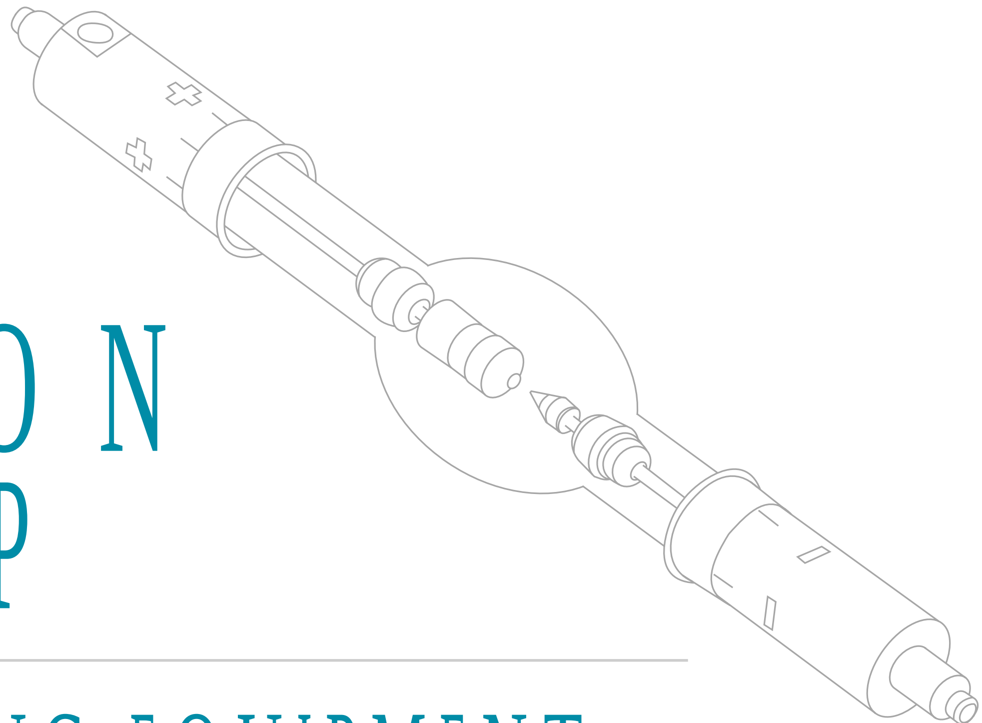
Steady-state operation

LTI's xenon lamps are considered low voltage, high current DC light sources. As an example, a 1000-watt lamp operates at 20VDC at 50 amps. The typical manufacturing tolerance on the lamp voltage is ±2 volts. During the life of the lamp, the voltage will rise as the cathode tip erodes slightly, which causes the arc gap to increase. Over the life of a lamp, the voltage can increase by 2 volts from its initial steady state operating voltage.

LTI's xenon short arc lamps are considered constant current lamps. This means the operating current is set for the lamp, and the voltage is established by the specific parameter of the lamp including arc gap, xenon pressure, operating temperature, etc. The operating current range for each of LTI's xenon lamps is specified by model, however in general the current should not be run at less than 85% of the nominal or more than 110% of nominal.

Current ripple

To ensure long lamp life, current ripple must be as low as technically possible. The quality of the direct current used to operate the lamp is of utmost importance – it is specified as a percentage. Ripple is one of the most critical elements that contributes to reduced lamp life and should be less than 10% peak to peak for xenon lamps up to 3000 watts, and less than 5% peak to peak for lamps over 3000 watts. Monitoring and measuring current ripple can avert reduced lamp life due to excessive ripple.



