FILAMENT LAMP ~ INTRODUCTION

What is a tungsten filament lamp?

It is a converter of energy.

The input energy is electrical power defined in Watts.

The output energy is visible light output defined in Lumens.

- **The key working part is the filament**.

The filament is made of tungsten wire which behalves as a resistance to the electrical input energy.

According to the temperature at which the filament glows will determine the appearance of the light emitted.

The input characteristic of the filament lamp is known as the **rating**.

The rating is expressed as Volts and Watts or alternatively Volts and Amps.

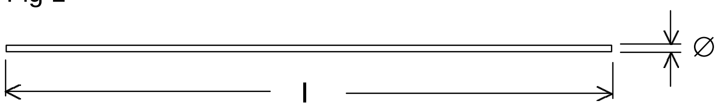
Volts x Amps = Watts

The tungsten wire is very fine in diameter, frequently thinner than a human hair.

The thickness of the tungsten wire determines the current consumption of the lamp.

The length of the tungsten wire determines the voltage of the lamp.

Fig 1



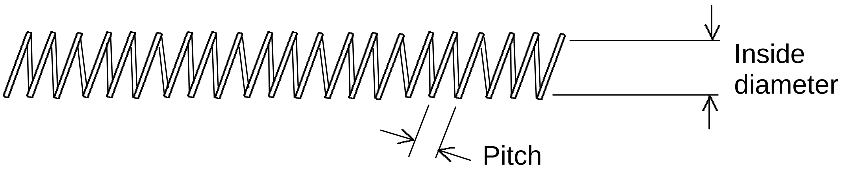
Current is related to ∅.

Voltage is related to l

For the filament to work efficiently it is necessary to coil it as shown by Fig.2

