

# Short Arc / Compact Source Lamps

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## What are short arc lamps?

A short arc lamp is generally a spherical or slightly oblong quartz bulb with two electrodes penetrating far into the bulb so that the tips of the electrodes are only a few millimeters apart. An arc is formed between these electrodes. The bulb is filled with xenon, mercury vapor, or a mixture of these at high pressure. The wattage can be anywhere from under a hundred watts to a few kilowatts, although less than about 150-200 watts is definitely a low power version. With the small arc size and this amount of power, the arc is extremely intense.

Short arc lamps are usually used in movie theater projectors, searchlights, specialized medical equipment with fiberoptic light delivery means, some stage spotlights ("followspots"), and some scientific equipment requiring an extremely intense light source. The high cost, short lifetime, limited efficiency, and major safety hazards of short arc lamps make them impractical for general purpose lighting.

## Hazards of and safety precautions for short arc lamps

**Short arc lamps have numerous hazards. They do not make good toys.**

The arc is about as intense as a welding arc or a carbon arc. One should not look directly at the arc. If your eyes are already adapted to bright light, you may get away with looking at the arc for up to a few seconds with no permanent eye damage - but doing this is NOT a good idea. You won't hurt your eyes looking at the arc through #12 welding glass - but there are other hazards. Filters made for looking directly at the sun will also make the arc safe to look at directly. Most other dark transparent materials will not protect your eyes since they let through enough infrared to risk cooking spots on your retina - an eye damage phenomenon notoriously lacking warning signs.

The arc emits almost every kind of ultraviolet in the book, including large amounts of UV-A, UV-B, and some UV-C. These different ultraviolet bands are bad for different parts of your eyes. Number 12 welding glass and sun-viewing filters will protect your eyes. However, the UVC, UVB, and the shortest UVA wavelengths can sunburn your skin. Serious sunburn and increased risk of skin cancer may result from significant exposure to this radiation. These wavelengths are blocked by ordinary glass, but for other reasons below it is HIGHLY RECOMMENDED to only operate short arc lamps in fixtures designed and made for them by qualified personnel - typically engineers and technicians who work for the fixture manufacturers.

The shortest ultraviolet wavelengths emitted by short arc lamps can generate ozone. Operate the lamps in an adequately ventilated area. If you can smell the ozone, it can noticeably irritate your lungs within hours.

Short arc lamps operate at red-hot temperatures of up to 900, sometimes even 1050 degrees C (approx. 1650-1900 degrees F) and contain very high pressure usually in excess of 10 atmospheres and often near or over 20 atmospheres, and in a few cases 50-plus atmospheres. They can explode. Rarely, but who knows how rarely, they explode when nothing can be detected as wrong. If operated in any way other than as specified or past their intended life expectancy, the risk of explosion increases. Explosions can be dangerous since they can result in red-hot (or hotter) pieces of glasslike quartz being shot out in all directions, possibly with considerable force. These lamps should only be operated in fixtures made for these lamps and designed to contain a lamp explosion. Some of these lamps contain mercury, so you might not want one to explode in your home even if there was no risk of fire or red-hot glass shrapnel.

Some short arc lamps require forced air cooling. This is another reason to operate them only in fixtures designed for the particular lamp being operated.

Many short arc lamps have pressure well above atmospheric pressure even when they are cold. You don't want to drop one and have it break.

Short arc lamps have quartz bulbs operated under stress at high temperature. The usual halogen lamp rules for bulb cleanliness apply. Carbon deposits can absorb light and make hot spots. Traces of any sort of ash, salts, metal oxides, or alkalis can leach into hot quartz and cause strains which can weaken the quartz. You should not touch the bulb. If you touch the bulb, you can clean it with alcohol so that no skin oil traces are left on the bulb. It may also be a good idea to rinse the bulb with distilled water.

Do not operate a short arc lamp that has been scratched or chipped.

