Germicidal Lamp Basics

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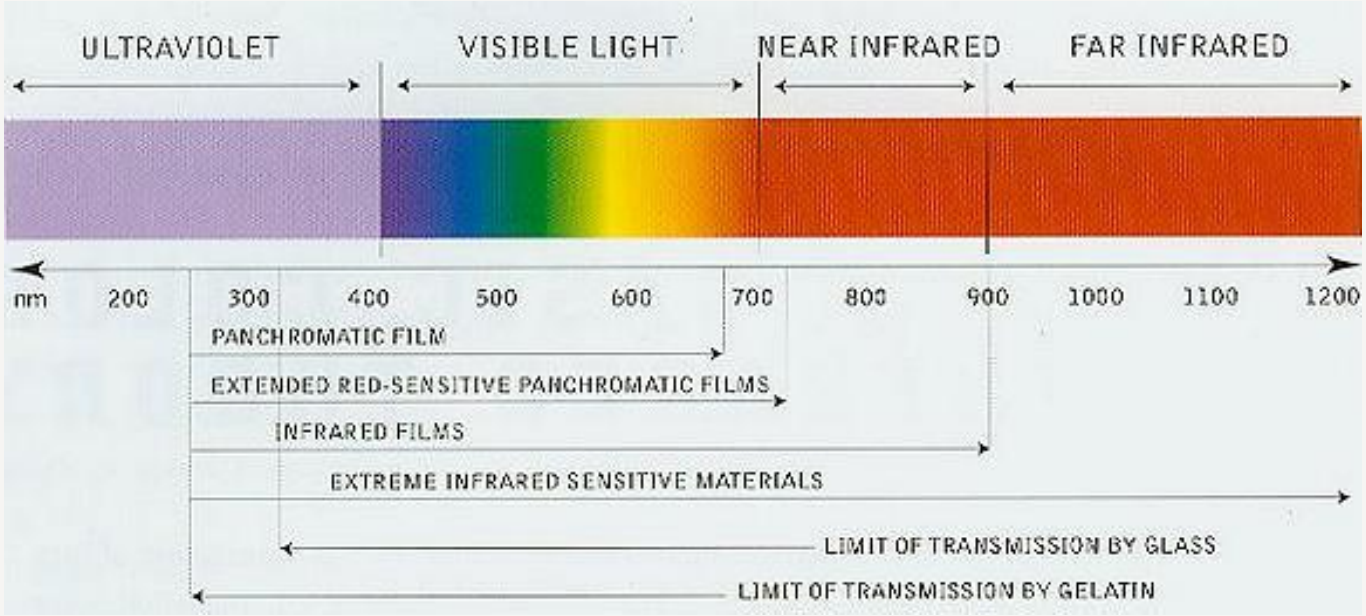
Germicidal Lamp Definition

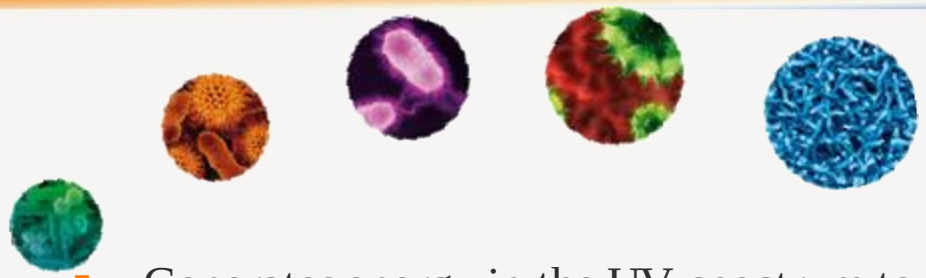
- A germicidal lamp is a special type of lamp which produces ultraviolet light (UVC).



Germicidal Lamp Definition

- A UV (ultra-violet) lamp that emits a significant portion of its radiative power in the UV-C Band (100 to 280nm)
- A UV lamp that generates energy at 185nm which is particularly effective in producing ozone.
- An ozone producing UV lamp that produces UV energy of wavelengths shorter than 220nm that decomposes oxygen, O^2 , producing ozone, O^3.
- A low-pressure mercury lamp in which the envelope has high transmittance for 254nm radiation

What does a Germicidal Lamp Do?

