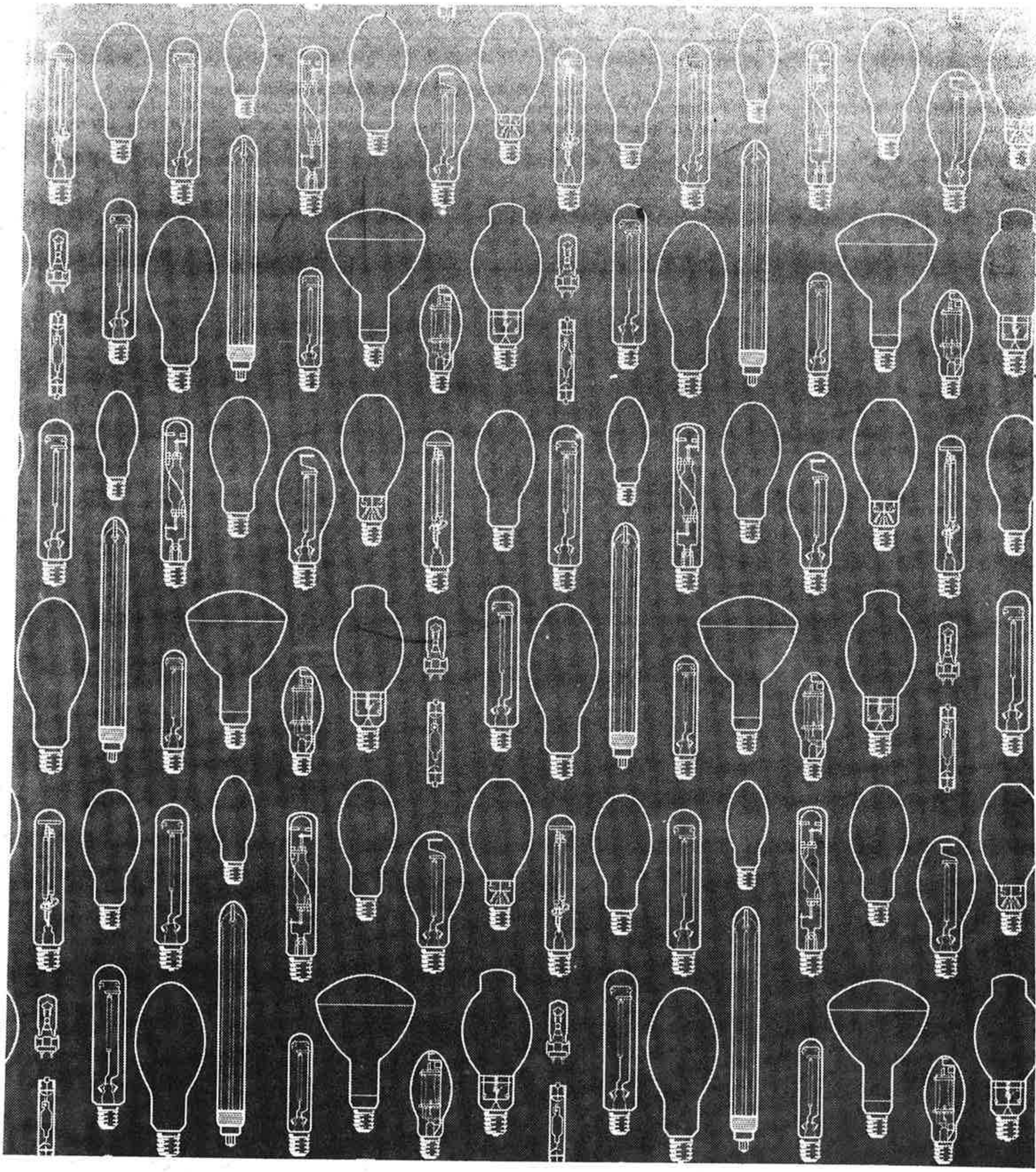
Sylvania Lighting International

Technical Product Manual H.I.D.



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SYLVANIA

Table of Content

INTRODUCTION

This technical manual for HID products was created in view of the fact that in the selling process of HID lamps the technical product knowledge is of vital importance. Therefore the main target groups of this manual are Sylvania sales people active in sales consulting, after sales and sales management.

Although the purpose was not to create a theoretical manual, some basic elements as lighting parameters and light radiation principles are described. From hereon the operation principles and manufacturing processes are described. This enables the reader to understand better the various advantages, disadvantages and applications of different productgroups.

In chapter 4 all aspects of the electrical auxiliary equipment are threated after an introduction of the starting principles of HID lamps. This is also meant to be used as a practical guide in the consulting of installation requirements and application possibilities.

And last but certainly not least some attention is given to the different aspects of product quality. After a description of the quality standards an overview is given of the prevention activities in the manufacturing process. The corrective action procedure as well as information on lamp life is attached in this manual.

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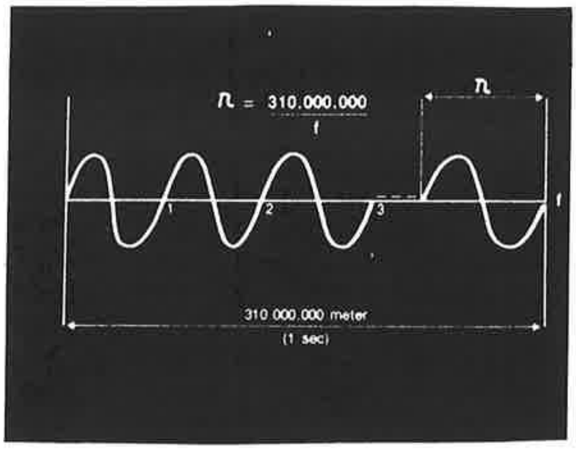
Product Management Discharge Lamps
Sylvania N.V. Tienen - Belgium

1. Light and its characteristics

1.1. Radiation of light and the human eye

In our environment we find several electro-mechanical waves to which we are exposed to. However our sensors are only sensitive to certain of these waves. Lightwaves belong to the category of harmonic waves with following characteristics:



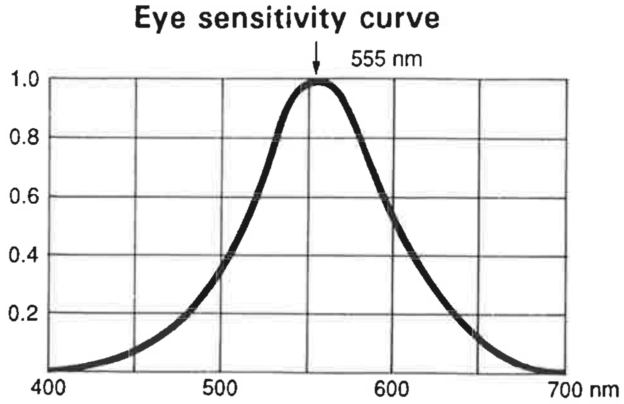
λ = the wave length [nm]
f = frequency [hz] (number of cycles per second)
310.000.000 m/s = speed of light

In the electromagnetic spectrum we find the visible spectrum between 400 and 700 nanometers. Above these wavelengths we find infrared, radar radiation, television, FM and radio radiation. Below 400 nanometer we find ultraviolet x-ray, gamma and cosmetic radiation.

Within the visible spectrum also colours are defined by their wavelength. Going from 400 to 700 nm we find the typical rainbow colours:

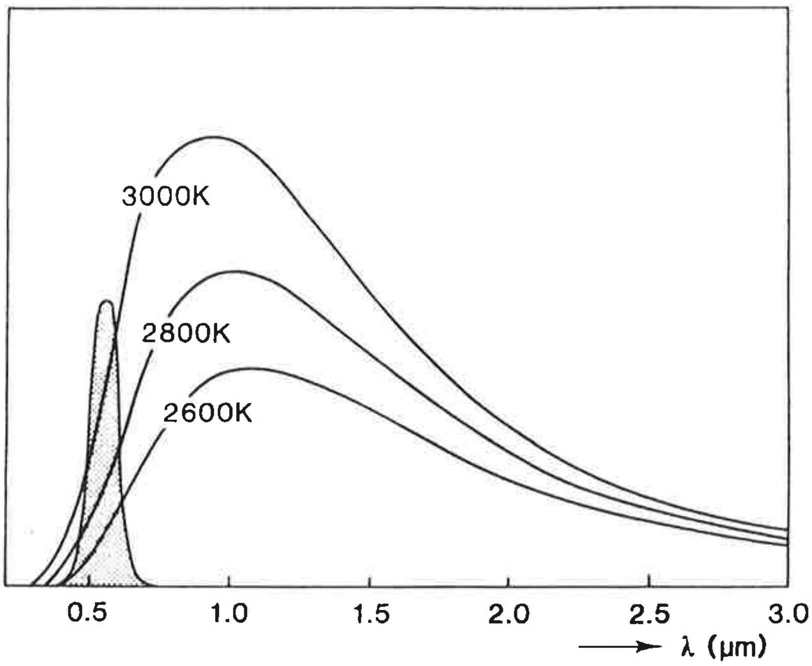
Violet
Indigo
Blue
Green
Yellow
Orange
Red

However, the human eye is not equally sensitive to all colours (or wavelengths). The V (λ) curve showes the eye sensitivity curve.

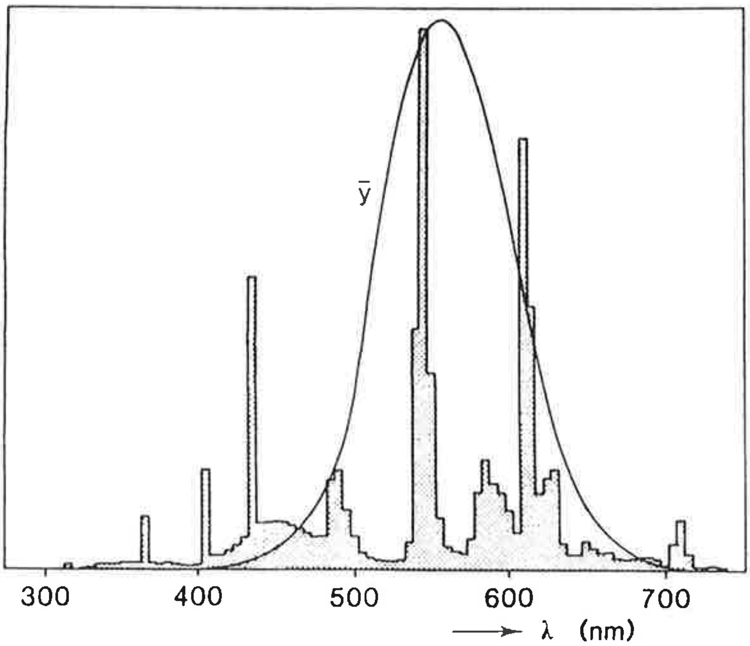


We can see that the maximum sensitivity is at 555 nm (a green - yellow colour).

In the design of lamps this V (λ) curve is very important. The radiation of a lightsource should be maximized in the V (λ) region in order to obtain the maximum lamp efficiency.
The lamp spectrum can be continuous or discontinuous.
Incandescent and tungsten halogen lamps have continuous spectra. As we can see from the figure, only a small proportion from the light source radiation is contributing to the eye sensitivity curve. The higher the radiation body (coil) temperature the less inefficient the light source will be.



Discontinuous spectra are radiated by discharge lamps. As such the lamp designer has a higher degree of freedom to finetune the lamp spectrum to the V (λ) curve. Therefore discharge lamps provide far better lamp efficiencies than incandescent or tungsten halogen lamps.



1.2. Quantities of light

1.2.1. Luminous flux (lumen)

As we just briefly indicated, the lumenoutput (∅) from a lightsource is the energy radiation within the relevant interval.

$$\varnothing = 683 \int_{380}^{780} V(\lambda)\, L(\lambda)\, dX$$

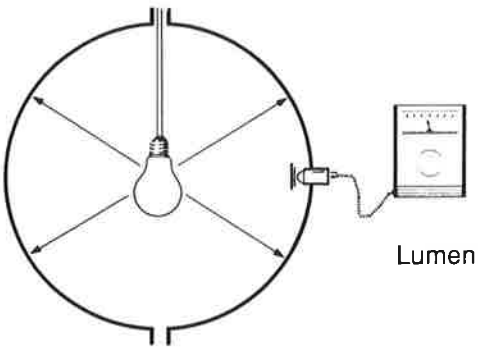
with V(λ) : eye sensitivity function

L(λ) : lamp spectral function

683 : photometric radiation coëfficient

In other words at each wavelength the corresponding value of the V(λ) curve is multiplied with the corresponding value of the lamp spectrum. All these values are then added (integrated) between 380 and 780 nm and multiplied with 683.