Fig 2

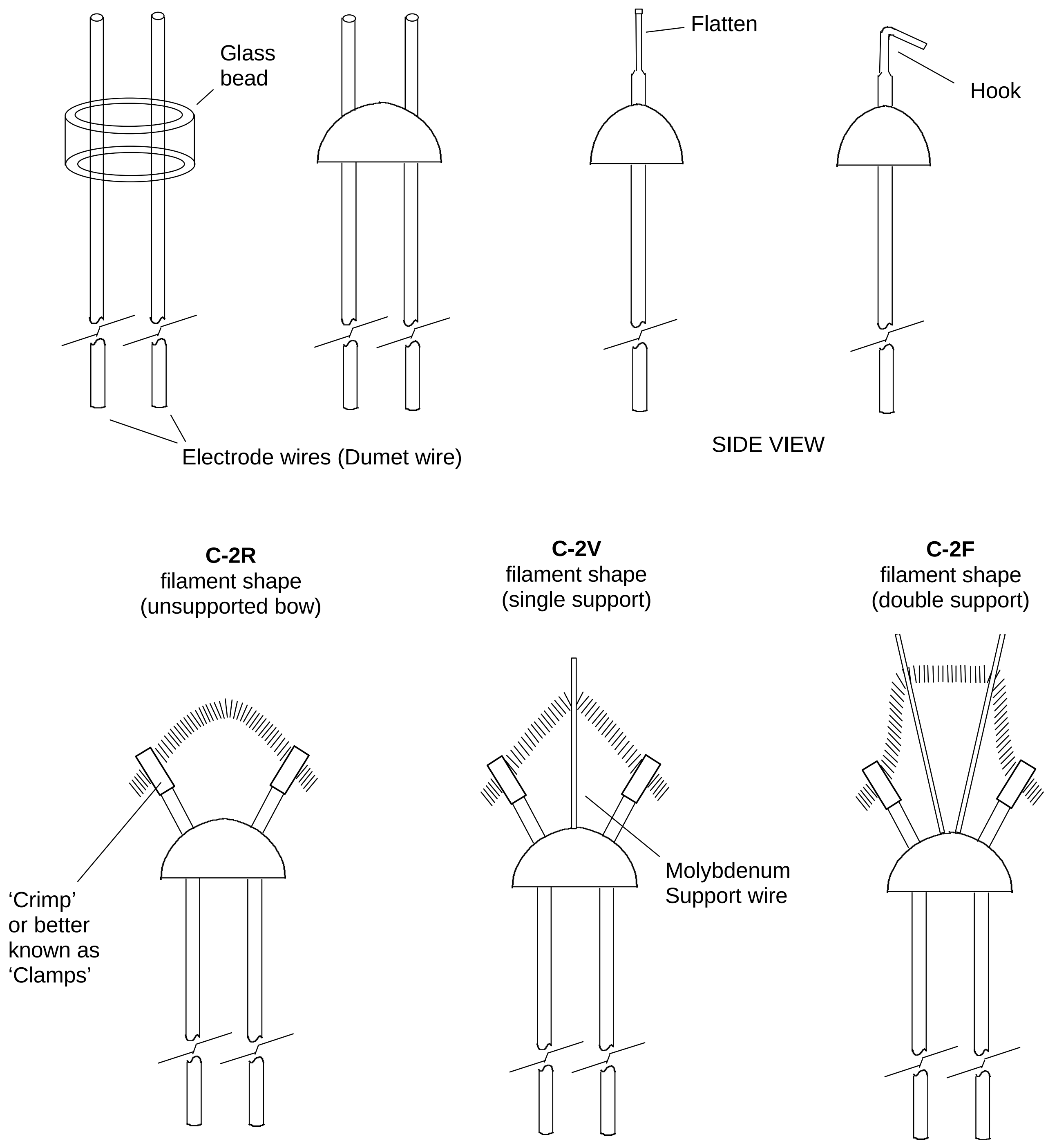
Single Coiled filament



The closer the spacing of the coils, (known as the pitch), then the hotter the filament can operate.