Short arc lamps should be operated only at the wattage they were designed for and with the type of current they were designed for. Overpowering them is obviously bad. Underpowering an arc lamp can also be bad, since a slightly-too-cool electrode does not emit electrons easily, and the voltage drop in the cathode region of the arc increases and causes positive ions to hit the cathode harder, which "sputters" off cathode material. This will discolor the bulb and may cause the bulb to overheat or have an abnormal temperature gradient somewhere and could make the bulb explode. Discolored bulbs as well as abused electrodes can really overheat if operated at full power.

Some short arc lamps are designed for AC, and typically have two identical main electrodes. Most are designed for DC and DC lamps usually have two visibly dissimilar main electrodes. Operating an AC lamp on DC will overheat and/or excessively age at least one electrode. Operating a DC lamp on AC will overheat and/or excessively age at least one electrode, as will operating a DC lamp with reversed polarity. Some DC lamps require well-filtered DC for full life expectancy and for proper function of aging electrodes. Aging electrodes have limits in the peak rate at which they can emit electrons without overheating or sputtering, and peak current has to be minimized. Excessive peak current may accelerate aging of electrodes that are in good shape.

Short arc lamps may have to be operated in a specific position so that convection currents -

internal and external - don't cause vulnerable parts of the lamp to overheat. This is another reason to use them only as directed in proper fixtures designed specifically for the lamp being used. Follow all directions that come with the lamp and all directions that come with the fixture.

With all this trouble and the high cost and short life expectancy of short arc lamps, it is no wonder why they are only used where there is no substitute for a small, very intense arc. Short arc lamps are not good toys for casual experimenters.

Posted in sci.optics and sci.electronics.misc by John Byrne :

Please be VERY careful with any high pressure Xenon lamps, especially the short-arc type. Even when cold, they still represent a very significant explosion risk, with cold fill pressures of 10-25 atmospheres. You drop one of these on the floor..... think of a hand-grenade! (and yes, it has happened to me!)

All xenon lamps are now shipped in multi-layer protective packaging, with many warnings about the use of FULL face and body protection BEFORE even opening the the box!

As to the operation of these lamps, don't try to make your own gear, it's just too expensive, and the ignition voltages required sometimes exceed 75kV.

UV is a definite problem, and also the explosion risk, so operation of this lamp will require a protective enclosure.

## **Short arc lamp types**

Short arc lamps can be mercury vapor, xenon, or mercury-xenon.

Mercury vapor short arc lamps contain a low pressure gas fill, typically argon, plus mercury. These lamps start easily without multi-kilovolt starting pulses but require a warmup period and have poor color rendering. The spectrum consists mainly of mercury lines but also has some continuous spectrum. The color rendering is better than that of a general-purpose unphosphored mercury lamp, but not good enough for color film projectors since the spectral output is low on red.

Xenon short-arc lamps do not require a warmup period and have excellent color rendering. The color is an icy pure to very slightly bluish white, with a color temperature usually in the mid 5,000's Kelvin. This is very slightly more blue than noontime tropical sunlight with clean air. The visible spectrum is almost entirely continuous spectrum, with faint visible xenon lines. Near-infrared xenon lines are more significant and detract somewhat from the efficiency at which visible light can theoretically be produced.

Xenon short arc lamps have the drawback of requiring very high voltage starting pulses around 30,000 volts. The actual voltage requirement varies with what model lamp is used.

Mercury-xenon short arc lamps are a compromise between mercury and xenon in both advantages and disadvantages. These lamps contain xenon at a pressure around 1 atmosphere (when cold). When started, there is significant light from the xenon arc. Warmup may take something like a minute, at which time full light output is achieved. The spectrum has both significant continuous spectrum from xenon and moderately strong mercury lines. The color and spectrum are somewhat like that of a "daylight" fluorescent lamp, except the yellow

mercury line is stronger with the still-high mercury pressure and this makes the short arc lamp not quite as blue nor have quite as good color rendering as the "daylight" fluorescent lamp. In addition, shortwave and mediumwave ultraviolet wavelengths of mercury can run strong compared to visible mercury wavelengths. The the really high mercury-pressure/power-intensity ratio of a mercury short arc lamp favors visible mercury lines while cutting back a bit on mercury (and therefore arc radiating opportunity) lets the arc temperature rise the few hundred to several hundred degrees K that gives a significant favor to ultraviolet mercury lines. So mercury-xenon short arc lamps have some use in industrial applications requiring such ultraviolet wavelengths.

