Light Sources

What is a Light source?

A light source, for the purposes of this class, is a device that creates light. In the performing arts, studios and film, we use many different types of light sources. The type of light sources used is rapidly evolving and each light source has it's own strengths and weaknesses. It is therefore, important to understand the differences and the history behind their development.

6 types of light sources typically used in performance situations or theatres:

1). Incandescence

2). Arc Light

3). Gas Discharge

4). Short arc

5) LED / OLED

6) Electroluminesence

INCANDESCENCE

- most common type of illumination in use in theatres. A metal filament is heated through resistance until it is so hot that it incandesces, or produces light.

- -flames are incandescent gas. Red hot steel is incandescent.

Incandescent lamps have 3 parts:

Bulb (the glass envelope)

Base – makes electrical contact and correctly positions lamp

Filament – typically tungsten, high temp/ high resistance

2 types:

Standard incandescent – w/tungsten filament, regular glass and inert gas. Not much improved from the lamp produced in 1910. Still made.

Halogen – w/ compact tungsten filament, halogen gas, and high temp glass bulb.

Approximately 90% of the power consumed by an incandescent light bulb is emitted as heat, rather than visible light.

Incandescent light bulbs are being phased out for newer, more efficient light sources.

Already gone in Brazil, currently being phased out in the EU, although they are supposed to be already phased out in the US, Congress intervened and they continue to be manufactured in the US.

-In the theatre, incandescent light sources are never referred to as bulbs. They are lamps.

And now, a little history:

The Filament Incandescent Lamp

-1802 first demonstrated by Sir Humphrey Davies - but no power available!

-1879 Thomas Edison invented first practical incandescent lamp. It had a carbon filament made by charring a strand of bamboo fiber – enclosed in an evacuated glass bulb. It produced 1.4 lumens of light per watt of electricity. Had an efficiency of 4%. Edison chose carbon because it had a high melting temperature.

Tungsten introduced in 1907 – melting point of 6120 degrees F,

1913 vacuum replaced with inert gas (argon or nitrogen) – now up to 14 lument/watt 10X Edison's lamp.

1910-1920 technology invented to create tungsten wire – more concentrated filaments.

Lumen Maintenance

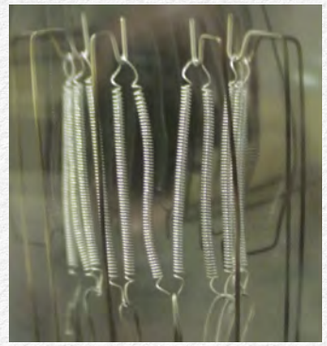
Sublimation: Tungsten converts from solid directly to a gas (skipping a state of matter – or sublimating) this gas condenses on the bulb of the lamp clouding it over time. The black coating on the inside of this lamp is actually condensed tungsten. As the bulb clouds more and more, the lamp is less able to shed heat. This increases the rate of tungsten vaporization, and ultimately the failure of the filament. When the filament fails, the circuit is broken. Burning out is actually a misnomer – lamps don't "burn" because the oxygen is missing. Lumen output of a lamp tends to drop off over time – so may be reported as " average Lumens"

The optics of a modern lighting instrument work ideally with a light source at a single point - or point source. The struggle with tungsten filaments is to pack as much tungsten in as small of an area as possible, with the hope of getting close to this theoretical point source.

FILAMENTS

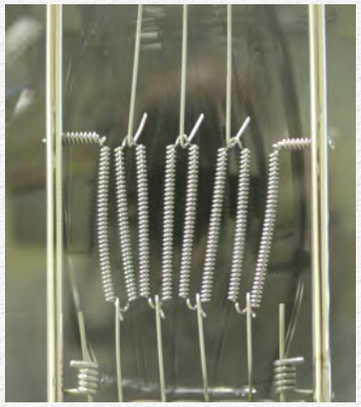
Filaments come in 5 different configurations depending on intended use.

These forms are:



Barrel

Corona



Monoplane

Bi-plane

coiled coil.