The filament is then mounted to the lamp electrodes as shown by Fig.3

Fig 3. ~ Mount construction

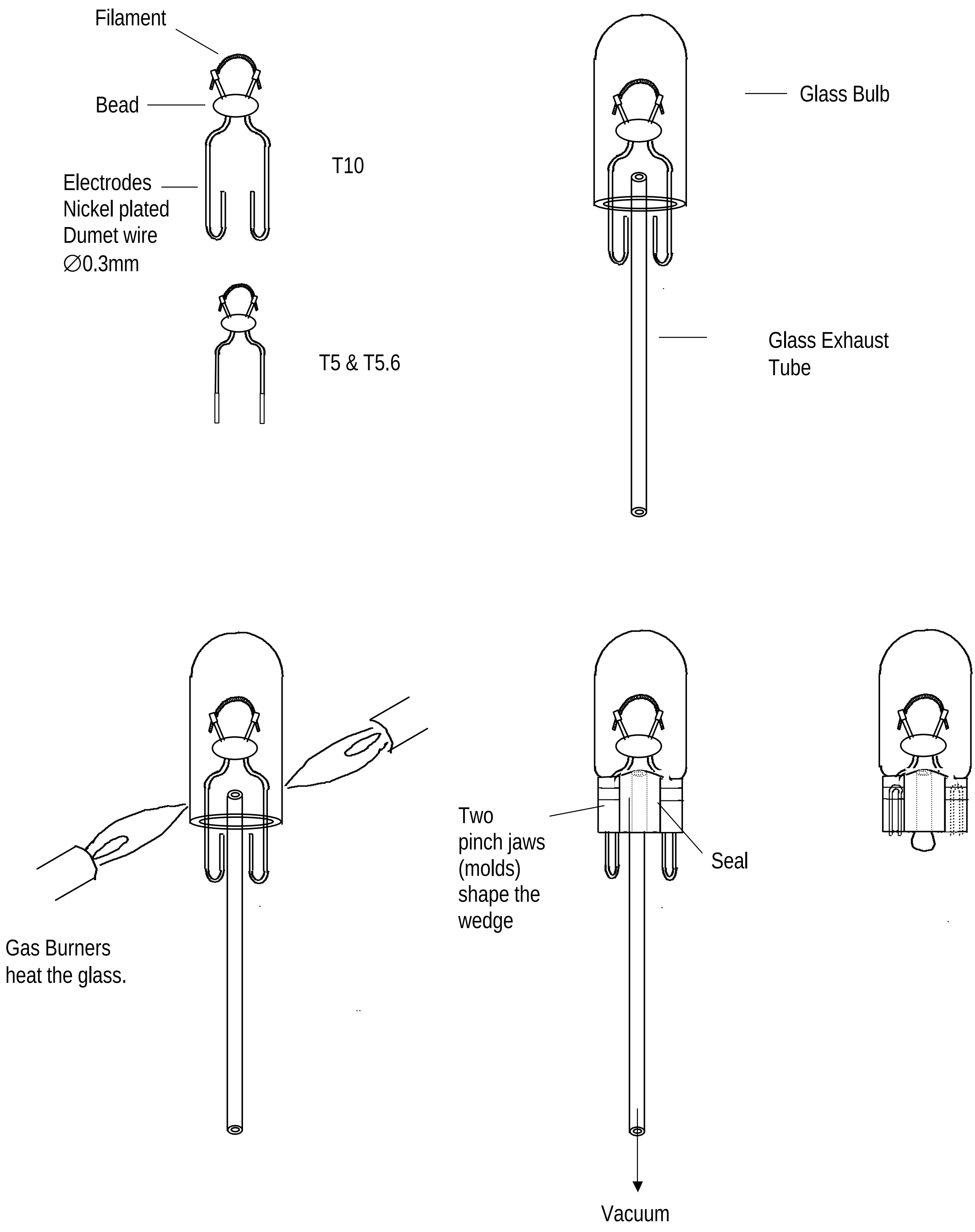


- The filament when mounted to the electrodes is known as the 'Mount'.

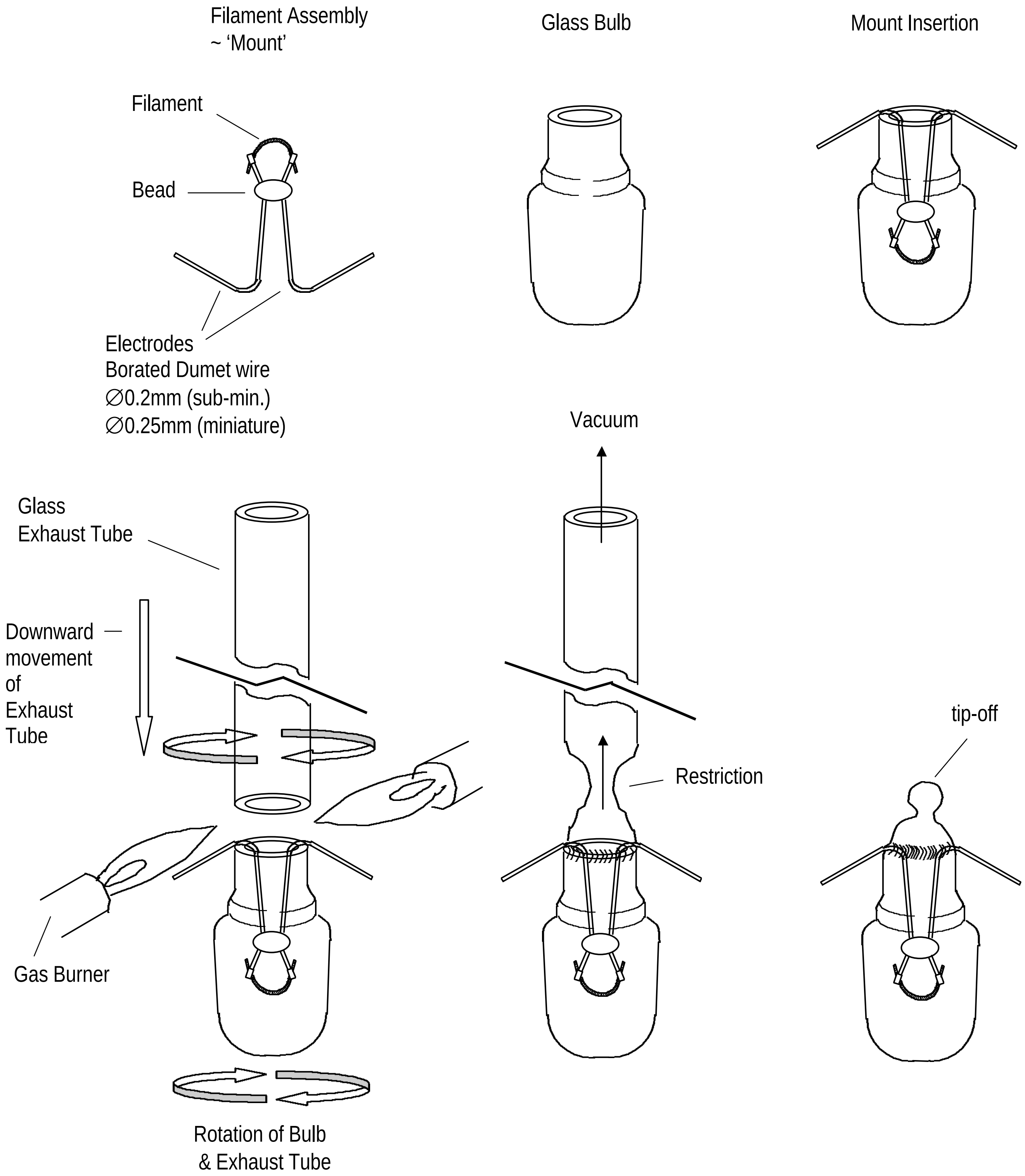
Other methods of attaching the filament to the electrodes are welding and swaging.