## Short arc lamp operation

A ballast is required to limit the current flowing through the lamp and also to provide any necessary high voltage starting pulses.

Some short arc lamps have only the two main electrodes. Others have a third electrode for applying the starting pulse.

In most short arc lamp fixtures, current limiting is achieved with an inductor. Some newer fixtures have electronic ballasts. Since the voltage across the arc is typically low compared to the line voltage, an inductor ballast will allow nearly constant current to flow through the lamp even if the voltage across the arc changes due to aging or warmup. Some electronic ballasts provide more nearly constant power, and the lamp does not overheat as badly if the arc voltage rises due to aging electrodes.

If the lamp has a starting electrode, the high voltage pulse may be obtained from simple, inexpensive circuitry. If a lamp with only two electrodes requires a high voltage pulse, then series triggering or pseudoseries triggering is required.

In series triggering, the secondary of a transformer that generates the high voltage pulse is in series with the lamp. This transformer may be the current limiting choke, with the secondary being the main winding and the primary being an auxiliary winding used only for high voltage pulse generation. With xenon lamps, the necessity of making a ballast main winding withstand 30,000 volt pulses can increase the cost of producing such ballasts.

Pseudoseries triggering is easier to accomplish with DC lamps than with AC lamps. In pseudoseries triggering of a DC lamp, a diode or several diodes are in series with the lamp. These diodes must withstand the pulse voltage since they prevent the main part of the ballast from shorting out the starting pulse. The starting pulse device, typically a low power very high voltage transformer of one kind or another, is connected directly across the lamp and is reasonably high impedance so that it is not adversely affected by the main voltage. The starting device ionizes the lamp, and then the main current flows through the diode(s) and the lamp.

Pseudoseries triggering has its own drawback with pure xenon lamps. A diode stack that withstands 30,000 volts can drop 20 to 30 volts when the main lamp current is flowing, which is almost as much voltage as the arc normally has across it. The diode stack would consume almost as much power and make almost as much heat as the lamp does.

Once the arc is established and the lamp is warmed up, the voltage across the arc is quite low - often around 30 volts. Very high pressures are required just to get the voltage drop of a short arc that high.

## Limited efficiency and lifetime of short arc lamps

Short arc lamps are not as efficient as general purpose high intensity discharge lamps. Since the voltage across the very short arc is low, a high percentage of this voltage is electrode losses. The voltage across the arc may only be around 30 volts. The electrode losses are typically a 10 to 15 volt drop, so nearly half the power delivered to the lamp is wasted heating up the electrodes.

Even after allowing for electrode losses, a xenon short arc lamp is less efficient than theoretically expected for a 5500 Kelvin blackbody radiator, since the xenon arc has strong near-infrared lines. Secondly, some of the power delivered to the main body of the arc is conducted and convected from it as heat instead of being radiated.

Thermal conduction losses can be significant for lower wattage short arc lamps. This loss is not as bad as it is in general purpose high intensity discharge lamps since the arc is shorter, but is still in addition to the horrendous electrode loss that short arc lamps have.

Expect short arc lamps to have unimpressive luminous efficacies around 40 lumens per watt delivered to the lamp. Xenon ones get a mere 13 lumens/watt for the 75 watt size, 13-20 lumens/watt for 150 watt sizes, 35-40 lumens per watt in 1-1.6 kilowatt sizes, and around 45-51 lumens/watt in 10-20 kilowatt sizes. Mercury and mercury-xenon short arc lamps are more efficient than xenon ones but less efficient than ordinary general purpose mercury lamps. Since the arc voltage is low and current is high, ballast losses may also be quite significant.