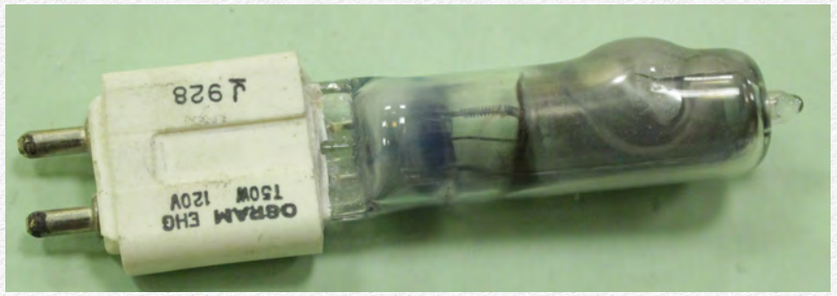
Both the Barrel and the Corona (crown) are very similiar. They look semi-circular from above. One way to tell the difference is the little springs on the barrel filament are more vertical (and there are more of them), while the corona filament ones are at more of an angle - like the top of a king's crown. Both of these filament configurations are designed to emit light in all directions.

The Mono-plane and Bi-plane filament configurations are somewhat similiar to each other. From above, it becomes clear that a mono-plane filament is arranged in a single plane. (get it?) While the bi-plane filament configuration has two planes. The bi-plane configuration has more tungsten springs crowded together - brighter light and closer to point source. Both of these filament configurations are designed to emit light in two primary directions.

The coiled coil configuration, and innovation which is seen primarily in Tungsten-Halogen lamps, concentrates a large amout of tungsten in a very small area in an attempt to get closer to that point-source ideal. A coiled-coil configuration is designed to emit light in all directions.

BULB – regular lamps are just glass. Because regular glass has a relatively low melting point, standard incandescent lamps tend to be bigger. Standard incandescent lamps also have a fixed burning orientation. This means that an individual lamp is designed to be used in a specific orientation (example: burn base down). Using a lamp outside of it's burning position may result in catastrophic failure.

Tungsten halogen lamps have a high temperature and pressure resistant glass based on quartz – like pyrex. This high temperature glass allows tungsten halogen lamps to be smaller and also have a universal burning position. A universal burning position means the lamp can be illuminated in any position. Because tungsten halogen lamps operate at much higher temperatures, they tend to provide a whiter light. Be careful when handling them, a fingerprint on the bulb will etch the glass under the intense heat resulting in lamp failure.



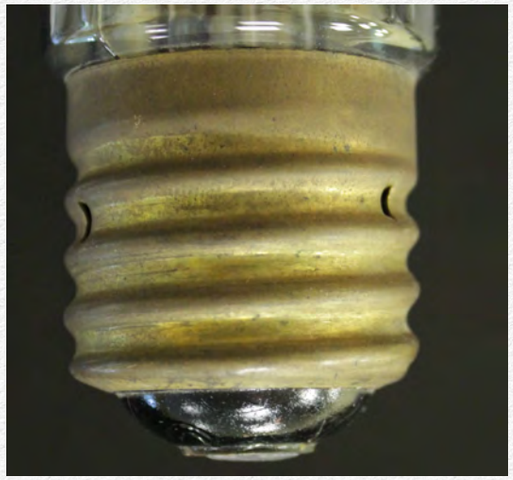
Bulbs have different shapes for

different uses: A+ Arbitrary (typical house hold light bulb),PS= Pear shape, G=Globe shaped, T= Tubular, PAR, R=reflector etc…

.The glass can be ordered in frosted or clear finish color – or lamp dip- can be applied in only lower wattage lamps. (non- tungsten halogen)

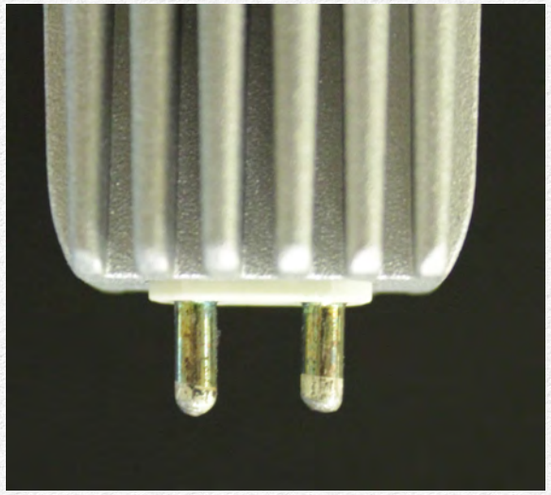
Diameter of bulb is expressed by how many 1/8th's of an inch it is at the largest diameter.