For a practical measurement the lightsource is positioned in an integrating sfeer and a photometric detector with V (λ) sensitivity is generating an electrical signal which is than converted into a lumenvalue.



1.2.2. Luminous intensity (Candela)

Where for the lumen output the total sfeer around the lamp is considered, the luminous intensity is related to only a fraction of the sfeer surface. This surface is defined as the steradiant (ω). The steradiant is the spacial angle which, when the top conincides with the center of the sfeer, projects a square on the sfeer surface with its sides equal to the radious of the sfeer.

$$I = \frac{\varnothing}{\omega}$$

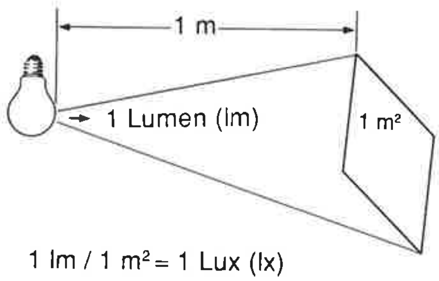
Since in 1 sfeer there are 4 π steradiants, a lightsource with an homogene light distribution would give a lumenoutput equal to 4 times the candela value.
The candela value is commonly used for reflector lamps because the candela is:

1. independent from the distance
2. the best paramater to characterize the lightoutput in a relevant area of the beam

1.2.3. Illuminance (lux)

Illuminance (E) is defined as

$$E = \frac{\varnothing}{A} \qquad \varnothing = \text{lumenoutput}$$



Illuminance

This parameter is most relevant in the calculation of lighting systems since the lux level is depending from:

1. The distance from the lightsource

$$E = \frac{I}{d_2}$$

I = lightintensity

d = distance from the object to the lightsource

2. The angle of coïncidence

1.3. Colour of light

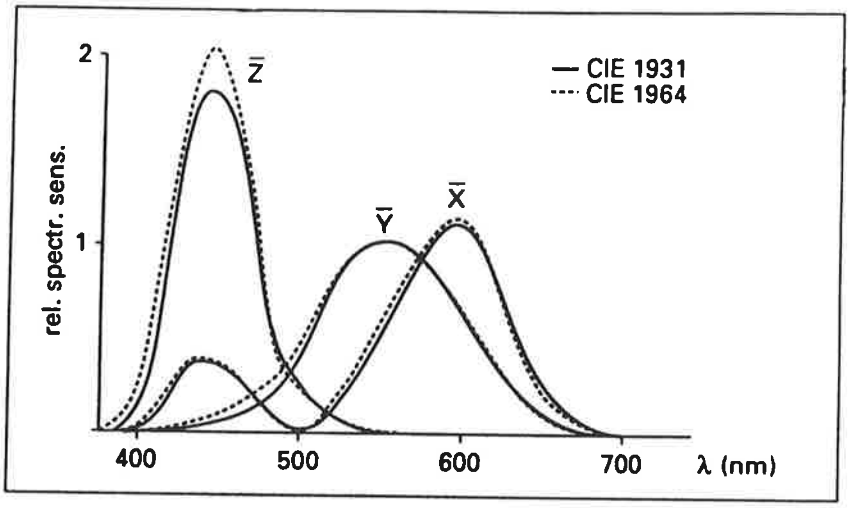
1.3.1. Cromaticity coordinates (x y)

Further to the definition of the eye sensitivity curve V (λ) three other sensitivity curves need to be defined in order to quantify colour.
These spectral trichromatic functions are:

$$x(\lambda),\ y(\lambda) \text{ and } z(\lambda)$$

From these we can calculate, as it was done for luminous flux, the tristrimilus values x, y and z

$$x = L(\lambda)\,\bar{x}(\lambda)\,d\lambda$$
$$y = L(\lambda)\,\bar{y}(\lambda)\,d\lambda$$
$$z = L(\lambda)\,\bar{z}(\lambda)\,d\lambda$$

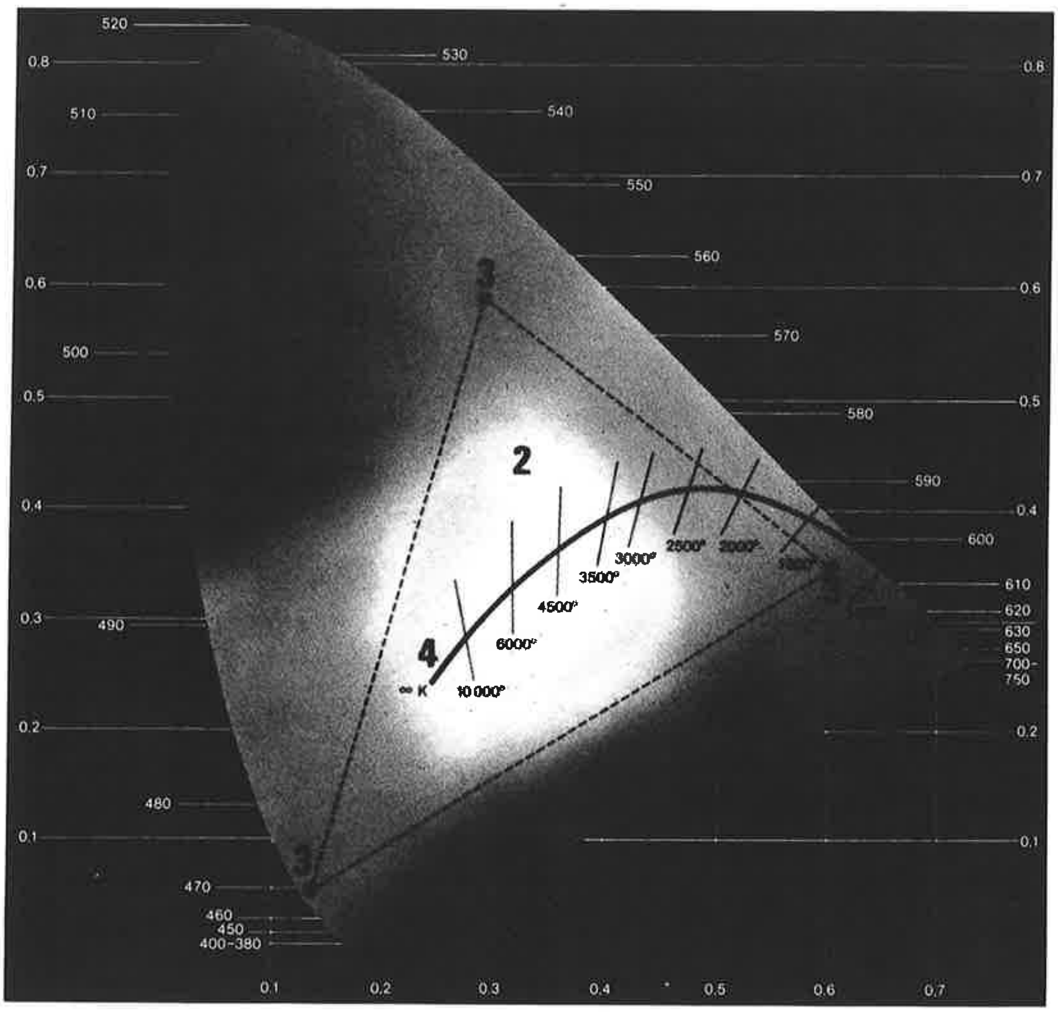


Since the human eye is more sensitive to the colour balance of a lightsource rather than the absolute colour quantity following ratio's are calculated:

$$X = \frac{x}{x + y + z}$$

$$y = \frac{y}{x + y + z}$$

The x, y values are called the cromaticity coordinates.
If the different possible colours are situated in relation to the x-y coordinates, the colour triangle can be defined. On the horizontal axis we see the x coordinates and on the vertical axis the y coordinates.
On the contour of the triangle the colours are monochromatic (pure colours) and the matching wavelenghts are indicated as well.



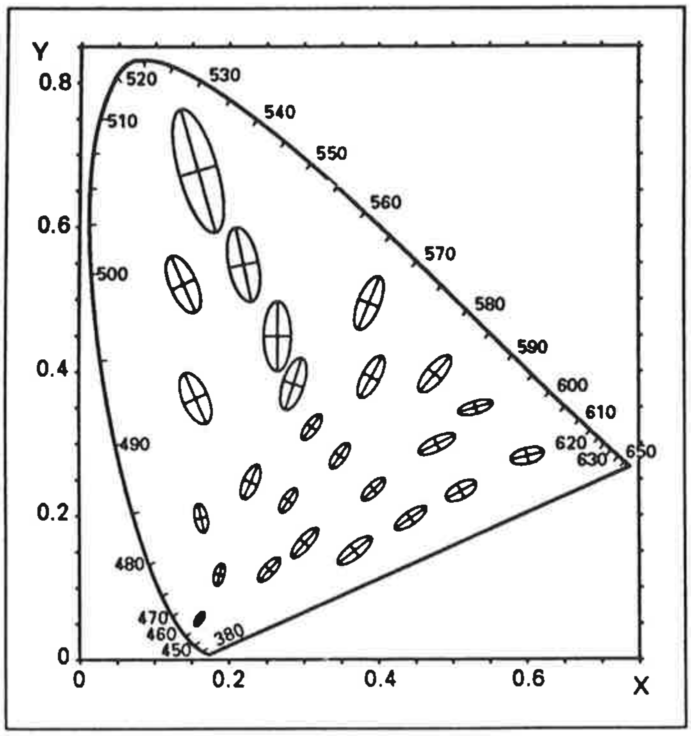
Colour definition of (1) monochromatic radiations, (2) mixed radiations and (3) the colour points of triphosphors. Line (4) the colour appearance of the perfect radiator at various colour temperatures.

1.3.2. Colour temperature (T)

The curved line on the colour triangle represents the colour evolution of a black body if it would be heated from 1000 K to 10000 K. The lines perpendicular to this black body curve enables one to determine the correlated colour temperature of a lightsource which is not exactly on the black body curve. However most of the lamps for general lighting are designed as close as possible to the black body curve. If not we experience the lamp colour as unnatural.
It should also be mentioned that contraditionary warm colours correspond to a low colour temperature and vice versa.

1.3.3. The Mac Adam ellips

The question "to which difference in x y coordinates are allowed", is answered by the Mac Adam ellipses. In the colour triangle the Mac Adam ellipses are (10 x enlarged) indicated. Within 1 ellips the colour impression remains unchanged.



We can see that in the different colour zones different allowable xy variations are allowed. A change of the cromaticity coordinates in the blue region is much easier noticed by the human eye than the same change in the green region.

1.3.4. Colour rendering (Ra or CRI)

Another quality aspect of a lightsource is how well different colours are recognized. In order to quantify the colour rendering, 8 principal colours were defined on the colour triangle. The sum of the deviations of the colour coordinates in relation to the reference colours will give an average colour rendering index.
The calculations are done in such a way that the maximum Ra value is 100 (incandescent or halogen lamps). A monochromatic lightsource (like low pressure sodium lamp) correspond to a colour rendering of 0.