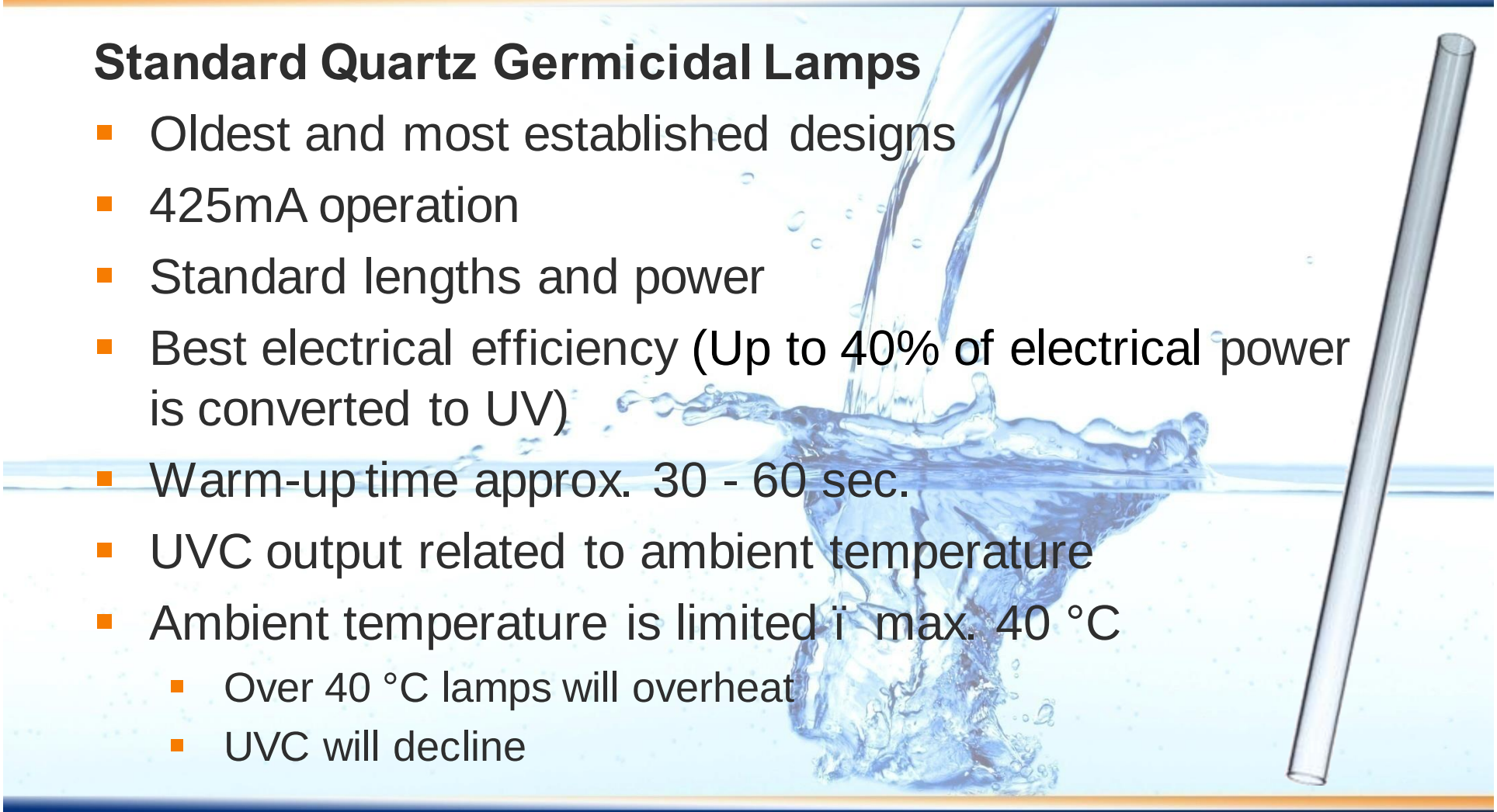


- Generates energy in the UV spectrum to destroy bacteria, fungi and viruses (microorganisms). Microorganisms include several distinct groups of disease causing germs (Viruses, Bacteria, Fungi, Algae and Protozoa.)
- The target of UV disinfection is the genetic material, nucleic acid. As the UV penetrates through the cell and is absorbed by the nucleic acids, a rearrangement of the genetic information occurs, interfering with the cell's ability to reproduce. A cell that can not reproduce is considered dead; since it is unable to multiply to infectious numbers within a host.
- The maximum absorption of UV light by the nucleic acid, DNA, occurs at a wavelength of 260nm. The germicidal lamp emitting UV at 254nm is operating very close to the optimized wavelength for maximum absorption by nucleic acids.

Two Main Types of Germicidal Lamps

- Low-Pressure Mercury Discharge
  - The most common form of germicidal lamp looks similar to an ordinary fluorescent lamp but the tube contains no fluorescent phosphor. In addition, rather than being made of ordinary borosilicate glass, the tube is made of fused quartz or soda-lime glass which allow the 185nm and/or 253.7 nm ultraviolet light produced by the mercury arc to pass out of the lamp unmodified. Germicidal lamps still produce a small amount of visible light due to other mercury radiation bands.
- Medium Pressure Mercury Discharge
  - Medium-pressure lamps are more similar to HID lamps than fluorescent lamps. These lamps radiate a broad-band UV-C radiation, rather than a single line. They are widely used in industrial water treatment, because they are very intense radiation sources. Medium-pressure lamps produces very bright bluish white light.

Standard Germicidal Lamp Types



Standard Quartz Germicidal Lamps

- Oldest and most established designs
- 425mA operation
- Standard lengths and power
- Best electrical efficiency (Up to 40% of electrical power is converted to UV)
- Warm-up time approx. 30 - 60 sec.
- UVC output related to ambient temperature
- Ambient temperature is limited ï max. 40 °C
  - Over 40 °C lamps will overheat
  - UVC will decline

High Output Germicidal Lamp Types

High-Output Quartz Germicidal Lamps

- Operate between 600 mA and 800 mA

  - T5 or T6 configuration (15mm or 19mm OD)
  - Approximately 2 times the UV output of standard germicidal lamps
- Same lengths as standard germicidal lamps available
- Same relationship and limitations in regard to ambient temperature as standard germicidal lamps

Amalgam Lamp Types

Low Pressure Amalgam Lamps

- Offer 3 to 4 times higher power density
- Designed for stable operation over wide ambient temperature range; influence of ambient temperature is lower in contrast to standard and HO lamps

- Preferred lamp choice for long-term applications with low or no cycles
- Usable in universal orientation applications

Amalgam Lamp Types

Spot & Pellet Amalgam Lamps

- Spot amalgam lamps have mercury amalgam applied on the inner surface of lamp.
- Pellet amalgam lamps have the mercury amalgam outside of the lamp arc.
  - Use of amalgam allows higher lamp current and power 1- 5+ A
  - Vapor pressure controlled by amalgam composition and location

- Lamp designs contain more robust filaments to withstand higher current operation
- Warm-up time: 3-5 minutes

Typical Germicidal Lamp Nomenclature

Designation	Lamp Type	Length	Shape	Diameter	Glass Type	Base Type
G	AAAAA	BBBB	C	DD	EEE	FFFF
Denotes "Germicidal" Lamp	Up to Five Characters Denotes "Lamp Type"	Up to Four Characters Denotes "Lamp Length"	T = Tubular	Two Characters Denote Diameter	Up to Three Characters Denotes Glass Type	Up to Four Characters Denotes Base Type
	PH = Preheat	Two digits = Length in inches		Expressed in eighths of an inch	L = Low ozone producing	2P = 2-pin
	HO = High Output	Four digits = Length in mm			VH = Very-high ozone producing	4P = 4-pin
	CL = Cell Lamp				LV(H) = Spliced Lamp	SL = Slimline or Single Pin
	U = U Lamp					MNBP = MINI Bi-Pin
	SL = Slimline (Single Pin)					MDBP - MEDIUM Bi-Pin
	PHA = Preheat Amalgam					
	PHHA = Preheat Amalgam Horizontal High Output					
	PHVA = Preheat Amalgam Vertical					
	PHHVA = Preheat Amalgam Vertical High Output					