BASE- a base serves to position the lamp correctly and to provide electrical contact.



Screw

pre-focus



Bi-pin

All come in different sizes (mini, candelabra, regular and mogul).

Screw bases are the configuration that is perhaps most familiar. They commonly come in mini, candelabra, regular and mogul. Screw bases were introduced by Edison and became the standard around 1909. They are often used for lamps emitting light in all directions.

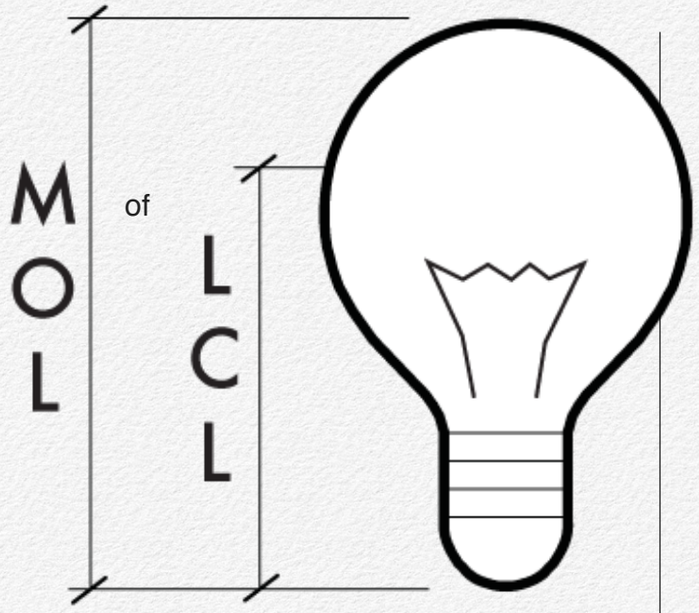
Pre-focus bases are used for lamps which require a specific orientation and come in a variety of sizes. A bayonet base is similar, but instead of tabs to position the lamp it uses metal buttons on the side of the base which fit into slots in the instrument or socket. Bayonet bases were invented in England and were widely used throughout the British Empire.

Bi-pin bases also are commonly used for lamps which need a specific orientation, but are also used because of their simplicity. Invented by Reginald Fessenden for the 1898 Chicago World's Fair when GE refused to allow Edison's screw bases to be used.

Light center length or LCL.

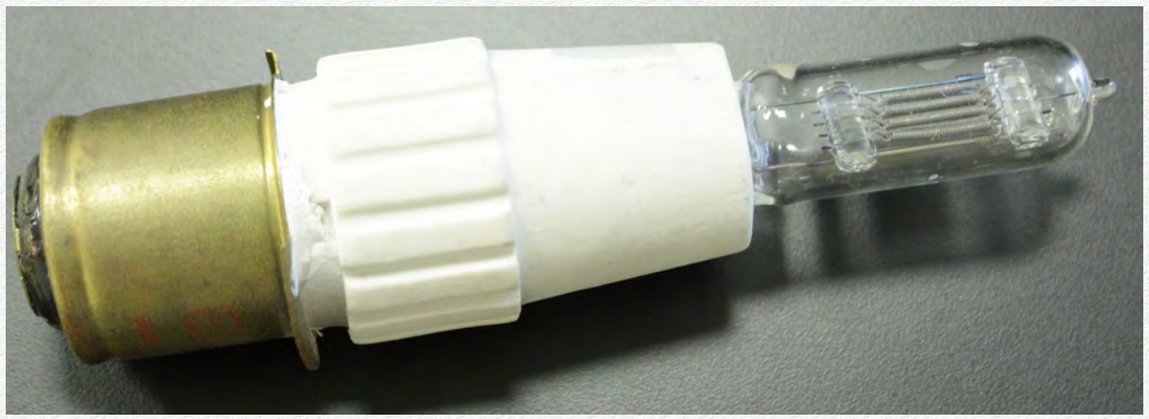
The length measured from the center of the filament to the bottom of the base. This information is important in order to make sure the filament is aligned properly for maximum light output.

MOL = Maximum Overall Length



Light Center Length (LCL) and Maximum Overall Length (MOL)

Using LCL, it is possible to get tungsten halogen lamps for older fixtures- these lamps are called RETRO-FITS.



quartz lamps w/ std incandescent bases matching original LCL. Used to upgrade old instruments to more efficient lamps. Retro-fits often have extra ceramic between the base and the bulb to compensate for older and larger LCLs.