The shaping of the electrodes beneath the bead varies according to the style of lamp, for example: bead-seal, butt-seal or wedgebase.

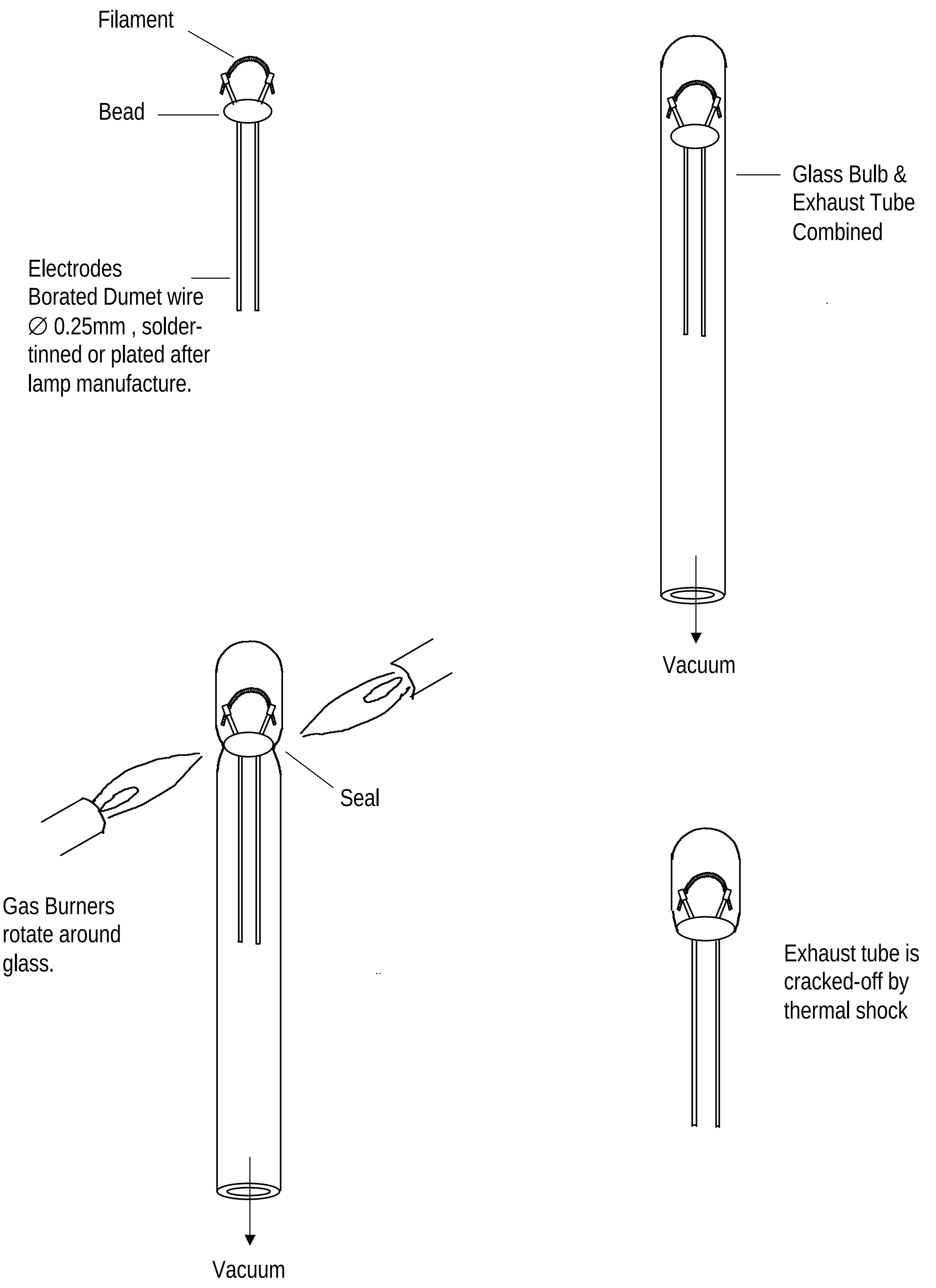
Wedgebase lamps ~ method of construction:



Butt-seal lamps ~ method of construction:



Bead-seal lamps ~ method of construction:



The radiation characteristics of tungsten filament lamps.

A tungsten filament lamp is essentially a device for converting electrical input energy into an output of radiant energy in the form of light and heat. This radiated output is in a continuous spectrum between 300 and approximately 3000 nanometres, with a gradual transition from one wavelength region to another.

Above 3000 nanometres, the energy emitted by the tungsten filament is progressively absorbed within the bulb glass.

Table 1

Spectral Output Energy	Energy Type	Energy Emission
Shorter wavelengths between 300 and 380 nanometres	Ultraviolet	up to 0.02%
Wavelengths between 380 and 760 nanometres	Visible Light	up to 3%
Longer wavelengths between 760 and 3000 nanometres	Near Infrared/Infrared	97% ~ 99%

It can be seen that most of the energy is outside the visible spectrum and this is the reason why filament lamps generate heat in addition to light.

For a filament to emit visible light, i.e. become incandescent, it is necessary to heat the tungsten material via the electrical input energy. Additionally, the heating must take place within an atmosphere free from oxygen otherwise the tungsten will very rapidly oxidize and burn out. The most convenient way of achieving this is to operate the filament within a vacuum and this is the method used for subminiature and miniature lamps.

In larger sized lamps including a few miniature lamps the vacuum atmosphere is replaced within an inert gas atmosphere. This enables higher filament temperatures to be achieved. This inert gas is usually mixtures of Argon and Nitrogen but occasionally rare gases such as Krypton and Xenon are used.

Table 2

Filament Operating Temperature	Colour appearance	Vacuum Lamp	Gas -Filled Lamp
1000ºK	orange glow	✓	(✓)
1800ºK 2500ºK	yellowish light whitish light	✓ ✓	(✓) (✓)
2900ºK	white light		✓

(✓) feasible but to no advantage.

Input energy is known in terms of Volts, Amperes and/or Watts.

- Volts are the electro-motive force applied across the lamp terminals.
- Amperes is the electrical current flowing through the filament of the lamp.
- Wattage is the product of Volts x Amperes.

These characteristics are known as the lamp rating and can be expressed as ‘V’ & ‘A’ (e.g. 6V 0.2A)

or V & W (e.g. 6V 1.2W).