XENON LAMP

OPERATING EQUIPMENT

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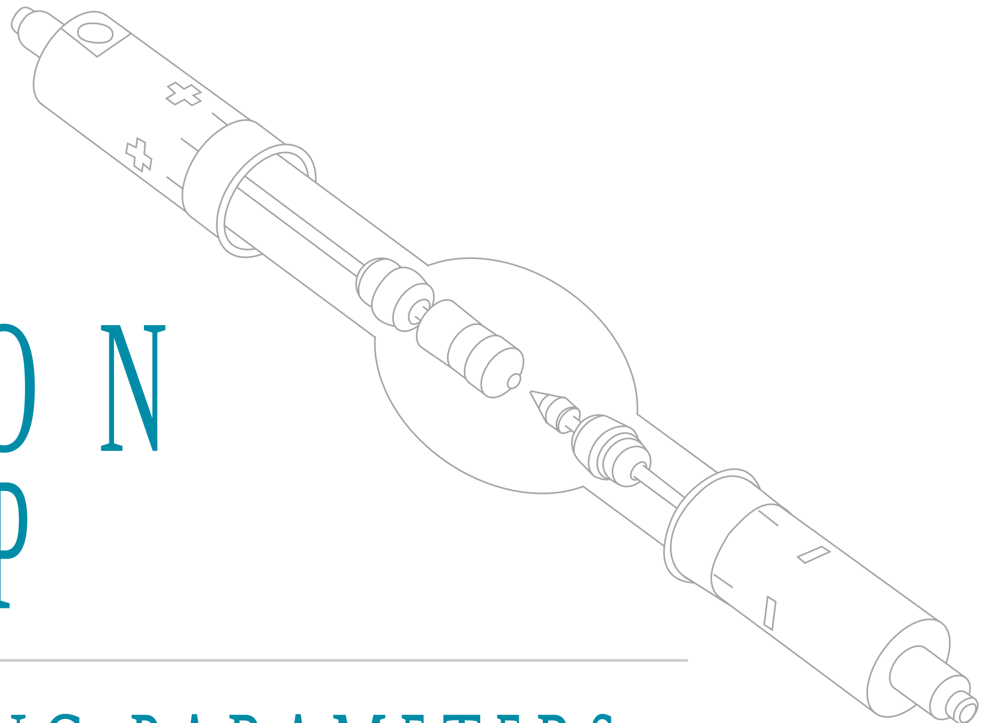
OPERATING EQUIPMENT

Lamp housings

Because xenon lamps are subjected to high thermal loads and are under high internal pressure, they must only be operated in enclosed housings. Housings should be designed with several safety elements in mind. First, in case of lamp explosion, housings should contain all fragments of the exploded lamp without allowing any elements to escape. Similarly, housings must be designed to provide protection against any UV radiation produced by the lamp. It is also advisable that housings be designed so the arc cannot be viewed directly, thus avoiding the potential for serious eye damage.

To anticipate the forces of thermal expansion, a lamp should be rigid mounted in its housing at one end only. In addition, lamp housings should allow adequate space for the fitting and/or removal of a lamp with the safety cover on, allowing the cover to be removed once the installation or removal is complete. Housings must also be designed with the cooling requirements of the lamp in mind; housings should ensure adequate cooling by allowing forced air through the end fittings and along the lamp envelope. Once the lamp is turned off, the cooling process should continue for several additional minutes within the housing.



XENON LAMP

OPERATING PARAMETERS

Lighting Technologies International™

OPERATING PARAMETERS

Burning position

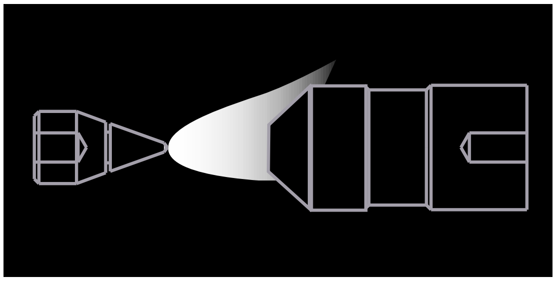
LTI's xenon lamps may be operated vertically or horizontally. In the vertical position, the anode is at the top, and the cathode is at the bottom. The arc burns most smoothly in this position; the configuration is rotationally symmetrical. Lamps operated in the vertical position may be tilted, however, it is recommended that the tilt angle be less than ±30˚.

In the horizontal position, the arc burns less smoothly and, without arc stabilization, may result in hastened electrode wear. While the rotation is not wholly symmetrical as in vertical operation, it is a necessity for some lamp housings. Every lamp designed for horizontal operation may also be operated vertically.

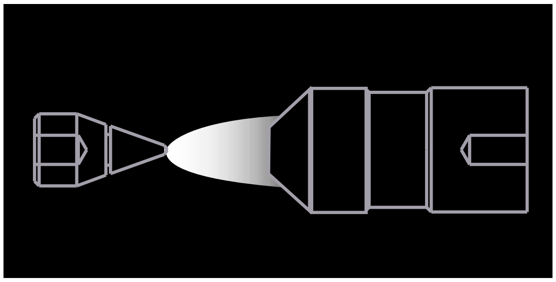
Magnetic arc stabilization

To achieve arc stabilization in the horizontal operating position, a small rod-shaped magnet may be mounted across the lamp axis, directly under the arc. Mounting the magnet under the lamp acts as a force to pull the arc downward, resulting in more arc stability. The strength of the magnetic field can be varied by adjusting the distance between the lamp and the arc – the nearer the magnet, the stronger the magnetic force. With correct stabilization, the arc should directly hit the anode face.