Between lampmanufacturers a classification system is worked out:

Colour rendering class	Colour rendering index [Ra]
1A	90 - 100
1B	80 - 89
2A	70 - 79
2B	60 - 69
3	40 - 59
4	20 - 39

2. Lamp operation principles

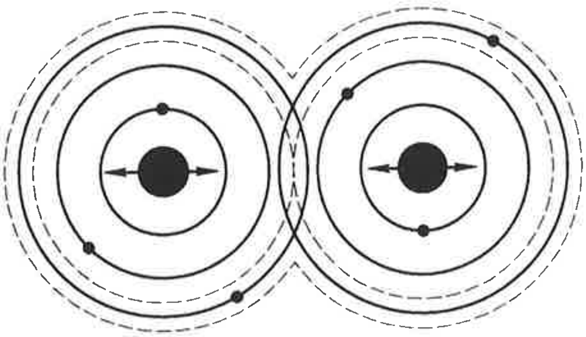
2.1. Principle methods of generating light

Light can be generated according to 3 principles:

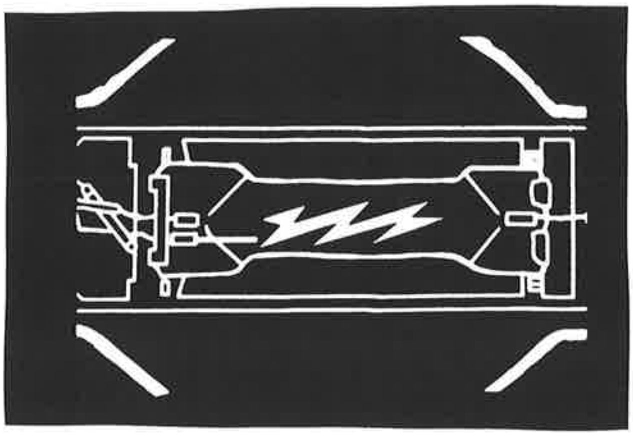
1. Thermal radiation (incandescent)
2. Radiation by discharge
3. Conversion of UV to visible light

The oldest commercial lightsource is the incandescent lamp which was introduced in 1878 by Edison in the U.S.A. and by Swan in Great Britan. These lightsources use today tungsten filaments which are heated by an electrical current to a temperature of approximately 2700 K.

At these temperatures the tungsten atoms become thermally agitated and are colliding with eachother in an irregular manner by direction and energy. In the collision the orbits of the outer electrons are deformed, equal to energy absorbtion and this energy is reradiated in the form of electromagnetic radiation when the electrons return to their natural orbit. The radiation which we obtained from this process is spread over a wide range of wavelengths in the visible and mainly infrared range.

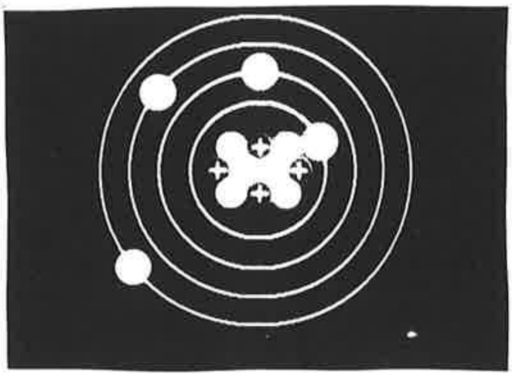


Another way to create light is by electrical discharge.

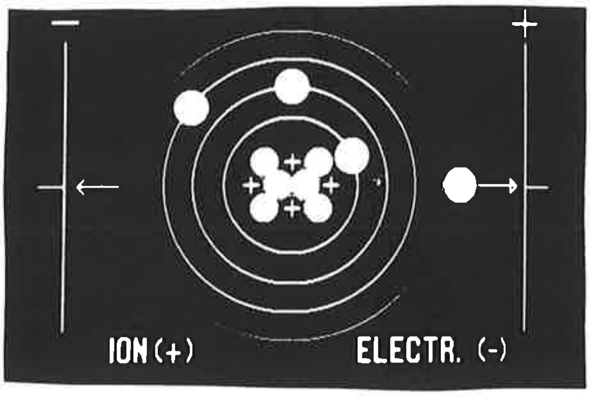


Looking at the burner of a high pressure mercury vapour lamp we can create stable discharge conditions through mercury vapour for example.

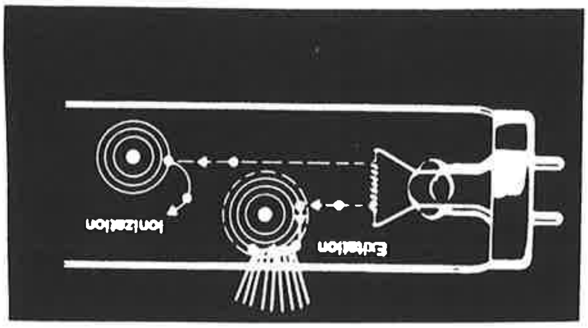
To understand the mechanism of discharge we have to look at the atom. The nucleus composed of neutral neutrons and positive protons is surrounded by a certain number of negatively charged electrons which balanced in total the positive potential of the necleus. This is a neutral atom.



Under certain conditions we can detach al electron from the atom. We have then a free negatively charged electron which is attracted by the positively charged electrode and we have a positively charged atom which is attracted by ther negatively charged electrode. From a given point in the discharge and the electrical potential of the electrodes both particles will now accelerate towards their respective electrodes.

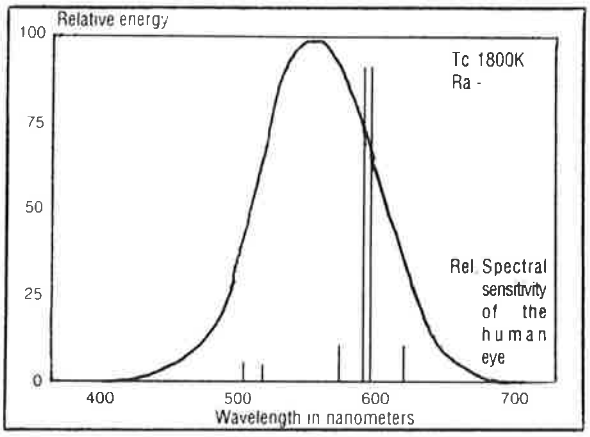


In a fluorescent lamp we have the emission of electrons from the electrode. We also have mercury vapour in this lamp. When the emitted electrons can accelerate over a longer distance they will acquire a certain kinetic energy. Colliding with a neutral mercury atom they will then dislocate an electron from this atom, so we obtain a positively charged mercury ion and we have two free electrons. If these two free electrons can achieve the same thing again when we will have four free electrons and if this process would go on we would come to eight, sixteen, thirtytwo, sixtyfour etc. free electrons, in a type of avalanche process. As we know, the flow of electrons represents an electrical current. If we would not control this current it would increase within a fraction of a second to a value which would burn out the electrodes. This process is called ionization. It does not give light but it permits a current to pass through the lamp. To produce light or electromagnetic radiation we look for a process of excitation. In this case the acceleration of the emitted electron goes over a short path only and in the collision with a neutral atom the electron will go momentarily to an unnatural orbit because of the absorption of extra energy in the collision. Going back to its natural orbit the electron will radiate electromagnetic radiation which in case of the mercury atom is mainly in the ultraviolet radiation range, but in case of similar discharge conditions with sodium vapour we obtain a monochromatic radiation in the visible range at 589 nanometres.



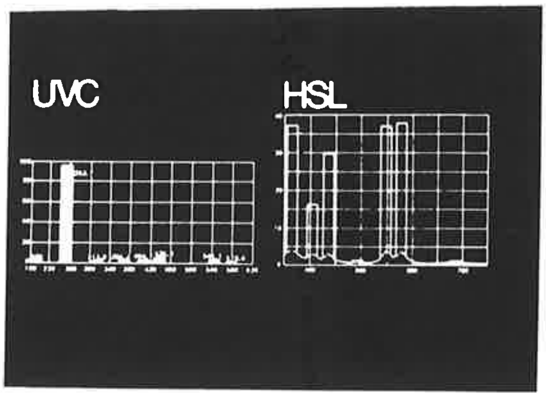
The main radiation for a low pressure mercury discharge is at 253.7 nm. For low pressure sodium lamps the main energy is radiated at 589 nm.

Low Pressure Sodium Lamps



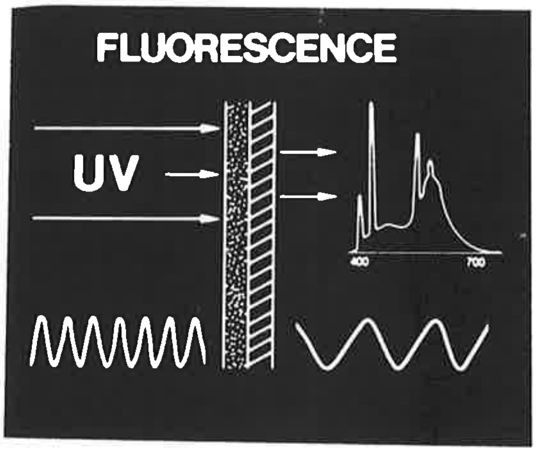
For mercury and for sodium vapour we find under these conditions of discharge major radiation at a specific wavelength. However both types of atoms undergo a variety of ionization levels with a variety of additional wavelengths being emitted.

On the left we have again emission of low pressure mercury vapour discharge and we can identify various weak radiations which are already defined towards the visible range. When we increase the vapour pressure then the major radiation of 257.3 nanometres (also called resonance radiation) will be absorbed by the surrounding mercury vapour which then will be excited within the discharge by the UVC radiation. This means that the energy emitted within the spectrum will shift from 253.7 nanometres towards emission lines in the visible spectrum as shown in the diagram for a clear mercury lamp on the right.



The same process takes place when we increase the pressure of sodium vapour going from the conditions of low pressure sodium to high pressure sodium, the resonance radiation is increasingly absorbed and the energy is radiated in other parts of the spectrum. We can observe this process when we start up a high pressure mercury vapour lamp or a high pressure sodium vapour lamp. Both will go during the initial run up period through a low pressure discharge mechanism.

Fluorescence is the conversion of short wave ultra violet radiation by a phosphor into visible light.



In fluorescent lamps we are utilizing the resonance radiation of 253.7 nanometres to excite a phosphor which will convert this radiation in longer wave visible radiation, the composition of this one depends on the mix of phosphors which we are utilizing.

Also high pressure mercury vapour lamps utilize the fluorescent technique, a phosphor of red radiation is excited with radiation created by the burner at wavelengths of 380 and 400 nanometres. As we can see from the spectral power distribution of phosphor coated almps the UVA radiation is strongly reduced and the energy is reemitted in the red part of the spectrum.

There is one lamp taking advantage of all three modes of producing light and these are blended mercury lamps. In this case light is produced with an incandescent filament, the high pressure mercury vapour burner and a phosphor coating.

Since high pressure sodium lamps do not radiate UV, the use of phosphor coatings makes no sense. The coating on SHP lamps acts only as a diffusor.

2.2. Lamp design & construction

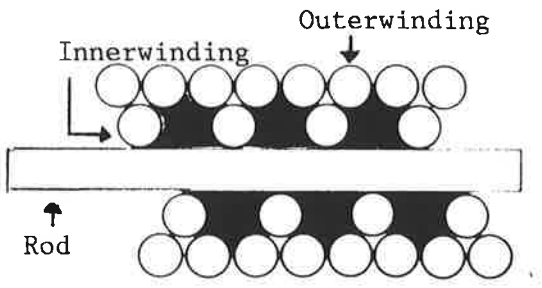
2.2.1. Mercury vapour lamps

1. Arctube

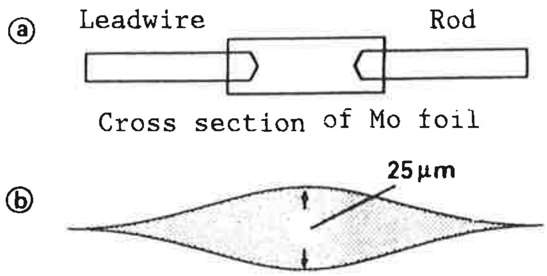
In the arctube two types of electrodes are used:

1. The main electrode
2. The starting electrode

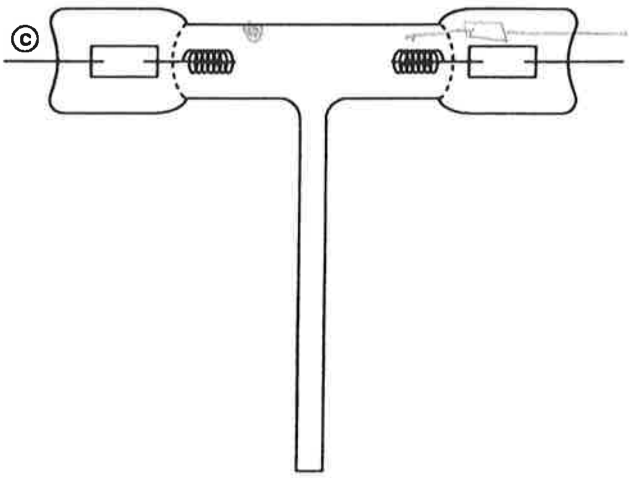
The electrodes are made of tungsten in order to reduce the evaporation rate at high temperatues. The tungsten coil of the main electrode is double winded in order to contain as much as possible emitter material. The emitter is coated on the electrodes so that the electrons are excited at a relatively low temperature. This extends the life of the electrodes.