Typical Germicidal Lamp Diameter

Tube diameter designations	Soft-Glass Dimensions		Quartz Dimensions
	Inches	mm	mm
T2	0.250	6.35	6
T4	0.500	12.70	13
T5	0.625	15.88	15
T6	0.750	19.05	19
T8	1.000	25.40	25
T9	1.125	28.58	28
T10	1.250	31.75	32
T12	1.500	38.10	38

Components of a Germicidal Lamp

All germicidal lamps contain the following components

- Glass
  - Quartz Glass
  - Soft Glass
- Filament Mount S/A
  - Lead Wires
  - Filament
  - Emission Coating
- Fill Gas
  - Argon
  - Neon
  - Xenon
  - Helium
- Mercury
  - Liquid Hg
  - Solid Hg
  - Amalgam
- Final Assembly
  - Ceramic Bases
  - Plastic Base
  - Return Wire/Lead Wires
  - Patented Solutions

Components of a Germicidal Lamp Glass

Lamps are produced using three main glass types: *Fused Quartz, Synthetic Fused Quartz* and *Soft Glass*

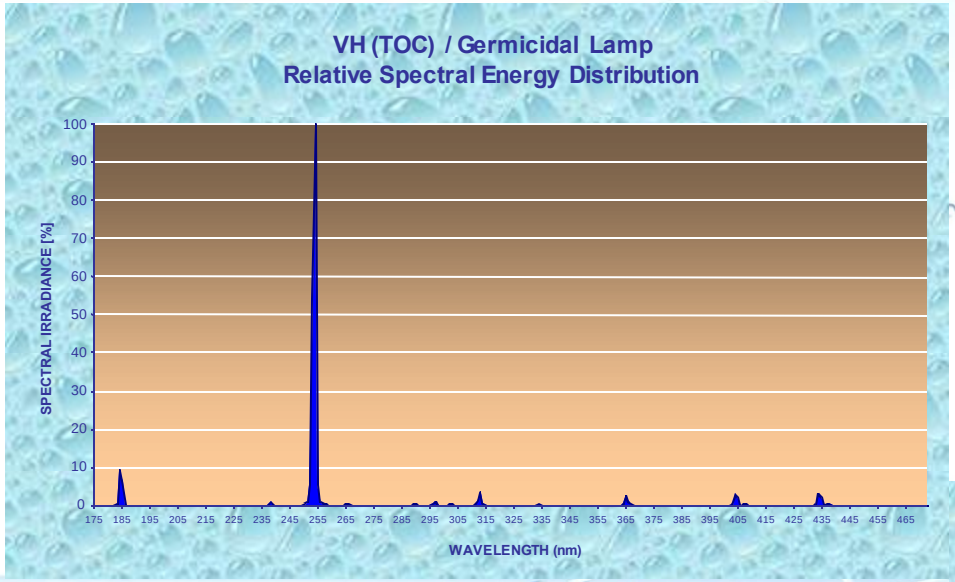
- *Fused Quartz*
  - ñLò Type Fused quartz is doped with titanium to block 185nm transmission and is used for low ozone producing applications.
  - ñVHò Type Fused (natural) quartz is not doped and therefore transmits in both the 185nm and 254nm region and is used for very high ozone producing applications.
- *Synthetic Fused Quartz*
  - Synthetic fused quartz is used for very high ozone producing applications due to superior transmittance at 185nm but at significantly higher cost.
- *Soft Glass*
  - Soda-lime glass
  - Transmits in 254nm region only
  - Lower Cost

Components of a Germicidal Lamp Glass

Comparison of Quartz vs. Soft Glass

- Quartz Transmission of UVC is approximately 9% higher than soft glass, thus leading to higher initial UVC output than comparable soft glass lamps.
- Quartz germicidal UVC lamps can produce both 254nm wavelength (killing wave) and 185nm wavelength (Ozone).
- UVC maintenance over the life of the lamp is much higher over the life of the lamps.
- Quartz lamps can maintain 85% of their output at 16,000hrs.
- Quartz glass allows high current, high-powered lamp designs. (i.e., Amalgam lamps)
- Soft glass will not allow the transmission of UVC wavelengths below 200nm and therefore can not be used to produce ozone at 185nm.
- UVC transmission maintenance over the life of the uncoated soft glass lamp is approximately 30% worse than that of quartz germicidal UVC lamps.
- Considerable advances in internal glass coatings have extended the life time of soft glass lamps to 9,000hrs with 80% UVC output maintenance.
- Soft glass germicidal UVC lamps are limited to operating currents of less than or equal to 850mA.

Components of a Germicidal Lamp Glass

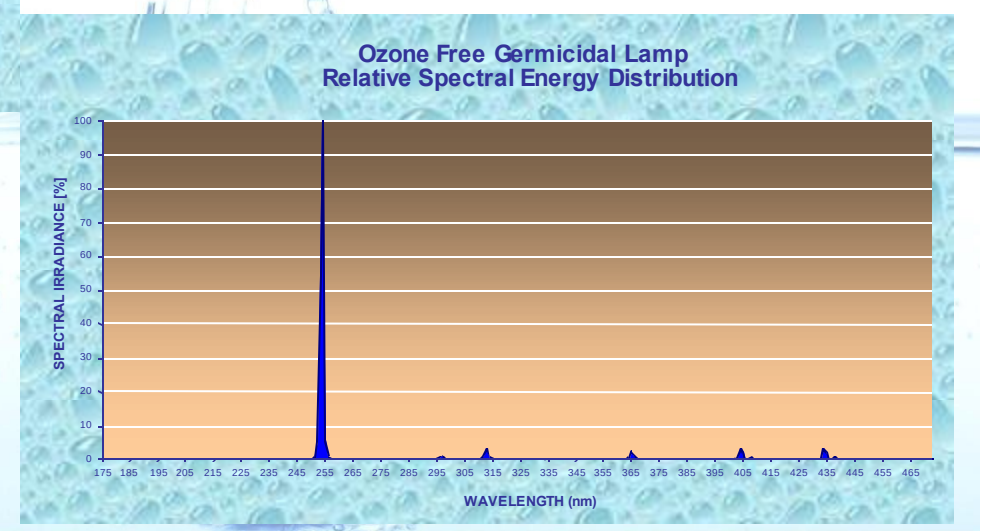


Ozone generating lamp

185nm line generates ozone.
Ozone is required for some specific applications to oxidize organic compounds.