PARs and R lamps are like small self –contained lighting instruments - they have lamp, reflector and in some cases a lens contained in the lamp.

More about Tungsten –Halogen lamps:

-commonly called “quartz” lamps also for the “new” glass used in their manufacture.

-more compact filament – closer to a point source = more efficient.

-same intensity throughout lifespan – no coating sublimated on the bulb because the halogen gas, under heat and pressure (when on) stops the sublimation process and the tungsten is re-deposited onto the filament. Typically these lamps have a longer life than an equivalent standard incandescent.

very hot source – required for sublimation cycle to be broken. This also yields white light

has weaker – less supported filament

- instruments with tungsten halogen lamps must be handled gently.
- NEVER touch the glass of the lamp its self.
- Universal burning position

Lamp Life-

Things that contribute to shortened lamp life

-too much heat

-rough handling

too high voltage – low voltage increases life

wrong burning position

ANSI developed a 3 letter identification code for all lamps. example EHG.

Incandescent light all emits light as a continuous spectrum. This is because it starts infa-red then moves through red, orange, yellow towards white as the heat increases. The white light generated is a collection of all of these wave lengths. Because of this method of light generation, incandescent light can be said to have a **color shift** during dimming. This has a consequence of changing colors of even gelled light at different intensities and of creating light that is relatively poor in blue wavelengths. More about these color issues when we get to color.

Color Temperature

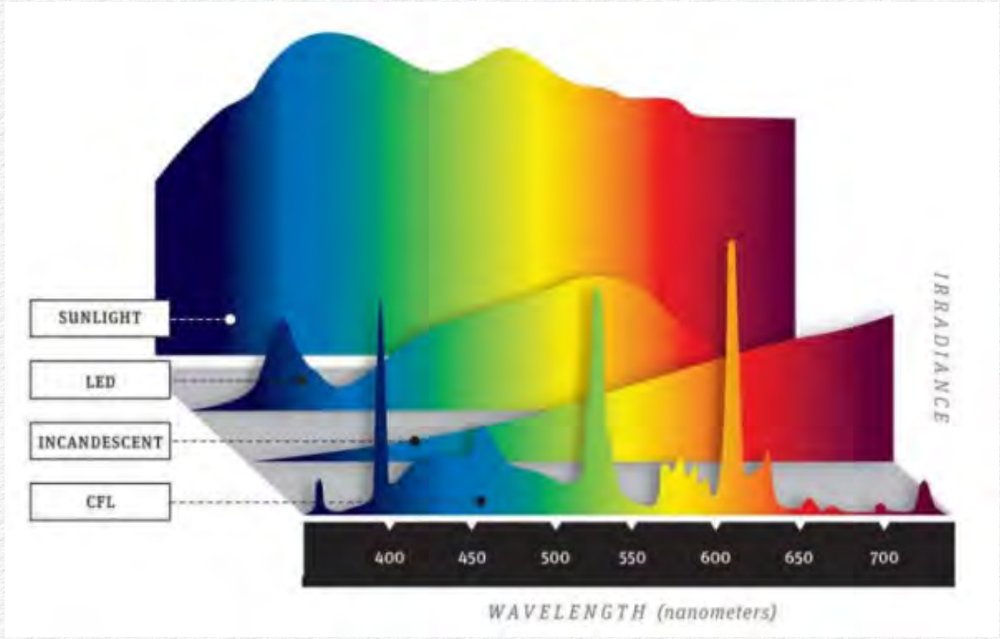
-blackbody – a theoretical device (spectrophotometer) which absorbs all light and emits specific wavelengths as optical temperature increases. Expressed in degrees Kelvin.