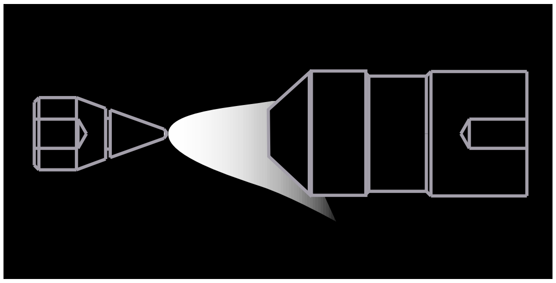
Unstabilized



Stabilized



Overstabilized



Lamp rotation

For lamps operated in the horizontal position, 180˚ rotation at half-life is recommended. This allows the deposition of vaporized electrode material in the bulb to be more evenly deposited on the bulb envelope and not blacken the bulb body on one side – which can ultimately cause overheating of the envelope and lamp failure. After rotation, many times the arc becomes unstable. Factors causing this include convection currents, magnetic stabilization and electron emission preference from the cathode tip. The lamp may stabilize by running at maximum current for a period of time and then lowering the current.

Cooling

Xenon lamps must be adequately cooled during operation. This is best achieved by forcing air through the lamp's end fittings and along the lamp envelope at a rate of 15-25 feet per second. The air stream should be as cylindrical as possible along the lamp axis so as not to put additional stress on the quartz glass. Once the lamp is turned off, continue the cooling process for several additional minutes. During operation, lamp seal temperatures must be kept below 225˚C.

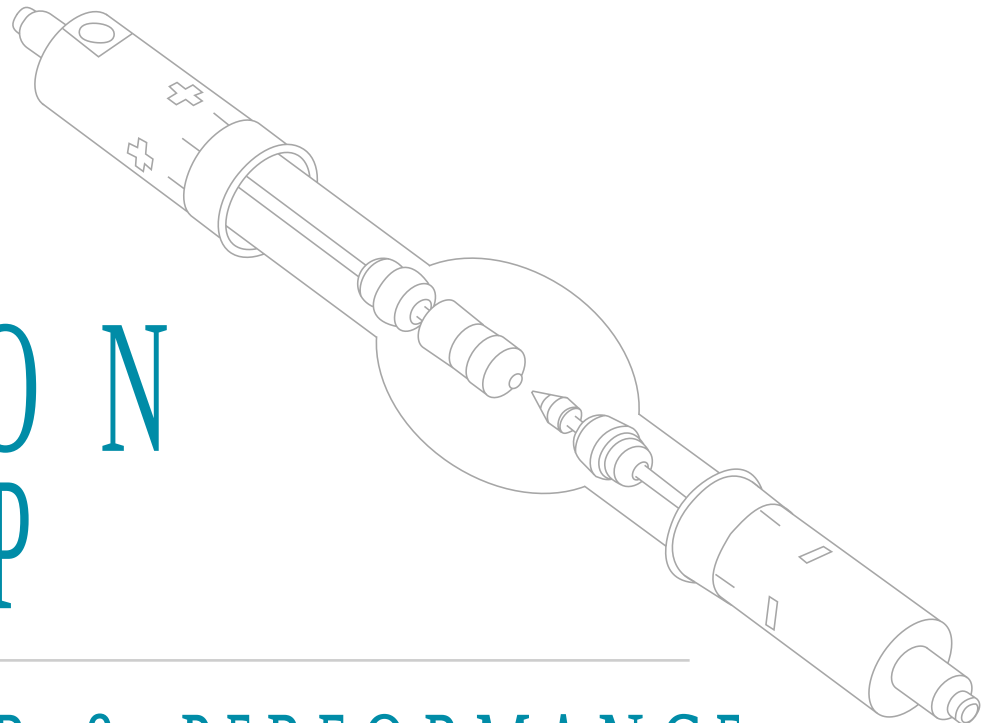
Excessive cooling can occur, which leads to arc instability. If the lamp voltage decreases by more than 1 volt when compared to the lamp voltage with no cooling, this indicates that too much cooling is being applied to the lamp.