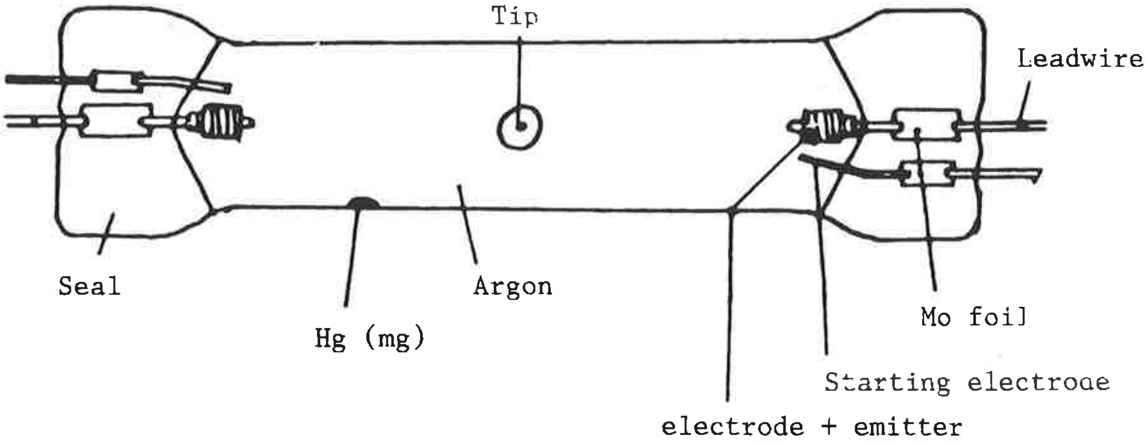
Because the leadwire of the arctube and quartz has different expansion characteristics, a molybdenum foil is used to keep the absolute expansion for the relevant temperatures within limits.



The arctube is made of quartz so that a relatively high wall loading can be obtained. This is necessary to optimize the lumen per watt versus life.
Before the sealing of the elctrode assembly (also called hairpin) the quartz tubes are tubulated. The exhaust tube permits to fill the arctube with mercury and Ar as a starting gas. Since a mercury lamp is an unsaturated lamp all of the mercury is evaporated when the lamp is warmed up. This also means that the slightest variation in the mercury weight will cause differences in lamp voltage, wattage and lumenoutput.

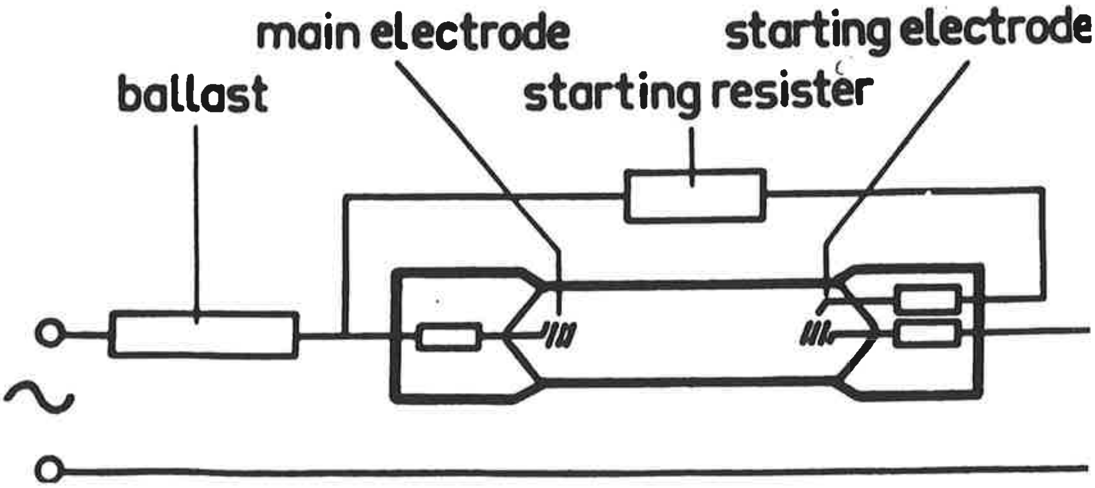


For example a 125W mercury lamp contains 20 mg of mercury. After the mercury dosing the arctube is filled with approximately 30 torr of Argon. The function of Argon is to facilitate the starting of the lamp. When the lamp is warmed up the working pressure inside the arctube is approx. 10 bar. After the gasfilling the arctube is tipped off and 100 % online inspected on voltage.



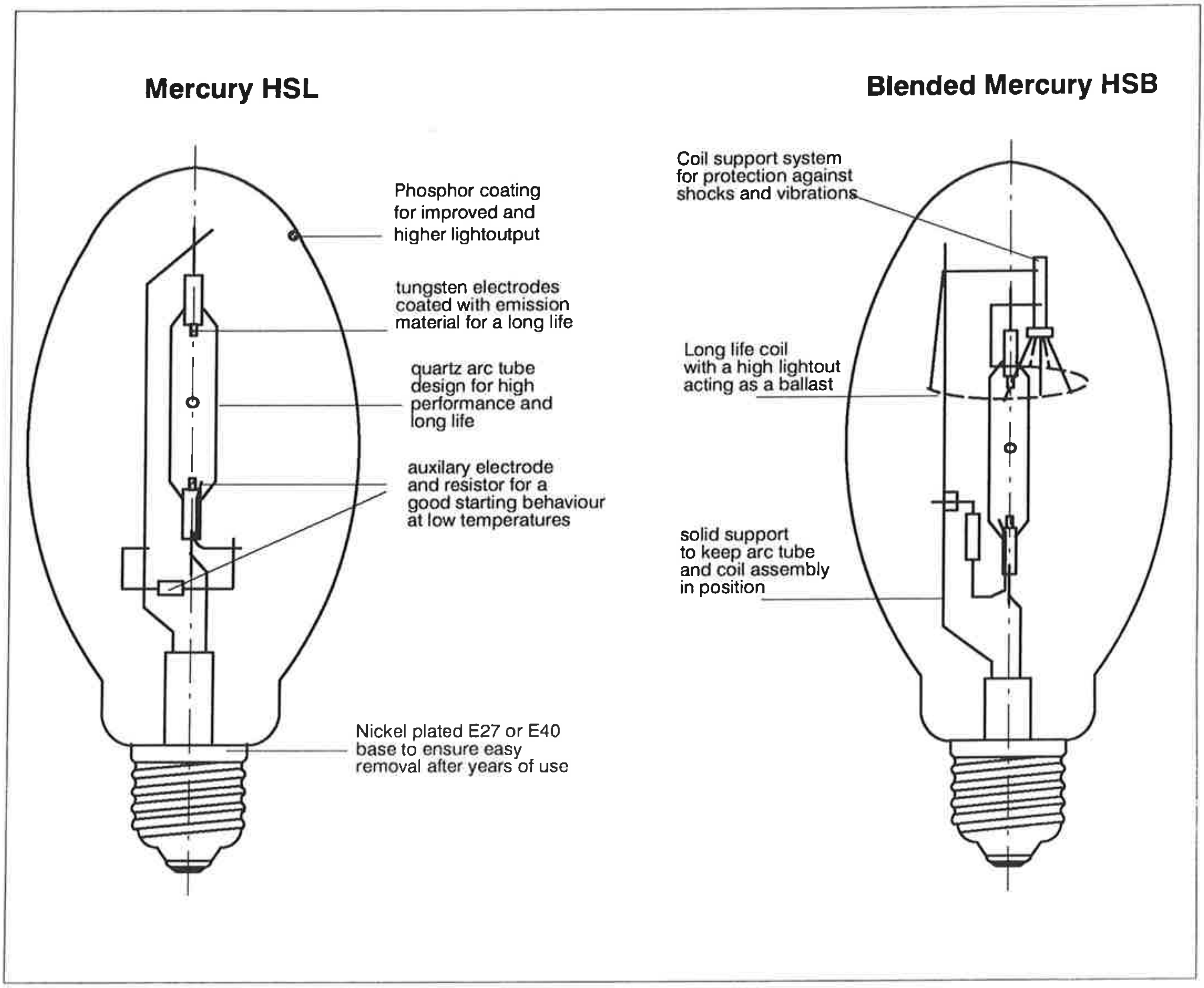
2. Mounting & lampmaking

Mercury lamps don't need an external ignitor because during start up first an arc will be generated between the starting electrode and the main electrode. As we can see this starting (or auxiliary) electrode is connected through a resistor on the same potential as the opposite main electrode.



In case of a blended mercury lamp an incandescent filament is connected in series with the arctube. This eliminates the need of a ballast. Since 60% of the consumed power goes to the filament, the luminous efficiency of blended lamps is only 21 - 28 LPW.

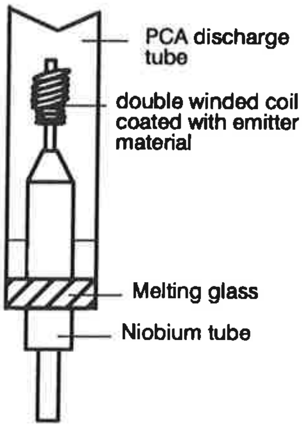
The lampmaking process starts with the (electrostatic) coating of the bulbs. After this the mounts and bulbs are sealed together and the bulb can be filled with a mixture of 80 % Argon and 20 % Nitrogen in order to prevent voltage arcing. The finishing of the lamp is mainly basing and soldering.



2.2.2. High pressure sodiuml lamps

The following is a summary of elements or components and their purpose used in discharge lamps:

1. *Electrodes:*



Double winded tungsten coil with a low evaporation rate at high temperatures.

Emitter material coated on electrodes so that electrons are excited at a relatively low temperature. This extends the life of the electrodes.

Niobium tube has the same coëfficiënt of expansion as the discharge tube. Together with the melting glass, this guarantees a perfect seal in all operating temperatures. The electrode assembly is then sealed with melting glass onto the PCA tube.