Ex. Stage lights = 3000 – 3200degrees K

Arc light = about 6000degrees K

A color difference of around 200 degrees K is imperceptible

Degrees Kelvin	Type of Light Source	Indoor (3200k) Color Balance	Outdoor (5500k) Color Balance
1700-1800K	Match Flame		
1850-1930K	Candle Flame		
2000-3000K	Sun: At Sunrise or Sunset		
2500-2900K	Household Tungsten Bulbs		
3000K	Tungsten lamp 500W-1k		
3200-3500K	Quartz Lights		
3200-7500K	Fluorescent Lights		
3275K	Tungsten Lamp 2k		
3380K	Tungsten Lamp 5k, 10k		
5000-5400K	Sun: Direct at Noon		
5500-6500K	Daylight (Sun + Sky)		
5500-6500K	Sun: through clouds/haze		
6000-7500K	Sky: Overcast		
6500K	RGB Monitor (White Pt.)		
7000-8000K	Outdoor Shade Areas		
8000-10000K	Sky: Partly Cloudy		



Different light sources emit light at different wavelengths or color temperature. This can be an especially important consideration when filming, photographing or making a video of something. This is especially true when using multiple types of light sources. More about this when we discuss color.

LOW VOLTAGE LAMPS

Low voltage lamps are incandescent lights that have very small filaments used as extremely intense, near point source light sources. Use of low voltage light sources require either a battery or low voltage power supply. Note that a modern SCR dimmer does not vary voltage and thus cannot be used for these sources.

According to Ohm's law (remember?) as voltage decreases, resistance increases. This means that a circuit of low voltage lights can build up resistance very fast.

Low voltage lighting is used for portable sources (like flashlights) or very specialized applications.

ARC LIGHT

- concept of 1st arch lamp demonstrated in 1808 by Sir Humphrey Davies (also credited with discovery of laughing gas), lack of electrical supply makes it un-usable. Used widely in the theatre by 1876. To create an arc, two electrodes are mounted touching each other in free air. As current is applied, the electrodes are slightly moved apart. As the electrodes move apart, electrons jump the gap and their intense energy creates intense heat and ionizes the air creating bright, and violet shifted light. This light is heavy in ultra-violet light. A natural example of arc lighting might be lightning.

- Was the first practical electric light. Used for street lighting until it is replaced by incandescent lighting. Continued to be used for applications requiring high intensity light - like movie projectors, follow spots, and searchlights. Carbon Arc is the most common type of arc light that was used in the theatre. Today, the arc has been replaced by newer, easier to use and safer light sources. We still use another version of the arc in the scene shop when welding steel. It is important to provide good ventilation, because one of the by-products of an arc is carbon monoxide. Also, because the arc is very small (almost a point source), very intense, and has ultra-violet light, it should never be looked into with un-protected eyes.

- Because the electrodes are consumed by the arc, using an arc spot-light required a skilled operator (raising the cost of operation) who had to periodically adjust the gap between electrodes (the light changes depending on the size of the gap), and replace them as they got too small to be useful.

GAS DISCHARGE

-Current passing through pressurized gas – excites gas and causes light to be emitted. Common type is Mercury vapor (fluorescent lights) which emits mainly in the UV range and requires a phosphor to emit visible light.

-Another common type is neon light. = glass tube with pressurized neon gas, an electrode on each end and a high voltage current. The gas becomes a conductor once the voltage is high enough, completing the circuit.

Color, intensity and color dependent on:

gas pressure

temperature

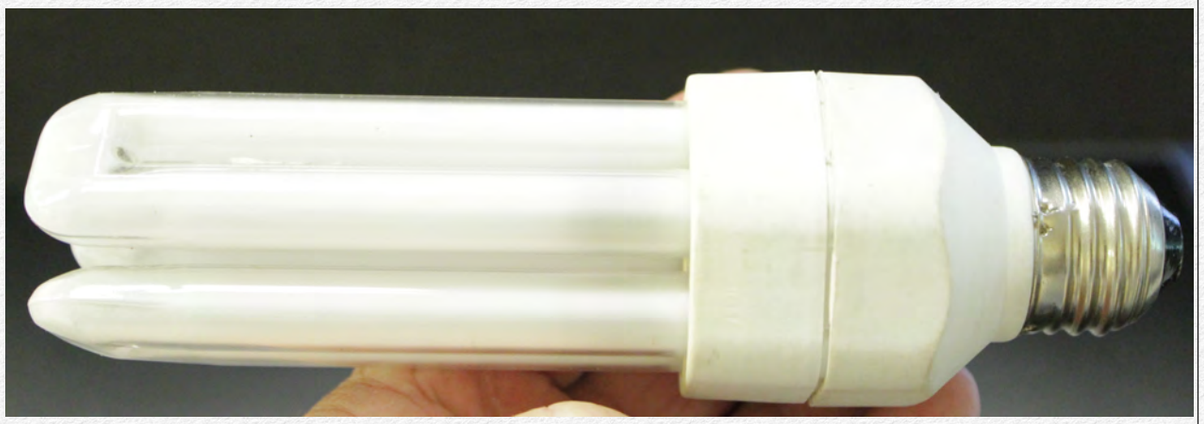
kind of gas and/or phosphor

these factors also determine the color of the light which is in line spectrums - to a continuous collection of wavelengths.