Current range

While a rated current is specified for all LTI lamps, a current range is also specified. It is recommended that a lamp be operated at slightly less than its rated current at the beginning of its life, while being operated at the maximum range at the end of its life. The main purpose of this adjustment in current is to compensate for the slight loss of light that occurs with lamp age. It is not advisable, however, to continuously operate the lamp at minimum or maximum current, as the lamp's performance and lifetime will be negatively affected.

Operating cycle

Because frequent ignitions hasten electrode wear, xenon lamps have the highest life expectancy if, once in operation, they are not turned off . Every additional ignition shortens lamp life. To avoid this problem, lamps are best operated at approximately 90 minutes per session, thus decelerating the process (caused by frequent ignitions) of electrode material being deposited on the lamp envelope's inner wall.



XENON LAMP

BEHAVIOR & PERFORMANCE

Lighting Technologies International™

LAMP BEHAVIOR

Lamp life

Average lifetime is stated by LTI for each xenon lamp. Lamps that are operated with the correct equipment and to the recommended specifications will typically be operable beyond their average lifetimes. However, after exceeding the average life by 25%, the bulb should be replaced due to increased the risk of explosion. Factors that negatively affect lamp life include overheating, excessive power supply ripple, low current, high number of ignitions, incorrect burning position, incorrect magnetic stabilization, excessive current, and uneven bulb darkening.

Blackening

As a xenon lamp progresses through its lifetime, it is subject to blackening. This is caused by tungsten material vaporizing from the electrodes and depositing itself on the inner walls of the quartz envelope. Blackening gradually reduces light output from the lamp; it also affects the spectral characteristics of the emitted light, causing it to appear more yellow. During the course of a lamp's normal lifetime, blackening will initially occur very slowly, then progresses at a more rapid rate. The blackening also causes the envelope to heat up due to absorption of energy from the radiated light.

Blackening may be accelerated due to excessive current, insufficient current, excessive ripple, or frequent ignitions.

Arc instability

The arc of a xenon lamp is not completely stationary, and several additional factors will contribute to its instability:

- Inadequate operating current
- Excessive current ripple
- Excessive inrush current
- Excessive forced cooling
- Improper lamp tilt
- Advancing age of lamp

An outward appearance of arc instability is "flicker", which is a sudden change in useful light in a given application. Flicker can be caused by several factors, some of which are listed below:

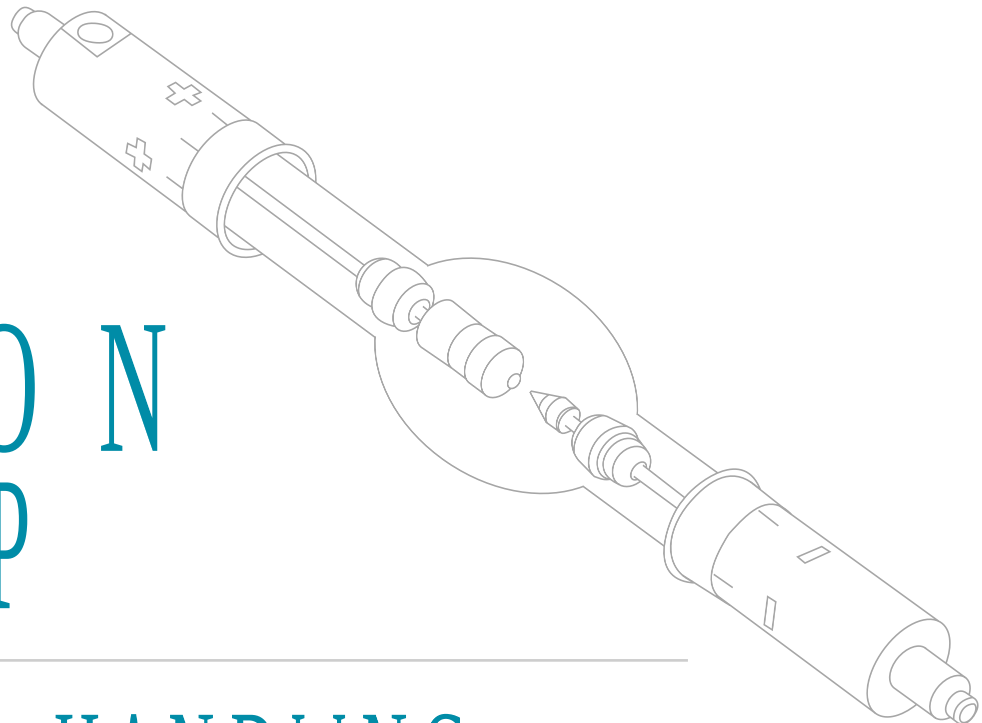
- **Lamp current**: Operating a lamp at low current causes the cathode tip to run to cold. This results in not enough electrons being supplied by the cathode tip, which causes the arc to move over the cathode tip surface looking for electrons. If the current is too high, the cathode tip runs too hot, which results in the evaporation of the thorium. The causes too few electrons to be emitted from the cathode, with resulting arc instability.
- **In-rush current**: High in-rush currents on a repeated basis cause the erosion of the cathode tip, which leads to arc instability.
- **Bulb cooling**: Excessive cooling of the bulb can cause thermal instability of the gas inside, which leads to turbulence and arc instability.
- **Start-up time**: Immediately after lamp ignition, some instability occurs as the lamp components are heating up. This effect passes after a few minutes of operation.
- **Burning position**: As specified in the section describing burning position, the closer to vertical a lamp is operated, the better its stability. As the lamp is operated off of its vertical or horizontal axes, the instability increases.
- **Lamp life**: As a lamp progresses through its lifetime, one of the normal changes is the structure of the