Ozone free lamp

For simple disinfection applications only 254nm line is required.
254nm line can also used for ozone destruction.



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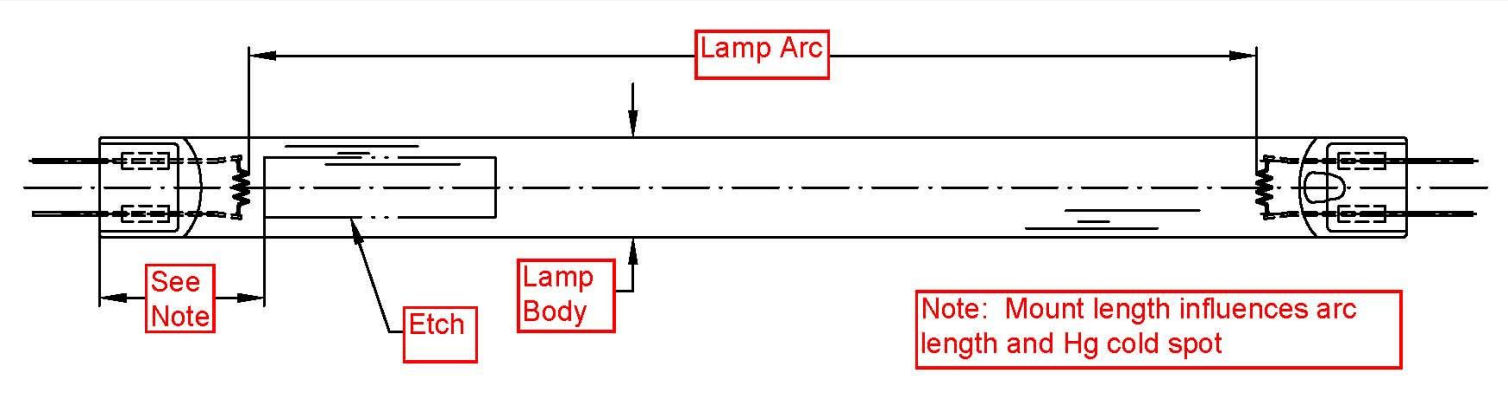
Components of a Germicidal Lamp Filament Mount Sub-Assembly

- Lead Wires: Provide electrical connection from ballast leads to lamp filament
- Lamp Filament (Coil)
  - Standard = Nominal 425mA
  - High Output = Nominal 600 - 800mA
  - Amalgam Lamp = Nominal 1.0 ï 5.0 A
  - Special Construction
  - Emission Coating



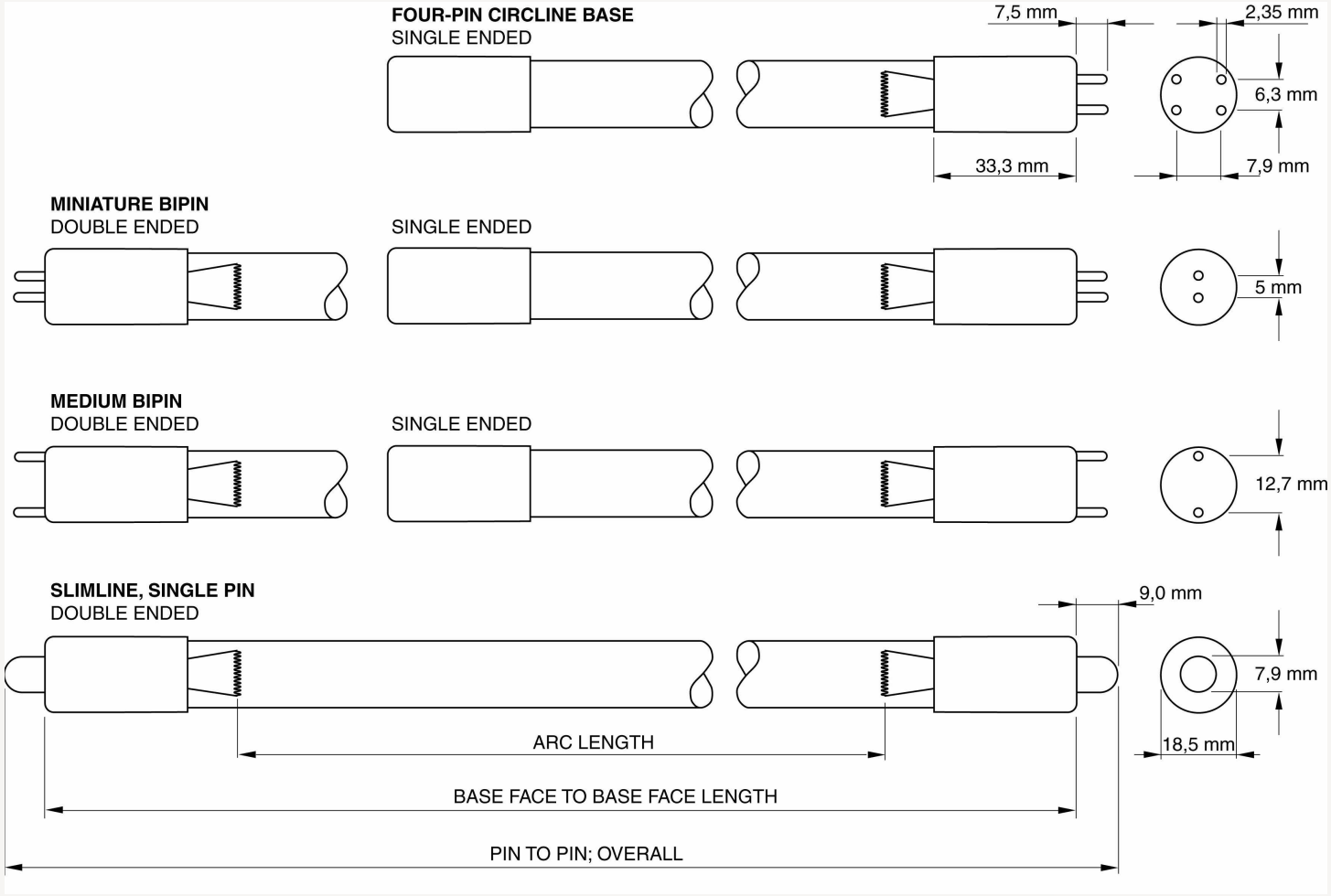
Components of a Germicidal Lamp
Fill Gas