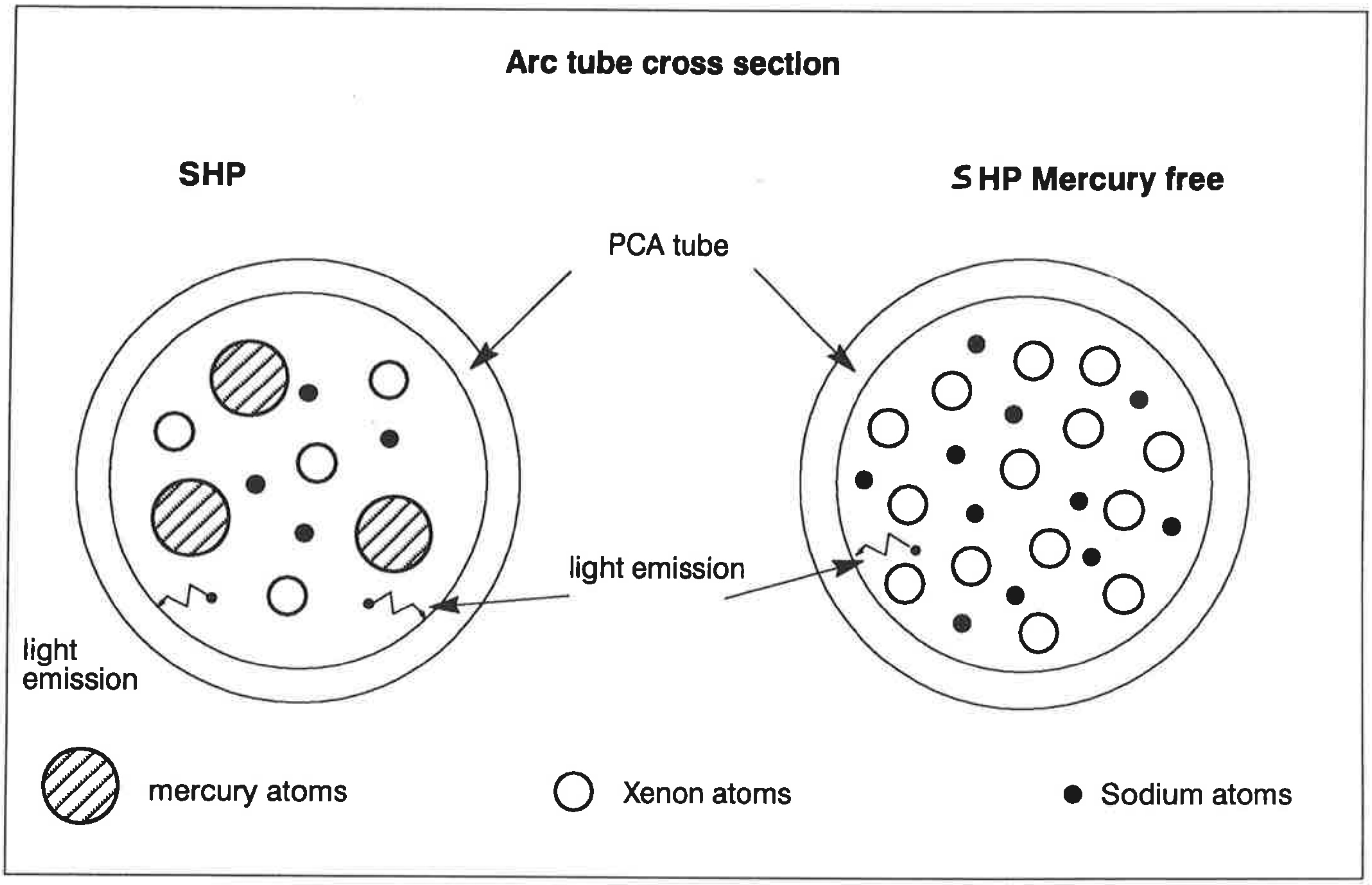
2. *PCA discharge tubes:*

Sintered Poly Cristaline Alluminium (Al_2O_3) with a transmission of 97%. PCA is almost not reactive with sodium at the operating temperature. In mercury lamps the arctube is made of quartz because wall temperatures are lower and there is no sodium in the arctube.

3. *The arctube contains:*

- Inert gas (Xenon), acting as a startgas and isolating the arc for a high lumenoutput.
- Filling pressure: 30 Torr Std. SHP
  300 Torr SHP Super
- Sodium (Na)/Mercury (Hg) amalgam. Na weight percentages variyng between 12 to 25 % depending from the lamp type.
  Na gives the specific spectrum of SHP lamps.
  Hg acts as a buffergas and allows the arctube designs to be more compact for a given arc voltage.

Mercury also reduces the heath conduction which results in higher lumen output.
In a SHP lamp mercury only generates radiation during starting.
Mercury Free SHP lamps do not contain mercury. The high lampperformance is achieved by a longer arctube and a higher Xenon pressure.

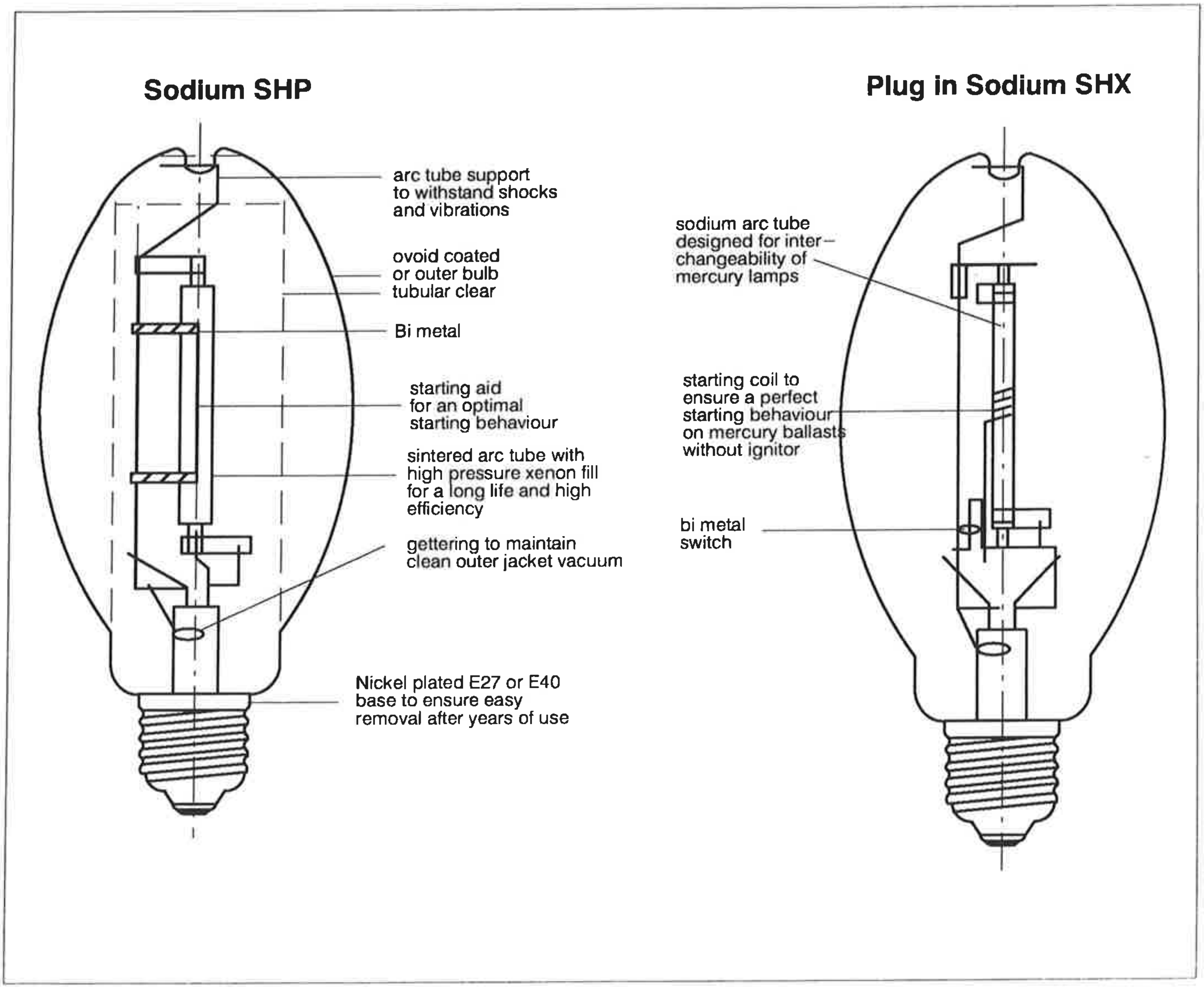


4. Mount construction

Support wires are made of nickel plated steel in order to avoid oxidation at high temperatures. A tungsten starting aid is used in SHX and SHP lamps for guidance of the electrons during starting. The aid is bend away from the arctube with bi metals after starting.

5. Lampmaking

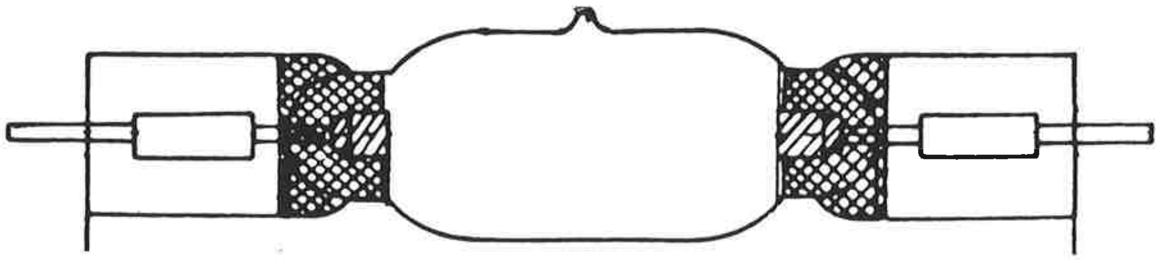
This process is nearly the same as for mercury lamps. The main difference is that the bulb is vacuum in order to isolate the arctube from heat losses and to avoid arcing between the metal parts. A getter is added to keep the vacuum pressure as low as possible.



2.2.3. Metalhalide lamps

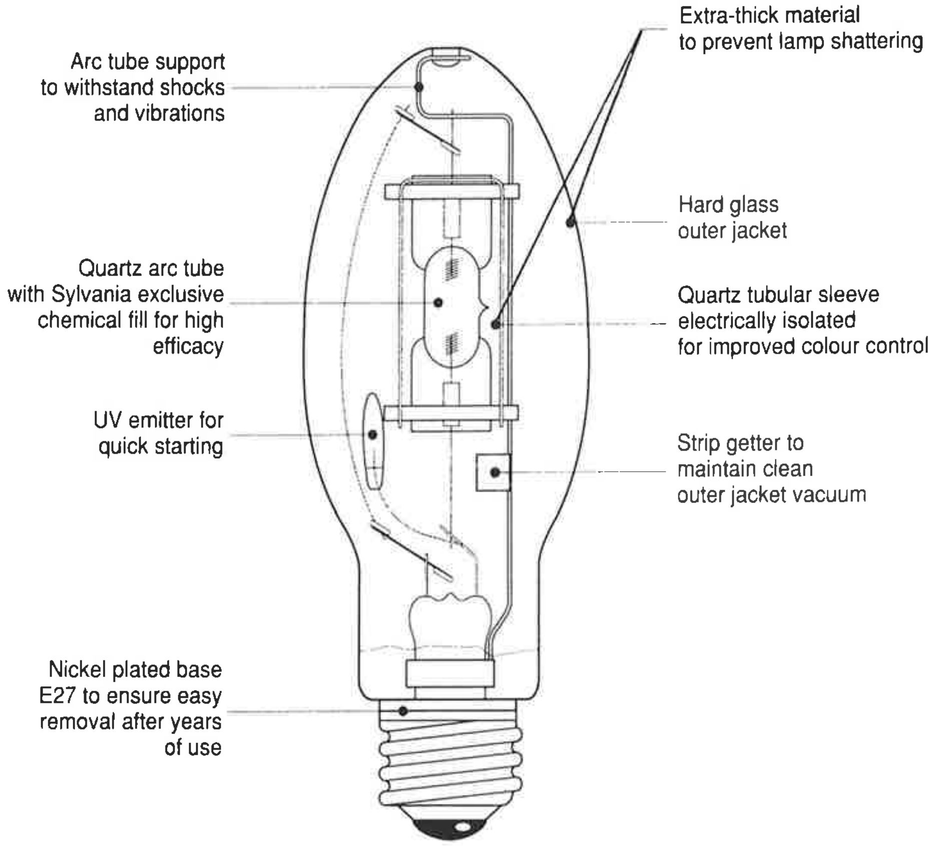
The construction of metalhalide arctubes is very similar to mercury lamps. Depending on the chemistry inside the arctube the tungsten electrodes are coated or not. However, the atmosphere purity and the tolerances on dimensions should be very well controlled during the process.
Changes in the arctubes dimensions will cause a temperature difference of the cold spot (the lowest temperature area in the arctube) which on its turn will determine which and how much of the metalhalides will evaporate.

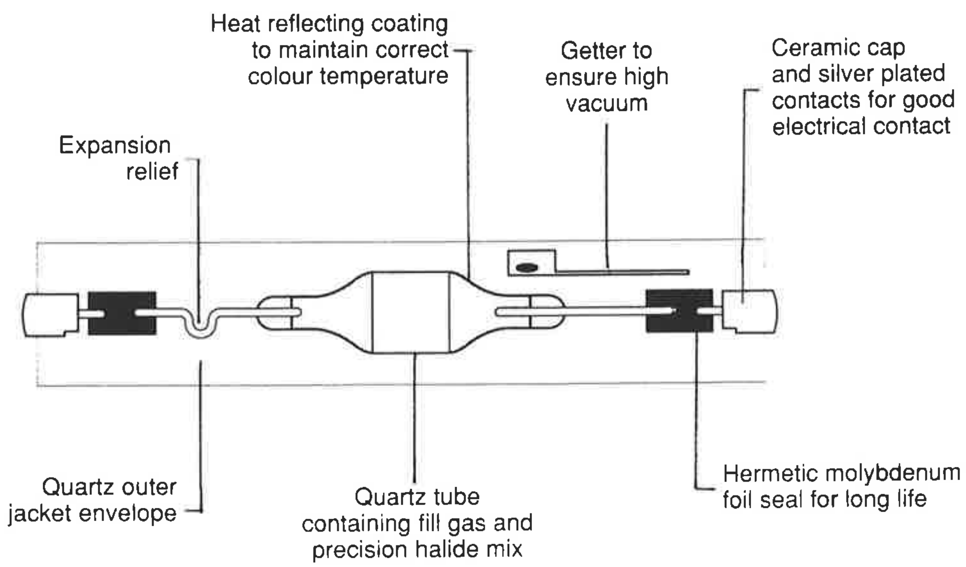
Some metalhalide arctube designs require a coating on the arctube seal in order to increase this cold spot temperature.
This coating is applied by the so called flame spray process. In other words the Zirconium oxide or aluminiumoxide powder is baked and applied at the same time with flames.