Sometimes in the case of low current lamps it is convenient to express Amperes as milliamperes, ‘mA’ meaning 1/1000 of an Ampere. Thus 6V 0.2A may alternatively be expressed as 6V 200mA

Output energy is known in terms of Lumens or Mean Spherical Candle Power.

- Lumen, ‘Lm’ is a measurement of luminous flux, i.e. light, and is an SI unit.
- Mean Spherical Candle Power, ‘mscp’ is an alternative measurement used commonly in the USA and is directly equivalent to 4π Lumens. (1mscp = 12.568 Lm).

Lumens per Watt (Lm/W)

The ratio of Output divided by Input is known as Luminous Efficacy in terms of Lumens per Watt.

Thus a lamp rating of 6V 0.2A, 6Lm has an efficacy of (6/1.2) = 5 Lm/W

This term is of importance to the lighting design engineer

LAMP LIFE

Life is the parameter of lamp performance, which is likely of greatest importance to most users.

It is also the parameter which is most difficult to be precise about, hence the wide variety of terms such as Design Life, Objective Life, Average Life, Nominal Life, Rated Life etc.

In practice the life in service is highly dependent on actual operating conditions.

This means for any given lamp, the life characteristics achieved in one application can be quite different to the life achieved in another application.

Factors such as choice of power supply, operating temperature, presence of external shock, impact or vibration can all influence the life figure achieved.

For this reason it is not possible to list the practical life value for each lamp against each operating condition.

Catalogue life hours is expressed as the figure to 50% failure rate, i.e. Average life.

This represents the values achievable under ideal operating conditions. (e.g. laboratory life).

WEIBULL distribution.

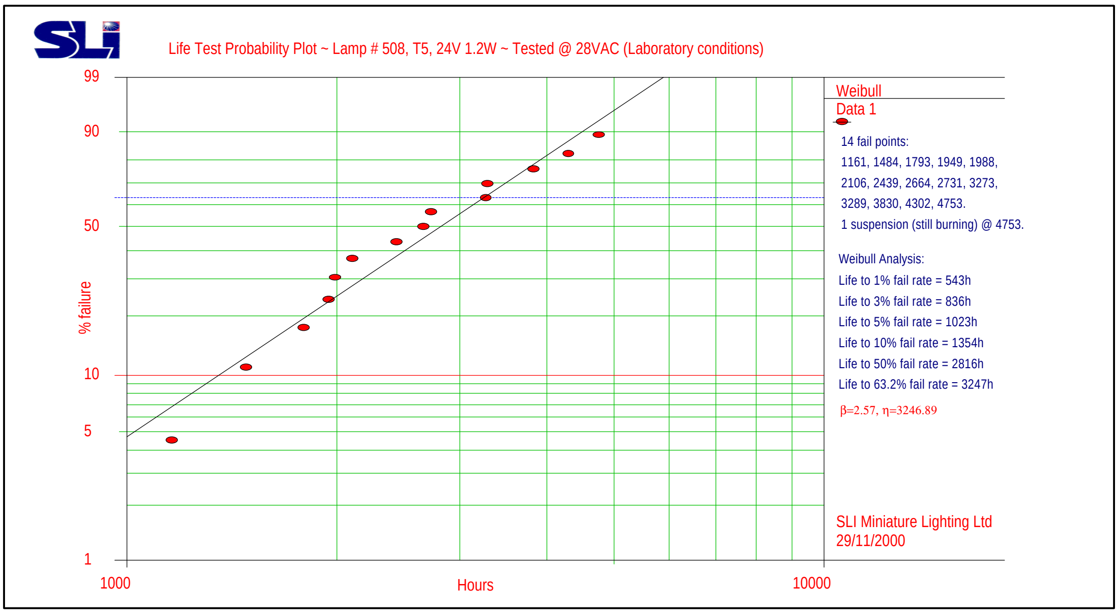
Sometimes it is more important to know something about the failure distribution. For example what percentage of lamps can be expected to fail within the first few hundred or first few thousand hours?