- All are essentially high vacuum lamps, filled to a very low pressure with one or more inert gases. The gas performs several key functions in lamp operation:
  - Reduces the required starting voltage for the discharge, such that it can be easily struck on simple ballasts. Different gases have different effects - for instance with Argon the starting is very easy but with Krypton it is somewhat more difficult.
  - It acts as a buffer gas to protect the electrodes, reducing the impact of ions which bombard them during the anode phase, and thereby reducing erosion of the electrode by sputtering and evaporation. This very greatly extends lamp life, the gases of higher molecular weight offering the greatest degree of protection of the electrodes.
  - It is adjusted to provide the right balance between rate of ionization of mercury atoms (required to maintain the current flow through the lamp) and the excitation of mercury atoms so as to optimize the UV generation efficiency.
  - Its presence randomizes the direction of motion of free elections in the discharge to control their mean free path length and velocity.
  - Depending on the lamp design and its intended application, the gas employed may be Argon, Neon or Xenon and/or a mixture of at least two of these components.

Components of a Germicidal Lamp Mercury

- Mercury is useful in lighting because it contributes to the bulbs' efficient operation and life expectancy. While the bulbs are being used, the mercury within them poses no health risk.
- Germicidal lamps operate at a very low gas pressure. They produce light when an electric current passes between two electrodes (also called cathodes) in a tube filled with low-pressure mercury vapor and inert gases. The electric current excites the mercury vapor in the tube, generating radiant energy, primarily in the ultraviolet (UV) range.
- Mercury Levels (determined by dose levels)
  - Liquid Mercury: 10 to 50mg per lamp
  - Solid Mercury: < 10 mg per lamp
  - Amalgam: (Mercury containing alloy)
    - Spot: ~ 30mg per lamp
    - Pellet: < 10mg per lamp

Components of a Germicidal Lamp Finished Assembly



Components of a Germicidal Lamp Finished Assembly

Custom Bases

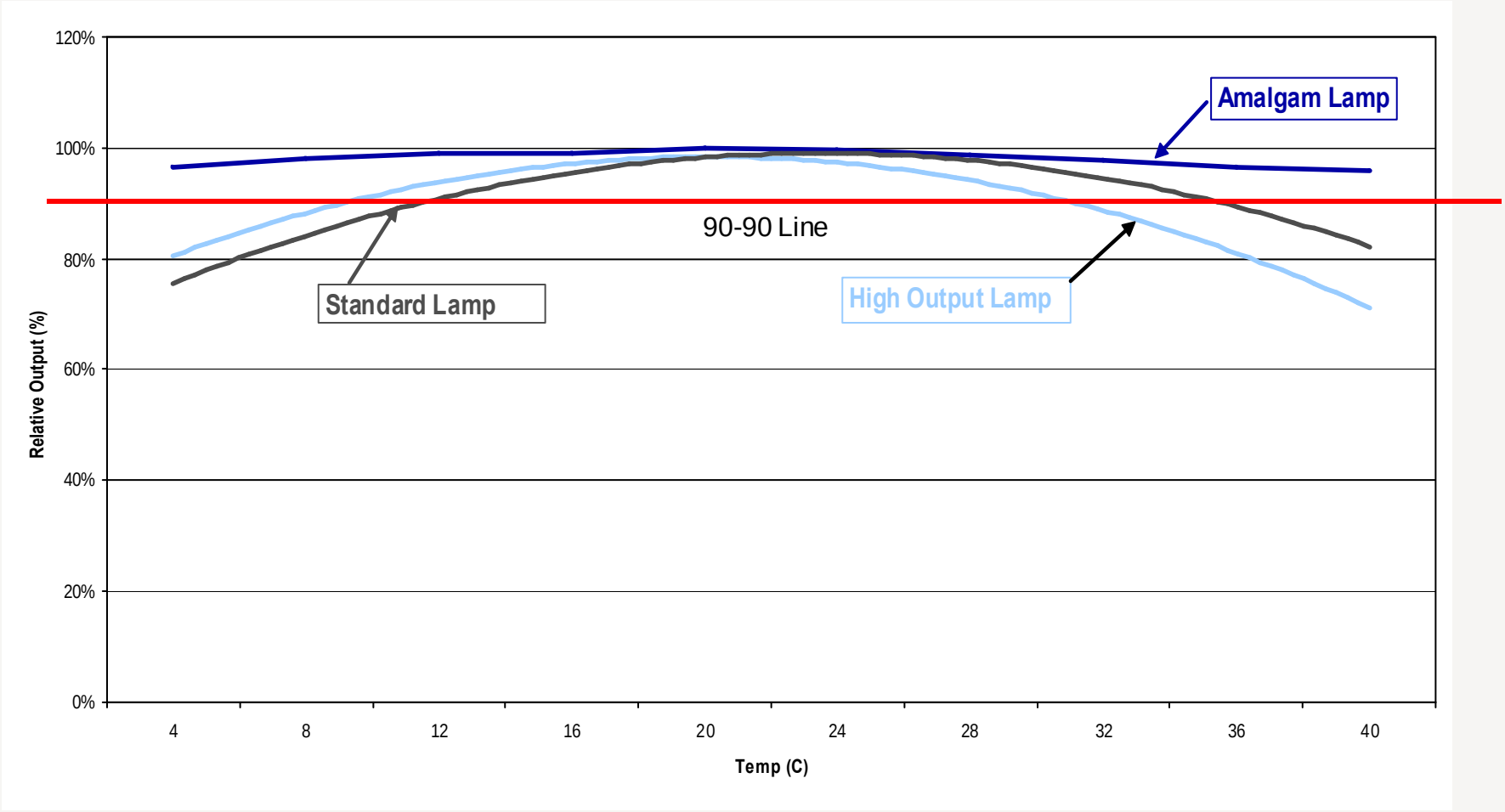
- Customer Proprietary
- Patent Protection
- Security for aftermarket