Also the outer jacketing is similar to mercury or sodium lamps. All metalhalide lamps are made of hardglass due to the higher bulb wall temperature. In protected versions a shroud around the arctube is mounted. Some types contain UV enhancers for an improved starting behaviour.

MP75/MP100


Extra-thick material
to prevent lamp shattering
Arc tube support
to withstand shocks
and vibrations
Hard glass
outer jacket
Quartz arc tube
with Sylvania exclusive
chemical fill for high
efficacy
Quartz tubular sleeve
electrically isolated
for improved colour control
UV emitter for
quick starting
Strip getter to
maintain clean
outer jacket vacuum
Nickel plated base
E27 to ensure easy
removal after years
of use


Heat reflecting coating
to maintain correct
colour temperature
Getter to
ensure high
vacuum
Ceramic cap
and silver plated
contacts for good
electrical contact
Expansion
relief
Quartz outer
jacket envelope
Quartz tube
containing fill gas and
precision halide mix
Hermetic molybdenum
foil seal for long life

3.1.2. Advantages and disadvantages

Advantages	Disadvantages
* Relatively low price	* Bad lumen maintenance
* No ignitor needed	* Low luminous efficiency
* Simple ballast	* Moderate colour rendering (except super confort)
* Long lamp life	* Difficult ignition at low ambient temperatures
* Universal burning position (except HSB lamps)	* Low lamp life (blended mercury)
	* Poor optical control in fixtures (except mercury reflector lamps)
	* Lamps are subjected to seperate disposal (and recycling)

3.1.3. Applications

* Standard Mercury (HSL-BW):
  - Streetlighting
  - Outdoor industry lighting (stock yards, docks, . . .)
  - Parks and gardens

* Super Comfort Mercury (HSL-SC):
  - Outdoor lighting mainly in nordic countries (lower colour temperature) and monument lighting
  - Indoor lighting (offices, hotels, super markets)

* Blended Mercury Lamps (HSB-BW):
  - Replacement for Inc. lamps for energy saving and longer life
  - A quick step up to a higher lumen package (cellars, garages)

3. Product range and applications

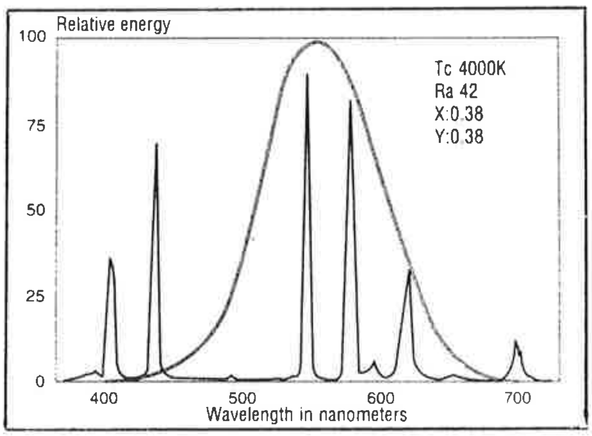
The purpose of this chapter is to give a summary of the product range. A detailed range description with codenumbers can be found in the lamp catalogue. If more technical details are required the lamp datasheets and the life and lumen maintenance curves should be consulted. Based on the general product range information, the advantages and disadvantages will be described. From hereon, the most favorable applications will be threated.

3.1. Mercury lamps

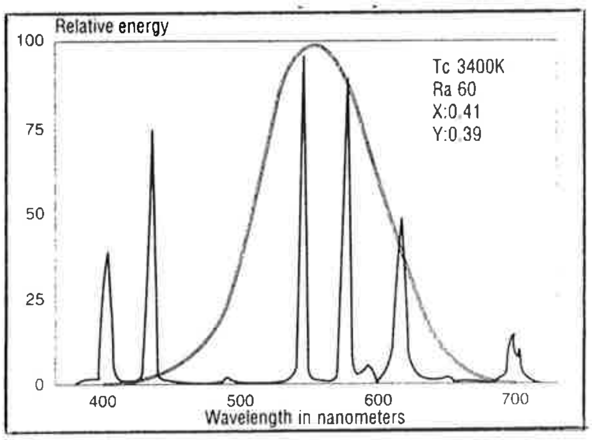
3.1.1. Product range

From the current discharge productgroups, mercury lamps are the oldest. In the year 1935, mercury lamps were commonly used in streetlighting. Several performance improvements made the product more attractive for a large application. In 1968 the luminous efficiency and the colour rendering was significantly improved due to the application of Yttriumvanadate coating, currently still used in the standard mercury lamps. After this an improved coating was used for super comfort mercury lamps resulting in a lower colour temperature, improved efficiency and higher colour rendering (see spectral distribution curves).

"Brightwhite" Standard Mercury Lamps

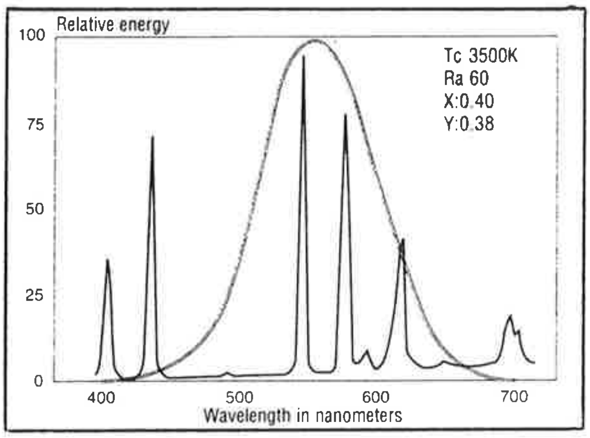


"Super Comfort" Mercury Lamps



Blended mercury lamps (HSB-BW) were mainly developed in order to avoid the use of a ballast. Since the tungsten coil inside the lamp, acting as a ballast, consumes the main part of the lamp wattage, the efficiency drops to a level of 21 - 28 LPW. The average lamp life is decreased to approx. 16000 hrs due to the presence of a filament in the lamp circuit. Because the colour rendering of incandescent lamps is superior to discharge lamps, blended mercury lamps show a higher Ra-value than standard mercury lamps.

"Brightwhite" Blended Mercury Lamps



Parrallel to the elliptical lamps, reflector mercury lamps (HSR-BW and HSB-R) were taken into the range.

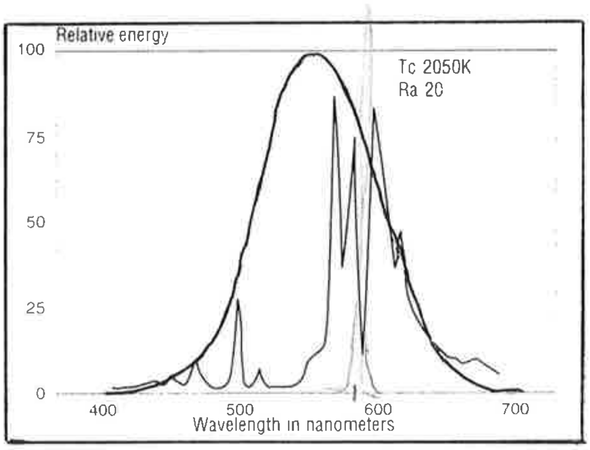
* Reflector mercury lamps (HSR-BW):
    - Dirty environment
        * foundries, steel mills
        * industry workshops
        * mining operations

3.2. High Pressure Sodium Lamps

3.2.1. Product range

Although the principal of a sodium discharge was evident, the real breakthrough came only 10 years after a high temperature resistant, tranluscent material (PCA) was discovered (in 1955). Since all high pressure sodium lamps are more or less based on the same principal, the spectral distribution of the various lamptypes don't show significant changes.

High Pressure Sodium Lamps



Standard high pressure sodium (SHP Standard)
were the first lamps in the product range. However for low wattage lamps *SHP Super* replaced the standard SHP lamps purely due to the difference in quality.

Because the Xenon pressure in super SHP is much higher than Std. SHP:

1. the luminous efficiency is increased with 15 %
2. the average life (for low wattage lamps) is almost doubled
3. a higher starting energy is required. So only super imposed ignitors can be used.

Since the difference for high wattage lamps (250 & 400W) is not so appearant both product types are kept in the range.
Due to the ignition requirements the selfstarting SHP lamps (with incorporated ignitor) are low pressure Xenon lamps.
High colour rendering (HCRI) SHP lamps were added to the range to provide the customer an alternative for improved colour rendering. However the actual life performance is below Std. or Super SHP lamps.
Based on the attractive LPW and life performance of SHP lamps, plug in SHX lamps were developed in order to retrofit existing mercury installations. Based on the energy saving the extra lamp cost is payed back within 1 year.
The two most recent developments of this year were:

SHP-S Mercury Free

and

SHP-S Twinarc

3.2.2. Advantages and disadvantages

Despite the fact that the luminous efficiency of high pressure sodium lamps is inferior to low pressure sodium, the most economical solution for exterior lighting is SHP. This for the following reasons:

1. The arctube is very compact. In case of tubular SHP lamps the fixture efficiency is one of the highest.
2. The combination of lumen maintenance and lamp life is optimal, this results in a high service level (certainly for SHP Twinarc).
3. The lamp and fixture prices can be situated between mercury vapour and low pressure sodium. However the cost of ownership of SHP justifies the extra cost versus mercury systems.

4. Since the launch of SHP-S Mercury Free lamps the recycling costs can be avoided and the political intrest is enhanced.

♦ Other advantages are:
- Universal burning position
- Good starting behaviour at low ambient temperatures

♦ Disadvantages are:

- Colour rendering	Ra: 20 (Std. or Super SHP)
	Ra: 25 (SHP Mercury Free)
- Colour temperature:	2050 K (Std. or SHP Super)
	2200 K (SHP Mercury Free)

3.2.3. Applications

The application of high pressure sodium lamps is mainly based on rational elements related to the cost of ownership such as:
- Average life
- Failure rate
- The combination of lamp and fixture efficiency
- Lumen maintenance

♦ Outdoor applications
- Streetlighting (roads, junctions, pedestrian zones, town centers)
- Stock yards
- Docks
- Monument lighting
- Airports
- Military installations

♦ Indoor applications
- Industrial workshops
- Warehouses
- Greenhouses (Super SHP)

3.3. Metalhalide Lamps

Based on the technology of mercury lamps, in 1960 experiments were done to fill the gap in the mercury spectrum by adding new chemical elements. Since the metalhalide technology is relatively new, the different lampmanufacturers used several chemistries. This results in a lack of standardization for metalhalide. Only recently an IEC standard proposal is circling around.
Therefore an overview will be given for the 3 major chemistries used by various lampmanufacturers:

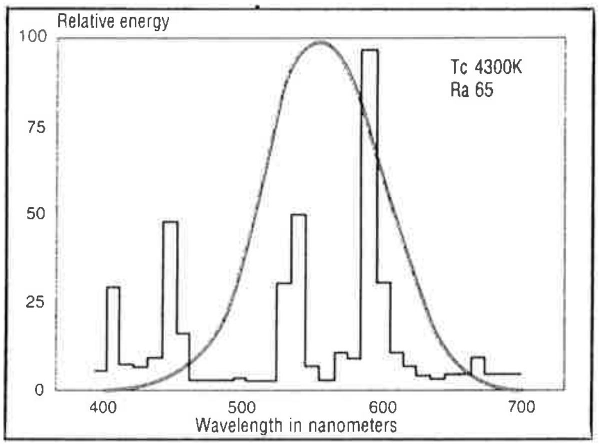
1. 3-colour chemistry
2. Rare earth
3. Sodium Scandium

3.3.1. The three-colour chemistry

In addition to Mercury and Argon following elements are added in the arctube:

Indiumiodide	->	Blue
Sodiumiodide	->	Red
Thaliumiodide	->	Green

HSI-T 250/400/1000/2000W 4K Lamps



The inherent advantage of this chemistry is that the reaction with the emitter on the electrodes is very slow. This enables the manufacturer to use an emitter which on its turn improves the starting behaviour of the lamp.