Short arc lamps have limited lifetime, typically a few hundred hours. Any evaporated electrode material will darken much to all of the inner surface of the bulb. This is unlike conventional discharge lamps which have the electrodes in the ends of a longer arc tube so that only the ends and not most of the arc tube are discolored. Metal halide lamps may also have some sort of a halogen cycle that keeps the inner surface of the arc tube clean, but most short arc lamps do not have halogen since halogen vapors cause starting to be even more difficult than it already is. In addition, halogens have some effect on the hot quartz which is already stressed enough as it is. This can result in silicon deposits on the electrodes and silicon can be vaporized from the electrodes onto the inner surface of the bulb, adding discoloration. Halogen problems have been overcome to an extent that permits the manufacture of "short arc" metal halide lamps, discussed in a separate section below. However, the arcs in these lamps are not as small nor as intense as in short arc mercury, xenon, and mercury-xenon lamps of similar wattage so these lamps are considered "medium arc length" and not true short arc lamps.

## Short arc metal halide lamps (HTI/HMI lamps)

Some metal halide lamps have short arc construction. These include most metal halide lamps under 100 watts, as well as the HTI and HMI lamps. However, the arc is larger in a metal halide lamp since the metal vapors in the arc easily glow at lower temperatures than mercury vapor and xenon do. For this reason, the arc is less intense than the short mercury and xenon arcs.

Conventional metal halide lamps of lower wattages have been widely available only in recent years. The arc tube construction often resembles that of a short arc lamp. In the Philips 70 watt metal halide lamp, the arc tube is a small sphere.

The HID lamps used in some auto headlights are metal halide lamps, with some xenon to give usable light output before they have warmed up. For more info, look in my [Automotive HID Lamp File](#).

HMI lamps are special high intensity metal halide lamps used in some followspots and are sometimes used for shooting movies. Larger multikilowatt HMI lamps used in moviemaking have a spectrum with a very large number of lines, and the visible spectral content is close to that of noontime sunlight. HTI lamps are a particular variation of HMI lamps. Although the arc in an HMI lamp is intense, it is not as small and concentrated as the arc in mercury and xenon short arc lamps. In fact, "HMI" literally means "hydrargyrum (mercury) medium-arc-length iodide". When maximum light concentration is required, "true" short arc lamps based on mercury and/or xenon are used.

### **Links to short arc lamp manufacturers / suppliers/etc.**

[Sylvania "Photo-Optic" Lamps](#), with many of these being short arc lamps.

You will see hundreds of records, each for various lamps, mostly HMI, HTI, other specialty metal halide, and ones for HBO (mercury short arc) and XBO (xenon short arc). Click on the first item in the line (the Sylvania catalog number) and you can get a brief spec sheet with info such as wattage, life expectancy, lumen light output and sometimes even arc voltage and arc current!

If their site changes enough to make the above link fail, hit the one below after seeing here what to do:

1. Hit their link to the General Lighting Product Catalog (including photo-optic).
2. Hit "Product Class Search".
3. Make the Product Class "Photo Optic", and the Primary category and Secondary Category both "All Records".

Now that you know what to do there, [Go For It!](#)

[Advanced Radiation Corporation](#), a manufacturer of short arc lamps.

Perkin Elmer, and especially its ORC division, makes short arc lamps:

[Perkin Elmer Alphabetical Product Listing](#)

[ORC Lighting Products](#)

[Products and Services : ORC Lighting Products](#)

[Component and System Light Sources](#)

I am aware that whenever I make links into Perkin Elmer besides to their home page, they often don't stay good for long. If the above don't work, then go to <http://www.perkinelmer.com> and try your luck from there.

[A web page that mentions some aspects of construction of short arc lamps, as in some explanation of their high cost!](#)

Note that I discourage casual experimentation with short arc lamps because of their high cost,

numerous hazards and generally short life expectancy.

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