electrodes and a gradual increase in arc instability.

- **Focusing**: Optimum performance of a xenon lamp in an optical system is when the cathode hot spot is positioned in the correct spot of the optical collector. If the lamp is not focused precisely and the tail of the arc is partially placed in the collection point of the optical collector, then flicker will result.

Ozone generation

Ozone, a colorless, odorless gas, is produced in small amounts by operating xenon lamps made of standard quartz glass. Avoid inhaling it, as it is damaging to the lungs over a period of time. All LTI xenon lamps, however, are manufactured using ozone-free quartz; this quartz effectively suppresses ozone emission, and the lamps are designated "ozone-free".



XENON LAMP

SAFETY & HANDLING

Lighting Technologies International™

SAFETY

Pressure

Xenon lamps are under high internal pressure, whether in use or non-operating. Always keep a non-operating lamp in its safety cover, and wear protective eyewear, a facemask, and gloves when handling.

Brilliance

Because the brightness of operating xenon lamps can match the brightness of the sun, never look directly at the arc gap of an operating lamp. Severe eye damage can result. Lamp housings should be designed to prevent the arc from being viewed directly.

UV radiation

Xenon lamps are capable of emitting UV radiation in the spectral region below 380nm. To avoid UV exposure to the lamp operator, lamp housings should be designed so such radiation is contained within the housing.

Ozone

Because some types of xenon lamp are ozone-producing, care must be taken to avoid inhalation at high concentrations. To this end, housings should include a suitable means of extracting or diminishing the ozone that is produced.

HANDLING

Mechanical installation

Xenon lamps should be exposed to as little mechanical stress as possible during installation, and care must be taken to install them with the correct polarity. In addition, to anticipate the forces of thermal expansion, lamps should be rigid mounted at one end only.

Xenon lamps are subjected to high thermal loads, and they are under high internal pressure. They must only be operated in enclosed housings. Non-operating lamps should be stored in their protective covers, and unprotected lamps require the user to wear safety glasses, a facemask, and gloves. When installing or removing a lamp from the equipment, the safety cover must be in place on the lamp.

Ensure adequate cooling of a lamp by forcing air through the end fittings and along with lamp envelope. Once the lamp is turned off, continue the cooling process for several additional minutes.