1. The Mercury ballasts in combination with low pulse ignitors can be used. This reduces the costs of the control gear.

2. The glow to arc transition is smoother. Therefore the lumen maintenance is better than with other chemistries. The life expectancy curves shows a sharper cut off. In other words the lamp life is more predictable. This because the electrode life is mainly relying on the emitter. Once the emitter is exhausted the electrode wear happens rather fast. This results in a lower average life.

Since the three colour chemistry generates 3 sharp peaks in the lamp spectrum, the colour characteristics are less under control than with other chemistries. This because if 1 colour is lost over life, the effect on the lamp colour is very appearant. The sharp peaks in the spectrum are also responsible for a moderate colour rendering (Ra $\approx$ 65) and a low luminous efficiency (LPW 65-70). And last but not least, the typical chemical balance makes it very difficult to develop lamps lower or higher than approximately 4000 K.

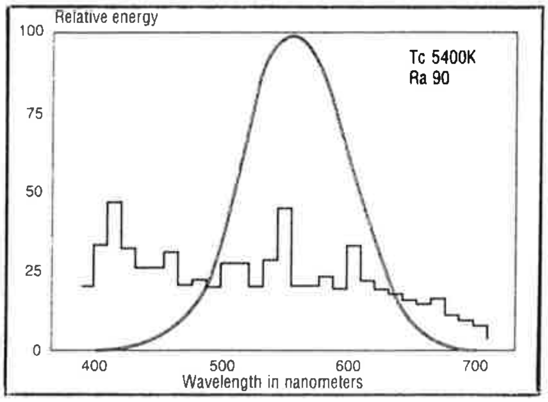
3.3.2. The rare earth chemistry

In contradiction to the three-colour chemistry the addition of:

- Disposium iodides
- Thoelium iodides
- Holmium iodides

provides a rather continuous lampspectrum.

HSI - T 250/400W 6K Lamps



This results in:

a) a high colour rendering
Ra 80 for long life lamps
Ra 96 for low - medium life lamps
b) an average luminous efficiency (typically 80 LPW)
c) a better colour stability (initially and over life)

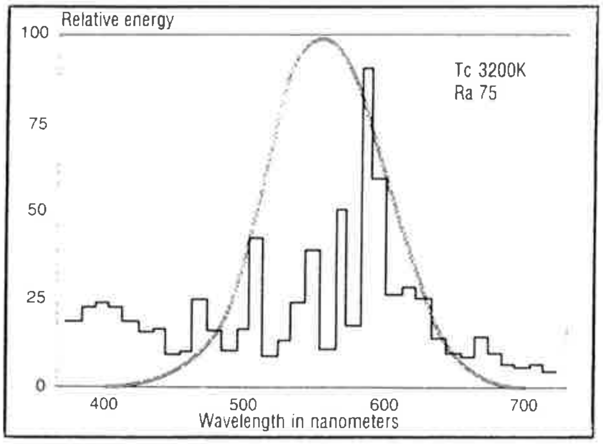
This chemistry also provides the development engineer a higher degree of freedom for the design of different colour temperature lamps (between 3800 - 5600 K). However nearly all of the disadvantages are related to the fact that the chemistry reacts with an emitter. So the use of an emitter is practically impossible. Because the electrodes can not be coated the required starting energy is higher. This results in:

1. the need for high pulse ignitors and a more costly ballast (because the windings should be better insulated)
2. A higher electrode temperature which enhances the likelyhood of electrode evaporation. As a consequence the lumen maintenance is not very good and the mortality curve is less predictable than with the 3-colour chemistry. However the <u>average</u> life is higher (> 15000 hrs).

3.3.3. The sodium scandium chemistry

Although sodium and scandium are the main chemical additions, quite often Lithium and Thalium are added to improve the colour rendering. Looking at the spectrum of the lamp, the sodium scandium chemistry looks like a mix of both previously described chemistries.

HSI - TD 150W 3K Lamps



This provides certain advantages because the continuous part of the spectrum provides an acceptable colour rendering and the peaks contribute to the high luminous efficiency (80 - 125 LPW). In case the right precautions are taken in the production process, this chemistry provides a good initial colour stability and the average life is extended because the wall loading can be kept well below a critical limit.
Furthermore, the chemistry offers more possibilities through chemical dosing, for development of different colour temperatures. Just like the rare earth chemistry, the sodium scandium approach results in the same disadvantages: related to the fact that a higher starting energy is required (low lumen maintenance and higher system cost).

Following Sylvania product types belong to this chemistry group:

Type	Base	Wattage
HSI - T	G12	70 & 150W
HSI - TD	R7s/PC2	70/100/150/250W
Metalarc	E27	MP 75/100/150W
Metalarc PAR 38	E27	100W
Britelux	E40	250 & 400W
Super Metalarc	E40	250 & 400W

The 3 main chemistries for metalhalide in summary

	3-colour	Rare earth	Sodium Scandium
Luminous efficiency (LPW)	65-70	< 80	> 80
Colour rendering (Ra)	65	80 - 96	75
Colour stability	Low	Medium	Medium
Freedom for development	Low	High	High
Lumen maintenance	Medium	Low	Low
Life predictability	High	Medium	Medium
Average life	Low	Medium	High
System cost (ignitor + ballast)	Low	Medium	Medium

3.3.4. Applications

In terms of performance metalhalide lamps provide the best optimum between lumen efficiency and colour rendering. However in area's where colour rendering is less important, and more attention is given to life and LPW high pressure sodium lamps are recommendable. A distinction should be made between the various lamp wattages:

- High wattage metalhalide (1000 & 2000W)
  mainly used in outdoor applications like
    - stadiums
    - airfields
- Medium wattage (250 - 400W)
    - parking lots
    - facade and monument lighting
    - gasstations
    - indoor sport arenas
    - factories
    - warehouses
    - shopping centers
    - airport terminal areas
- Low wattage
    - shopping displays
    - retail stores
    - offices (uplighters)
    - showrooms
    - public areas (lobbies, banks, train stations, museums)

3.4. Product classification versus luminous efficiency and colour rendering

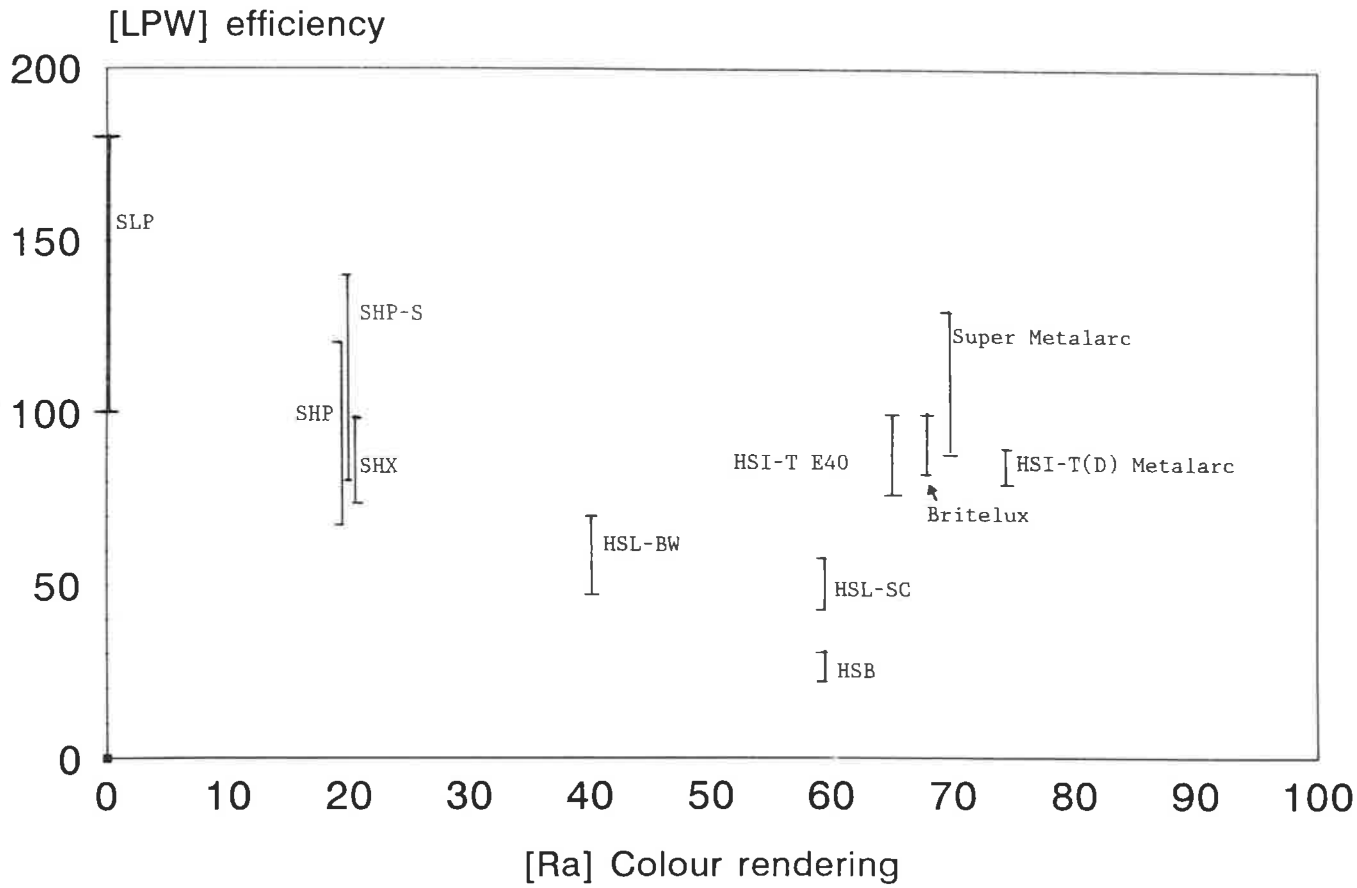
See graph next page.

4. Electrical parameters and equipment

4.1. The starting of discharge lamps

Unlike high pressure mercury vapour lamps, modern discharge lamps such as metalhalide and high pressure sodium lamps, cannot be started simply by applying the mains voltage. These lamps require starting-voltage pulses of order of 1 . . . 5kV, the maximum permitted amplitude of the pulse being limited by the lamp construction and by the type of holder (E27, E40).

Product classification versus luminous efficiency and colour rendering

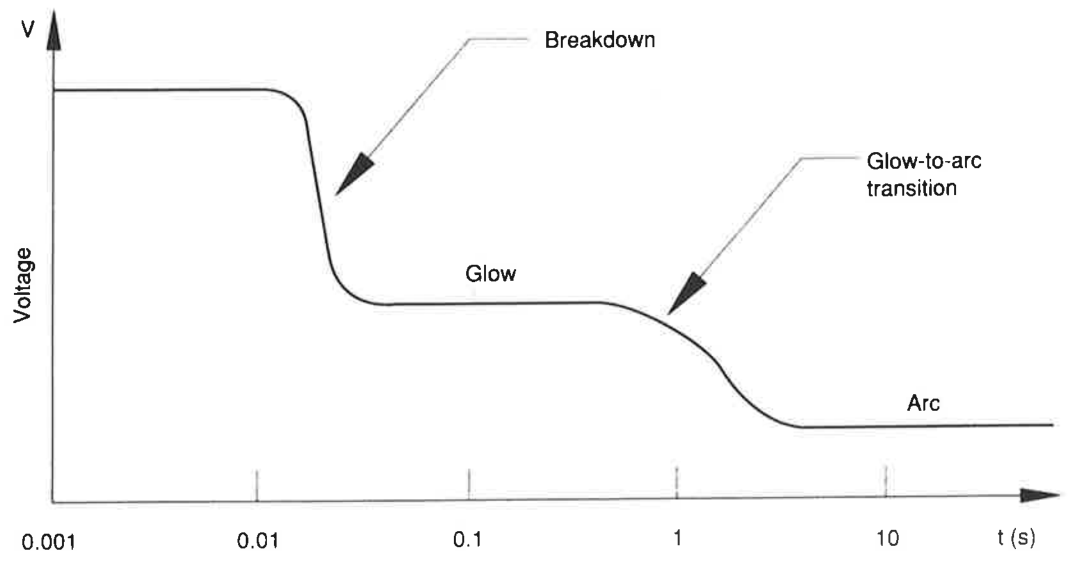


The function of an ignitor is to superimpose one or more of these voltage pulses on the lamp no-load voltage before the lamp strikes. With cold lamps, ignition takes place immediately after the ignitionpulse occurs. In the case of hot lamps which have gone out because of a power failure, accelerated ignition is possible at a certain stage as the lamp cools down. Hot metalhalide lamps, for example, restart after 5 to 10 minutes and high pressure sodium lamps after about 1 to 4 minutes.