In this circumstance it is useful to plot lamp life as a Weibull distribution where sample life test results can be used to make statistical forecasts or predictions about the failure rates expected for the entire population.

This technique is commonly used for automotive applications where life figures are listed as life hours to 'x'% failure. Example B1 = Life to 1% failure rate, B5 = Life to 5% failure rate etc.

This is particularly helpful in determining component reliability information over vehicle warranty period.

Example of Weibull Life Graph:



AC life VS DC life. (Alternating Current VS Direct Current)

<u>The catalogue figures are for AC operation under ideal operating conditions</u>.

In the case of most subminiature/miniature lamps below 0.2A (200mA) current consumption, it is important to remember that the DC life will be considerably less than the AC life. This is due the effects of uni-directional current flow, which cause a phenomenon known as 'DC notching'. This results in 'saw tooth' notching within the surface of the filament tungsten wire creating weak or 'hot' spots, leading to premature failure. The effects are much more significant on lamps with current consumption of 0.05A (50mA) and below, since the tungsten wires used for making these lamps are by necessity very fine in diameter.

In these circumstances the DC life may be 50% of the catalogued AC life.

Re-rating a catalogue item.

Frequently a customer asks for a rating that is not shown within published catalogue listings.

Under these circumstances the first step is to see if an existing lamp rating can be used.

For example an existing lamp may be rated as 14V 3W.
Q. What would the rating be at 12V?

	14V	Calculation	Multiplier	12V
Current (A)	0.214	$(12/14)^{0.55}$	0.92	0.197
Wattage (W)	3	12 x 0.197	------	2.4
Lumens (Lm)	15	$(12/14)^{3.5}$	0.583	8.8
Mscp (cp)	1.2	$(12/14)^{3.5}$	0.583	0.7
Life (Hours)	5000	$(14/12)^{12}$	14	70000

Therefore it can be seen by using standard calculations the 14V 3W rating re-rates to 12V 2.4W with a corresponding reduction in light output and an increase in lamp life.

The calculations are based on the following formulae:

Current multiplier = $(V1/V2)^{0.55}$`

Light output multiplier = $(V1/V2)^{3.5}$

Life multiplier = $(V1/V2)^{1/12}$

Where V1 is the original voltage and V2 is the re-rated voltage.

The lamp performance curves often seen within catalogues are based on these formulae.

<u>NB. Special care should be taken since error can occur due to the exponential nature of the calculation.</u>

This holds particularly true when re-rating the life characteristic.

For this reason the calculations hold true within ± 15% of the original voltage rating.

For calculations beyond ± 15% an adjustment has to be made for the calculated life value. This is to compensate for the ‘runaway’ effect of the 12th power exponential.

Thus for the example shown above, 70000 hours would be adjusted back to 50000 hours.

Custom designs.
When re-rating is not the solution, custom ratings can be designed for the customer by changing the detail design of the tungsten filament. Therefore for example, any given lamp rating can be designed for long life / low light output or short life / high light output.

LAMP SIZES ~ are coded in terms of bulb glass diameter.
Two general size groups included within the product range:

SUBMINIATURE ~ Includes all size up to and including 7mm diameter.

Size (mm)	Includes	Lamp Construction	Popular Lamp Types
2.5		Bead Seal	Wire Terminal & Micro Midget Flange
3		Bead Seal	Wire Terminal (short & standard), Bi-Pin, Sub Midget Flange, Neo-Wedge & SMD
4	4.2mm	Bead Seal & Butt Seal	Wire Terminal, Bi-Pin, Neo-Wedge & SMD.
5	4.8mm	Bead Seal & Butt Seal	Wire Terminal, Bi-Pin, Neo-Wedge & SMD. E5 Screw.
		Wedge Base	Wedge Base & Socket assemblies.
6	5.6mm	Bead Seal & Butt Seal	Wire Terminal, Bi-Pin, Midget Flange & Midget Groove.
		Wedge Base	Wedge Base & Socket assemblies.
6.5		Wedge Base	Wedge Base & Socket assemblies.
7	6.6 & 6.8mm	Butt Seal	BA7 Bayonet.
		Wedge Base	Wedge Base & Socket assemblies.