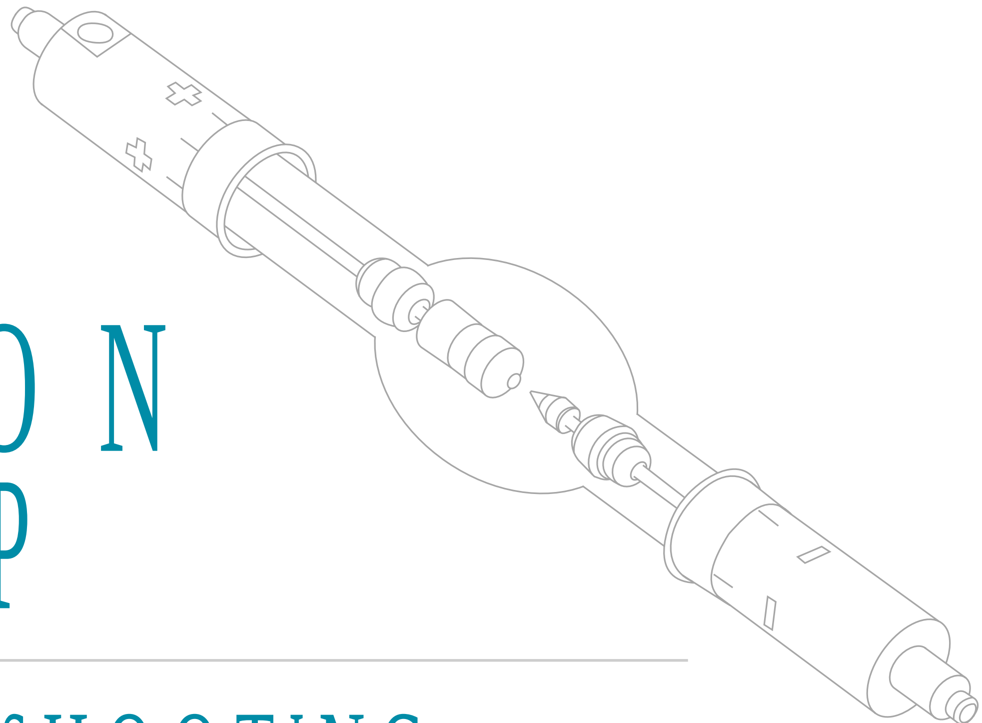
Electrical connection

Clean and inspect electrical connections periodically. A layer of oxidation can build up as a result of lamp heating and cooling, ultimately leading to overheating and failure. Also, electrical connections endure severe strains as a result of high current and temperature; periodic inspection thus reduces the possibility of damage.

Xenon lamps are best operated between 85% to 110% of rated power. New lamps should be operated at 85% power, and as the lifetime progresses, power may be increased until the maximum 110% of rated power is achieved. Replace lamps that do not provide sufficient output at the maximum rated power.

Cleaning lamps

Take care to keep the lamp envelope clean of fingerprints, dirt, and dust, as each can cause early failure. If necessary, carefully clean the lamp with alcohol and a cotton swab or lint-free cloth, always using appropriate facial and skin protection.



XENON LAMP

TROUBLESHOOTING

Lighting Technologies International™

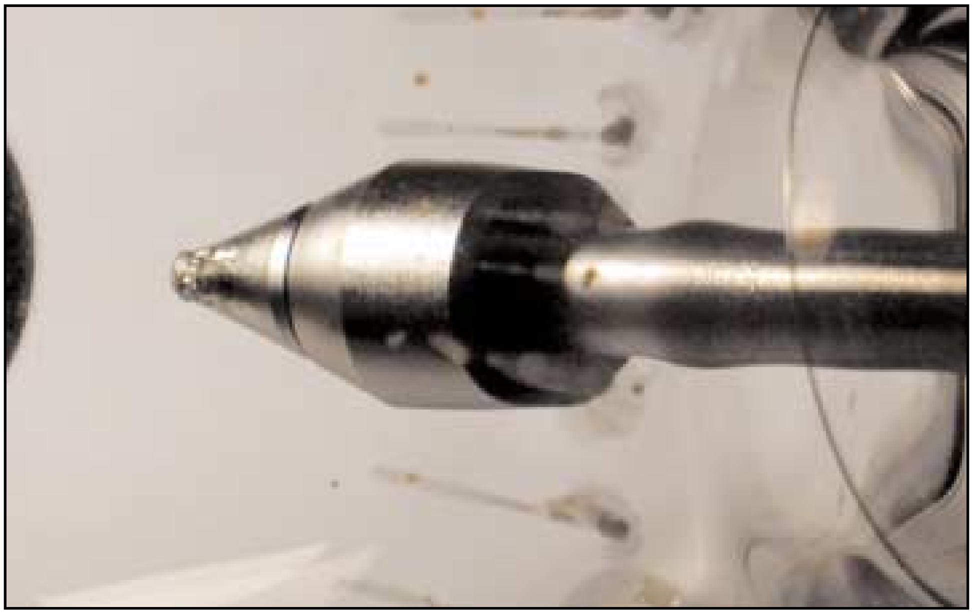
TROUBLESHOOTING

Discolored endcap

Typically, a discolored endcap is caused by overheating a bulb. To avoid this problem, ensure that proper cooling procedures are in place, and airflow is positioned correctly. Also check electrical connections. Lamp bases should not exceed 225˚C.