Germicidal Lamp Performance

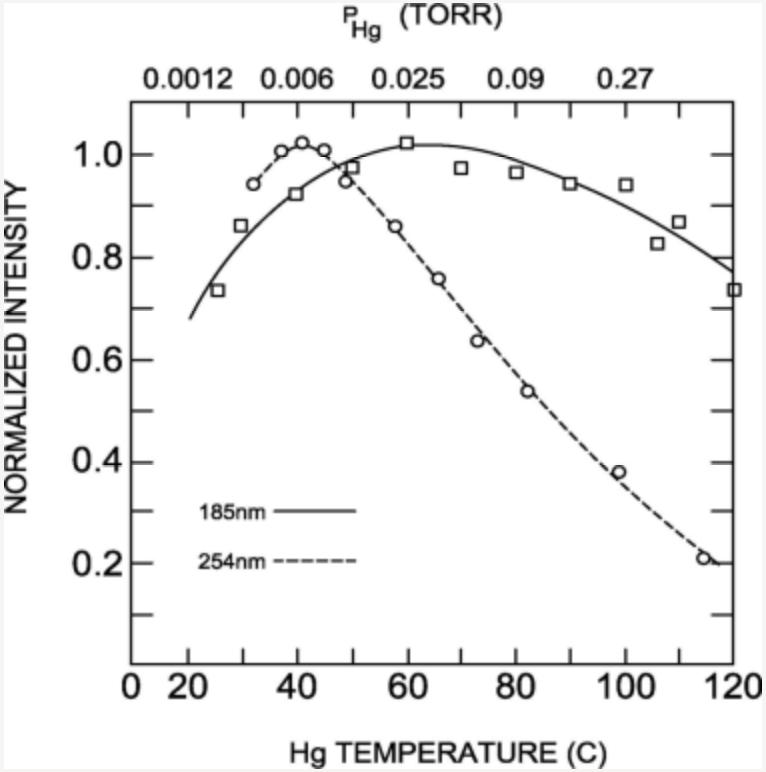
Characteristic	LP (Quartz)	LP (Softglass)	LP Amalgam	MP
Emission	185+254nm	254nm	185+254nm	polychromatic
Gas vapor pressure	1 - 10 mbar	1 - 10 mbar	1 - 10 mbar	1 - 5 bar
Hg Operating Temperatures	30-50°C	30-50°C	90-120°C	600-800°C
Arc length	5 - 155 cm	7 - 148 cm	27 - 200 cm	5 - 150 cm
Lifetime	16000h [1]	13000h [1]	16000h [1]	3000 - 5000 h
Germicidal efficiency (200 - 300 nm)	30 - 40%	30%	30-35%	12-16%
Power density (W/cm)	0.3 - 0.5	0.25 - 0.3	1.0 - 2.0	50 - 250
Influence of ambient temp.	HIGH	VERY HIGH	LOW	NEGLIGIBLE

[1] With Longlife Coating

Relative UVC Output vs. Temperature



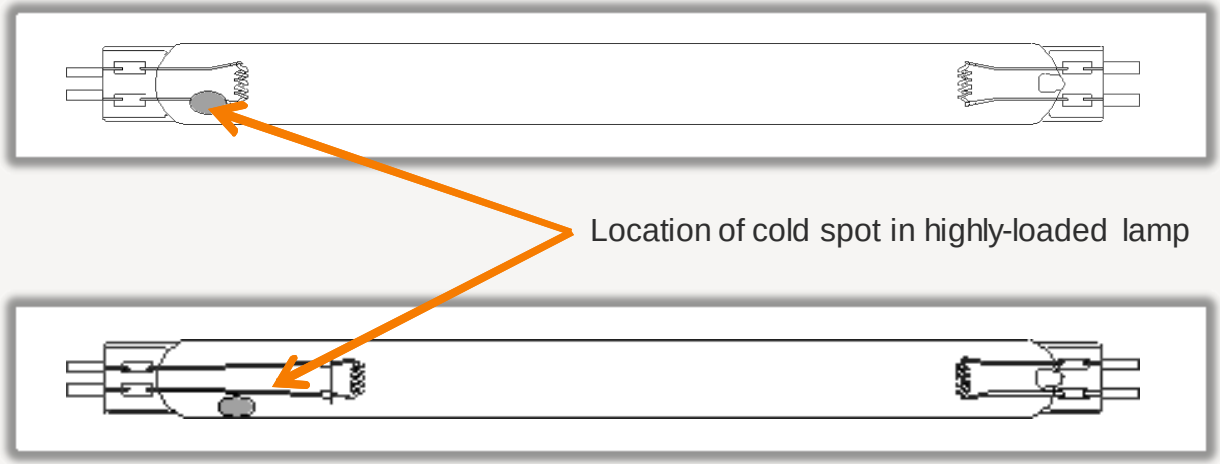
Optimum Mercury Vapor Pressure



- The concentration of mercury atoms in the discharge (the mercury vapor pressure) must be controlled in order to optimize the conversion of electrical power to UV radiation.
- The lamp will produce its maximum output when the mercury vapor pressure is approx. 6 microns (.006 Torr).
  - At **low vapor pressures** the lamp output is low since there arenôt many atoms available for the e^- to excite!
  - At **high vapor pressures**, the majority of available atoms are in the ground state (not excited) and can absorb whatever 254nm photons are produced.