MINIATURE ~ Includes all size above 7mm up to around 25mm diameter.

Size (mm)	Includes	Lamp Construction	Popular Lamp Types
9	8.5mm	Butt Seal	Bayonet BA9
10		Butt Seal	Bayonet BA9 & Screw E10
		Wedge Base	Wedge Base & Socket assemblies.
11	12mm	Butt Seal	Bayonet BA9 & Screw E10
13		Wedge Base	Wedge Base
15		Wedge Base	Wedge Base
20		Wedge Base	Wedge Base
25		Pinch Seal	Bayonet BA15

BULB SHAPES & DIAMETER CODES:

Prefix Letter indicates shape of bulb.
T = Tubular
G = Globular
S = Straight side wall

Two systems used for coding the glass diameter.

- European = Metric System. Example: T10 = Tubular shape, 10mm diameter.
- USA = ANSI System, where one unit of diameter equals one eighth of an inch (1/8”), such that T-1 = Tubular shape, 1/8 inch diameter (ANSI = American National Standards Institute)

This is a potential cause of confusion, therefore it is important to remember to use a hyphen within the USA system of coding to differentiate.

COMPARISON OF POPULAR BULB DIAMETERS.

European Code	ANSI equivalent code	Derived from	Equivalent dia. Decimal (inches)	Equivalent dia. Metric (mm)
T2.5	T- ¾	¾ x $^{1}/_{8}$”	0.09375	2.5
T3	T-1	1 x $^{1}/_{8}$”	0.125	3
T4	T-1¼	1¼ x $^{1}/_{8}$”	0.15625	4
T5	T-1 ½	1 ½ x $^{1}/_{8}$”	0.1875	5
T5.6	T-1 ¾	1 ¾ x $^{1}/_{8}$”	0.21875	5.6
T6.5	T-2	2 x $^{1}/_{8}$”	0.25	6.5
T7	T-2¼	2¼ x $^{1}/_{8}$”	0.28125	7
T9	T-2$^{7}/_{8}$	2$^{7}/_{8}$ x $^{1}/_{8}$”	0.359375	9
T10	T-3¼	3¼ x $^{1}/_{8}$”	0.40625	10
G11	G-3 ½	3 ½ x $^{1}/_{8}$”	0.4375	11
T13	T-4	4 x $^{1}/_{8}$”	0.5	13
T15	T-5	5 x $^{1}/_{8}$”	0.625	15
T20	T-6$^{1}/_{3}$	6$^{1}/_{3}$ x $^{1}/_{8}$”	0.7917	20
S25	S-8	8 x $^{1}/_{8}$”	1	25

LAMP BASES (CAPS).

The codification of lamp bases generally follows an IEC system. (International Electrotechnical Commission).

- The first letter and second letter (where applicable) indicates the style of cap, e.g. E = Edison Screw, BA = Bayonet Automobile, SX = Shell with flange.
- The first digit(s) indicate the diameter of the cap. (e.g. 5 = 5mm diameter).
- The small case letter after the digit (where applicable) indicates the number of contacts where s= single contact and d = double contact.
- The digit after the forward slash indicates the length of the cap. e.g. /13 = 13mm long.

Example: BA9s/13 indicates that this cap is a 9mm diameter bayonet cap, intended by design for automotive use, has a single contact and is 13mm long.

Examples of popular cap terminology:

IEC Code	Known as (Europe)	Known as (USA)
E5	Lilliput Edison Screw (LES)	Midget Screw Base
S5.7s	Midget Groove	Midget Groove
SX6s	Midget Flange	Midget Flange
E10	Miniature Edison Screw (MES)	Miniature Screw
BA9s	Miniature Centre Contact (MCC)	Miniature Bayonet
BA15s	Small Centre Contact (SCC)	SC Bayonet
BA15d	Small Bayonet Cap (SBC)	DC Bayonet

N.B. Some base styles have not yet been incorporated within the IEC system. (e.g. Neo-Wedge).