Mushroomed cathode

A mushroomed cathode is the result of excessive power supply ripple caused by a power supply phase loss, a defective power supply, or bad connections. Check the AC ripple, electrical connections, and line phases.



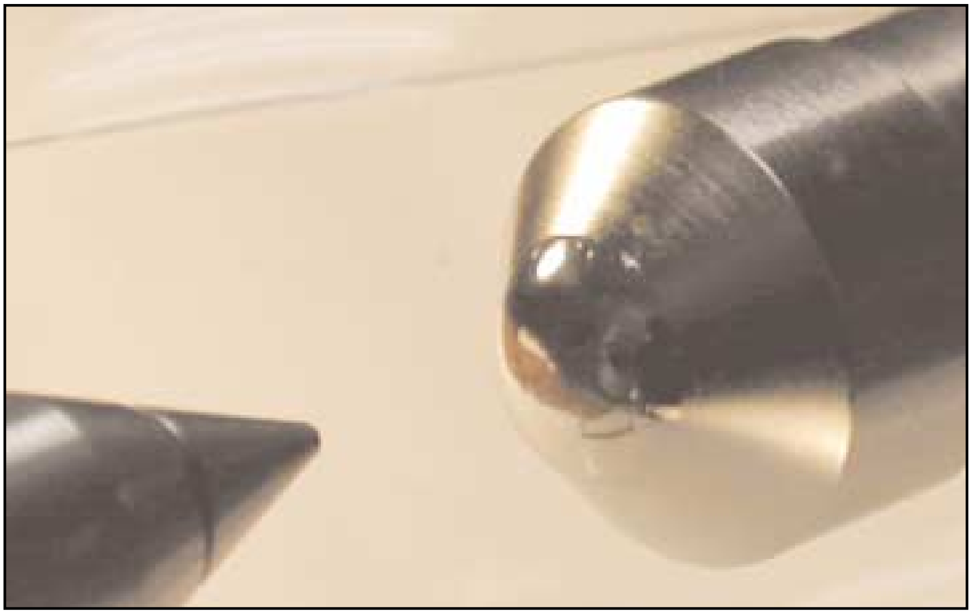
Melted cathode

A melted cathode is caused when a lamp is installed in reverse, (i.e. reverse polarity). When installing a lamp, ensure that the anode and cathode are placed correctly.

Uneven bulb darkening

Darkening may occur on one side of the lamp envelope if the bulb has not been rotated. Rotate the bulb 180˚ at half-life to prevent this from occurring.

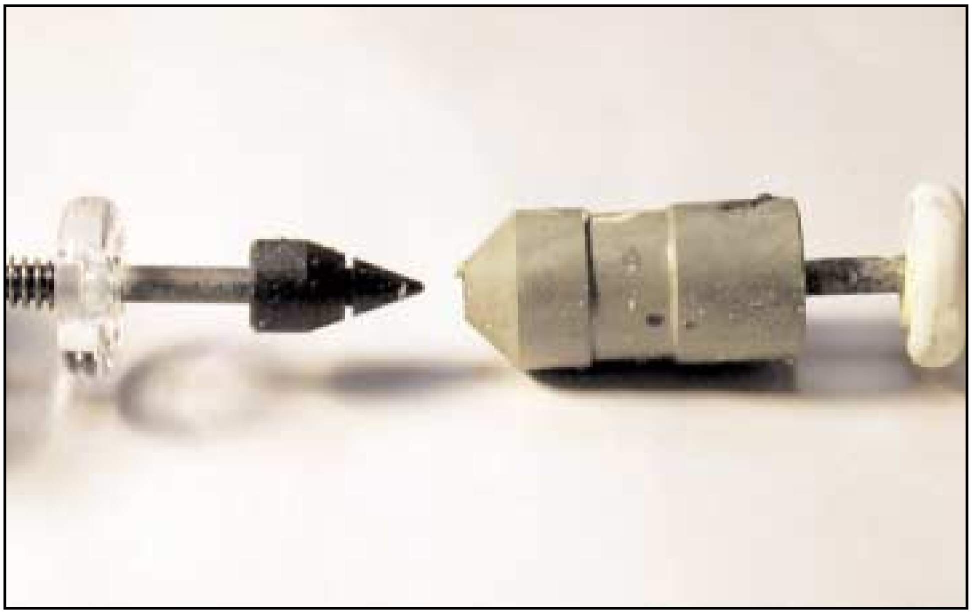
Melted anode
Typically, a melted anode face is the result of operating a bulb at a level exceeding the power range specifications. To avoid this problem, ensure the current is within the recommended operating range (85-110%).