The Cold Spot

- Only 1% of the lamp surface needs to be held at ~45º C (this is when the lamp will produce its maximum output.)
- **Lightly-loaded lamps:** no definite cold spot (still air operation)
- **Highly-loaded lamps:** Cold spot behind cathode in region shielded from positive column. Now temperature of cold spot dependant on: The infrared radiation falling on it from (1) the inner wall of the lamp, (2) the positive column directly, and (3) the filament. One filament may also be mounted on extended leads to provide for more isolation from filament heat.



Mercury Vapor Pressure Control

One way to **control mercury vapor pressure** is to incorporate an amalgam into the lamp structure:

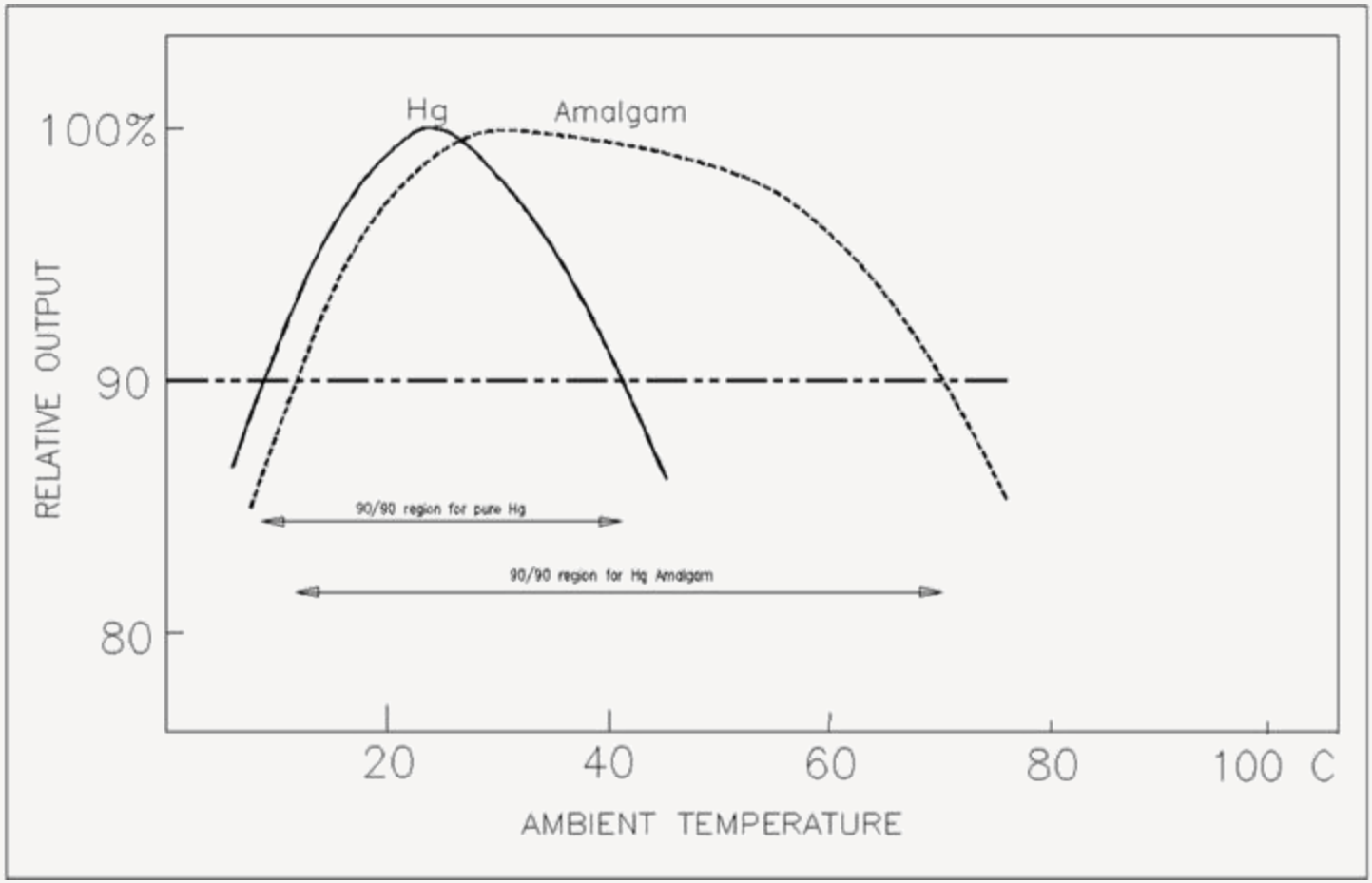
- Amalgams are alloys of mercury and other metals such as indium, lead or zinc and can be formulated to act as a reservoirs for mercury
- Amalgams release only enough mercury to hold mercury vapor pressure
- Ideally, the amalgam lamp design will stabilize the lamp mercury vapor pressure in the so-called 90/90 region (optimum operation)
- The range of bulb wall temperatures where the lamp output drops to no more than 90% of its peak value.