Gas discharge lamps are rarely used in the theatre for performance lighting.

Because the entire glass tube emits light, it is difficult to use gas discharge sources in a lensed system (like a theatrical lighting instrument). Because they use a transformer, they can be very noisy, and they are difficult to dim or change the intensity. They do not depend on the production of heat for illumination. They are efficient energy users.

Fairly new to the scene are compact flourescent lamps. They are designed to directly replace standard incandescent lamps, and are targeted at lowering residential energy demand.



SHORT ARC

Short Arc light sources are a cross between an arc source and a gas discharge source. The first commercial short arc lamp was introduced by Osram in 1951. The arc happens in a pressurized, sealed enclosure filled with Xenon gas. During use, a high voltage charge passes between two electrodes, ionizing the Xenon and creating and energized plasma. Unlike a traditional arc light, the electrodes are not consumed so there is no need to adjust the electrode gap (it isn't possible anyway). The light produced is an intense, white light in a continuous spectrum at nearly a point source. As a result, color rendering is very good and the color temperature is about 6200 degrees K. These lamps are most commonly used in film projectors, large venue follow spots, architectural lighting and scientific applications. The arc produces UV light and intense heat, so short arc lamps are made with a heavy quartz glass envelope and any short arc source use in performance must include a UV filter to protect performers. These devices operate under high pressure (10 atmospheres at room temperature to 40 at operating temperature). They are fairly hi efficiency at about 40 lumens/watt. They can not be dimmed on but once on, can be dimmed down to 10%.

This is a DC device
- so it requires a power inverter - oh, and it isn't self limiting so it will consume more and more power until something fails(requires a voltage regulator) - Oh, and remember that high pressure inside an heavy quartz glass envelope? - It can EXPLODE at any time - for no apparent reason. For that reason, it is stored in a case designed to contain any explosion (see picture). The manufacturer recommends that when changing lamps or any exposure to lamps, that the user wear eye protection. Some say full body protection should be required. Oh yeah, the best for last... If you were standing next to a short arc source and looked directly at the exposed lamp, and were wearing contacts, the light is so intense that it could WELD the contacts to your corneas!

This all seems like a lot of danger for some light, yes? Not really. Almost any electrical device if used improperly can be dangerous or life threatening. The light from a short arc source is glorious, white light. It eliminates the danger of carbon monoxide (from arc lights) in enclosed spaces and can be operated by someone with basic skills. Modern fixtures using this light source must, by law be designed to contain a possible explosion, must be fitted with a power interrupt switch (in case the enclosure is opened) and a UV filter. Its all good.

LED/ OLED

-electronic light sources

-new emerging technology.

-low power consumption

-colors generated in very pure wavelengths

-allows for excellent color mixing

The ETC D40 (shown above) uses the X7 color system: amber, yellow-
red,red,green,cyan,blue and indigo. This system allows a wide range of color mixing. This fixture at full gives an equivalent light to a traditional 1000W PAR while consuming only 96watts.

-no heat generated

-extreme long life (25, 100,000 hours continuous use)(more than 11 1/2 years of on time)

-use electronic means for intensity control (DMX)

-like all electronic devices are heat sensitive.

ELECTRO LUMINESCENT

- a phenomenon of electrons moving through certain materials.

- does not generated heat

-common example is night lights and watch faces (Indiglo), instrument displays.

-brightness of the surface appears the same from all angles of view.

-not usable in a lensed system, typically used as faux neon - also in models

SAFETY

-If you don’t know what you are doing, don’t do it. Get help. Ask your supervisor.

-ALWAYS unplug an instrument before working on it

-lamps are expensive - treat them with care

-un-shielded Arc or Short Arc light can blind you.

-fingers off quartz lamps

-the bulb or envelope of a burning lamp is too hot to handle - even with t he best gloves. Think about it - tungsten heated up to white hot...