Discolored bulb
The bulb body may turn bluish in color if the bulb has leaked. As with the discolored endcap, ensure that proper cooling procedures are in place, and that airflow is positioned correctly. Seal failure is generally caused by overheating.

Explosion

If a lamp explodes unexpectedly, fingerprints or dust may be to blame. To avoid this problem, clean lamp envelopes with alcohol and a cotton swab if they are touched accidentally, or if they have accumulated dust or dirt. Also, ensure that lamp life is not exceeded by more than 25%; aging quartz loses mechanical strength with advancing age.



Current ripple

High peak-to-peak current ripple causes cracking and melting of the cathode tip. After prolonged use, the anode surface will also melt and distort. Excessive ripple is the number one cause for short lamp life and arc instability.

Quartz devitrification

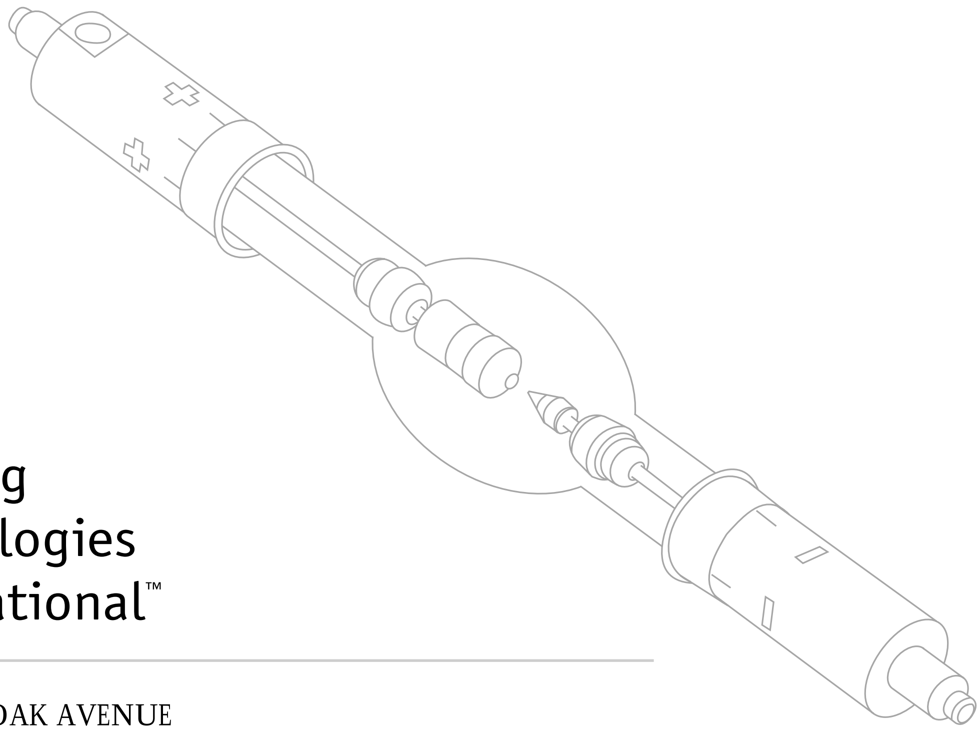
Quartz devitrification is caused by the useful life of the lamp being exceeded or the lamp being operated beyond the maximum current range.

Flicker

Flicker may result from a faulty lamp, unsuitable operating equipment, or incorrect operating mode. Ensure that the lamp is being operated at the recommended current, and that it is adjusted correctly. New lamps sometimes flicker when they are first installed – they must be operated for several minutes for thermal stabilization to take place.

Unable to light

Lack of ignition is caused by poor connections, low open circuit voltage, or end of lamp life. Check connections, open circuit voltage and lamp life.



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