Mercury Vapor Pressure Control

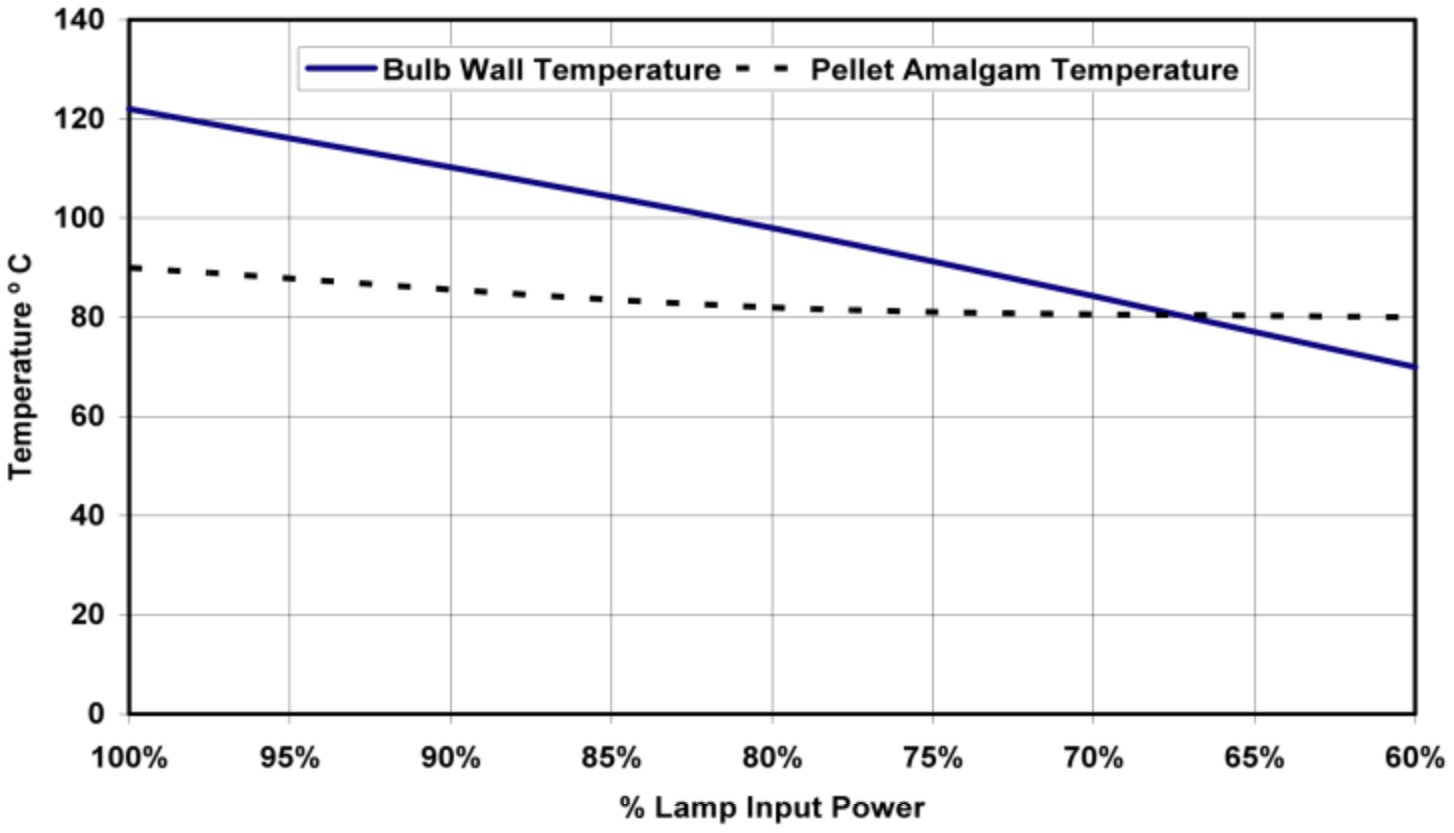
- **Early amalgam germicidal lamp designs** would place the amalgam spot or spots on a location at the inside wall of the lamp fully exposed to the positive column:
  - Locations have advantage of rapid warm up and stabilization since mercury vapor can diffuse readily throughout the volume of the lamp.
  - Major disadvantage: Portions of the lamp envelope adjacent to the positive column are exposed to widest temperature variations from varying ambient and lamp operating conditions.
  - Temperature variations can overwhelm the best amalgam compositionôs ability to hold lamp output in the 90/90 region.

- **Newer lamp designs** shield amalgam from positive column by placing it outside discharge volume at one end of lamp:
  - Temperatures can be up to 20° C lower than on the lamp wall

90-90 Range for LP vs. Amalgam Lamps



Bulb Wall vs. Pellet Amalgam Temperature



Factors Affecting Lamp Performance

- Lamp Design
- Ambient Temperature (Temp. of Gas or Liquid around lamp);
- Thermal Conductivity of Medium;
- Age of Lamp;
- Operating Frequency of Ballast;
- Frequency of On / Off cycles

Which Germicidal Lamp Do I Choose

- *Standard Lamps:* Applications where flow rates are lower, and exposure time can be longer.
- *HO Lamps:* Applications where higher flow rates or dosages are required while maintaining a limited footprint
- *Amalgam Lamps:* Applications where very high output is required and/or ambient temperature is an issue.

Lamp Ballast Options

Preheat Start

- The cathodes of the lamp are preheated electrically for a few seconds before a high voltage is applied to start the lamp.
- The preheating is accomplished by applying current to the cathodes for sufficient time to heat them.
- The preheat lamps have two connections at each end.
- This lamp type results in a slight delay in lamp starting
- Pre-heat ballasts tend to be more expensive
- Required for high current lamps (>300W)
- Required in applications with multiple lamp starts per day

Lamp Ballast Options

Instant Start

- The instant start lamp requires a high starting voltage, which is supplied by the ballast.
- Since there is no preheating of the cathodes, there is no need for a starter circuit
- Electrode heating is provided by the arc once it has been established.
- The instant start lamps have a singleï pin base at each end of the bulb.
- A few instant start lamps have biï pin bases, with the pins connected together inside the base.

Lamp Ballast Options

Programmed Start Lamps

- The programmed start ballast incorporates a starting method which is gentler on the lamp than either the rapid or instant start ballasts.
- Program start ballasts incorporate a precise starting scenario which breaks the process into unique and well defined steps that eliminate the pitfalls of the other starting methods.
- The first step in the series is the application of cathode heat. While this heat is being applied (preheat interval), voltage across the lamp is reduced to a level that reduces damaging glow current. The duration of this step is pre-programmed into the ballast circuitry. Since the lamp voltage is kept very low, the lamps cannot ignite until the cathodes are heated to optimal temperature and the ballast program moves to the second step.
- The second step of the starting process is the application of lamp voltage. After the programmed time of step one has been reached, a voltage is applied across the lamps, igniting them with minimal loss of the emissive material. Minimal loss of the emissive material equates to gentle treatment of and prolonged life for the lamp.

Questions

Thank you for your attention!