The starting phases are shown in the following diagram. The high voltage pulses cause the breakdown (ionisation) of the low pressure atmosphere in the arctube. During a short time the discharge goes through a glow stage until the arc is firmly established in the mercury vapour. At this moment we have a low pressure mercury arc vapour discharge.

The heat is which is developed by the discharge will now evaporate all the mercury, which means an increase of mercury vapour pressure and temperature, as shown in the table. From a certain temperature on, the metalhalides or sodium start to evaporate. Stable conditions are reached with an arctube temperature of about 800 °C.

Lamp starting phases



4.2. Ignitors and circuits

In the ignitor circuit switching elements are incorporated in order to generate the high voltage peak. Two types of switching elements exist on the market:

1. Electronic switches which have no parts to wear
2. Non-electronic switches (like bimetal glow starters, gas or air spark gaps) which are subjected to wear because they contain mechanical elements. In most cases when the lamp is at the end of its life the switch continues to operate until (after 5 - 8 days) it ceases to function.

Ignition systems

Various ignition systems can be used. The ignitors available on the market are of the superposed-pulse and socalled implulser type. The last years, the main ignitor manufacturers have only super imposed ignitors in the range.
Figure 1 to 3 show common systems.

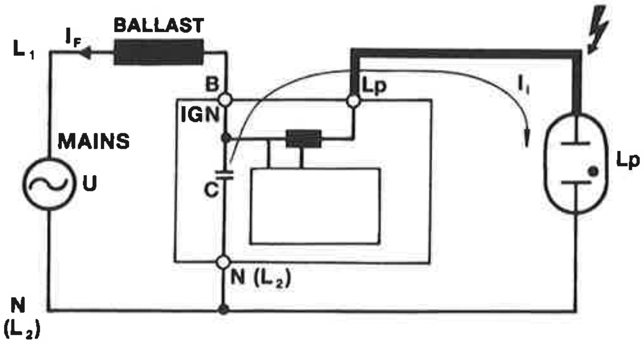


FIG. 1 SUPERPOSED PRINCIPLE
- (A) SUITABLE FOR ANY PULSE VOLTAGE UP TO 100 kV
- THE SYSTEM PREFERRED
- COMPATIBLE WITH ANY BALLAST

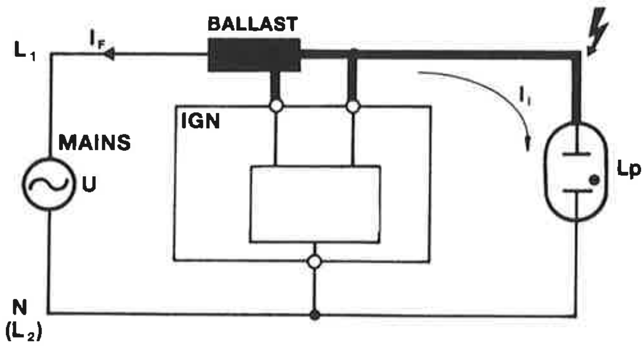


FIG. 2 THREE POLE SERIES
- BALLAST SPECS AFFECT THE PULSE VOLTAGE
- BALLAST EXPOSED TO PULSE VOLTAGE

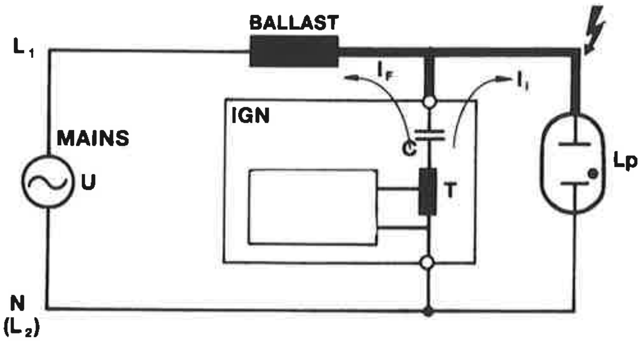


FIG. 3 TWO POLE PARALLEL

— (A) HIGH PULSE VOLTAGE $\hat{V} \gg \hat{U}$

— BALLAST EXPOSED TO PULSE VOLTAGE

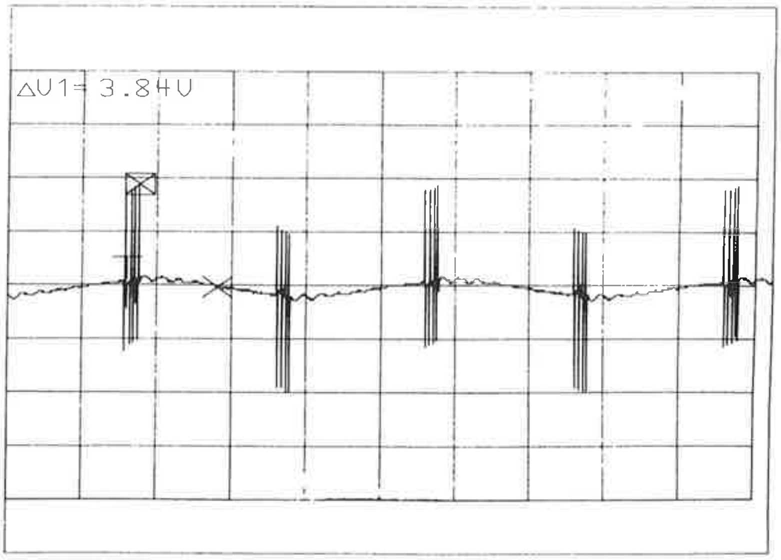
One can see that:
In case 1 (Fig. 1) the pulsed voltage is present only on the lead from ignitor to lamp base contact. The choke is subjected to a harmless feedback voltage U_F only during ignition.
In cases 2 and 3 the choke carries the pulse voltage, which requires certain requirements on the ballast.

Less commonly used are ignitors for instant restart.
Voltage pulses of up to 35 kV peak and 20 - 30 pulses per half cycle are required for instant restarting of a hot lamp. Only electronic superimposed pulse ignitors are suitable.
In general, the action time of these ignitors is very short (2 seconds) because the restriking time is less than a few 10ths of a second.
This action time, however, must be adjusted in such a way that the lamp is also started if it should extinguish after the first restrike.
In addition, a short time cut out switch is installed in the circuit, as a protection in case a lamp does not start any more, as under end of life conditions.
The correct circuit installation as well as additional components are listed by the ignitor manufacturer.
Because of the high voltages involved, the fixture must be equipped with a safety switch to the choke compartment which disconnects the circuit when the compartment is opened for service.
In attachment copies of ballast and ignitortypes related to possible lamptypes.

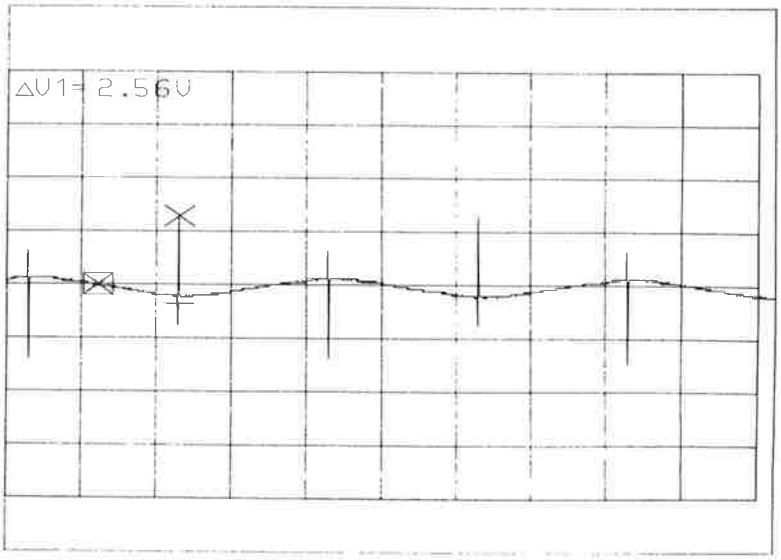
The ignitor of internally ignited lamps are mainly glove bottles which act as a switch. The interuption of the current causes a high voltage peak due to the ballest in series with the lamp.

The following graphs show actual measurements of possible systems.

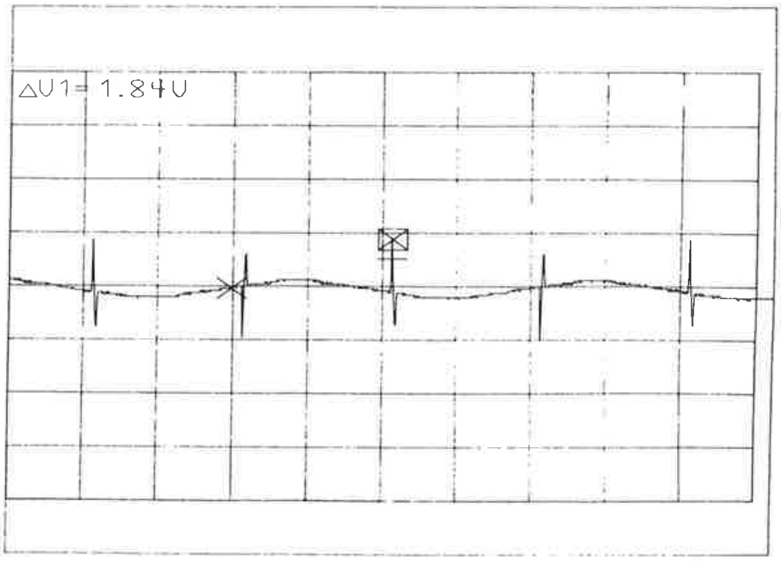
a) 3 pin superimposed electronic ignitor



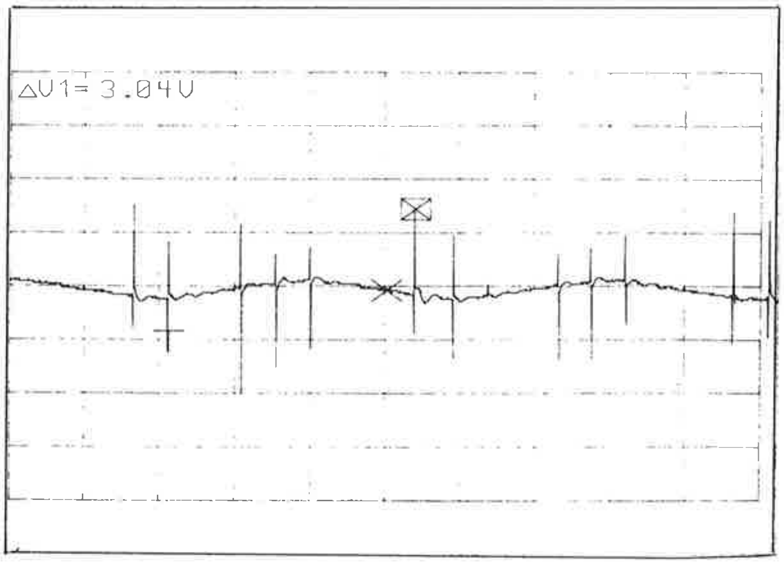
b) 2 pin ignitor parrallel with the lamp



c) 3 pin ignitor with the ballast acting as an impulser



d) Internal ignited lamp

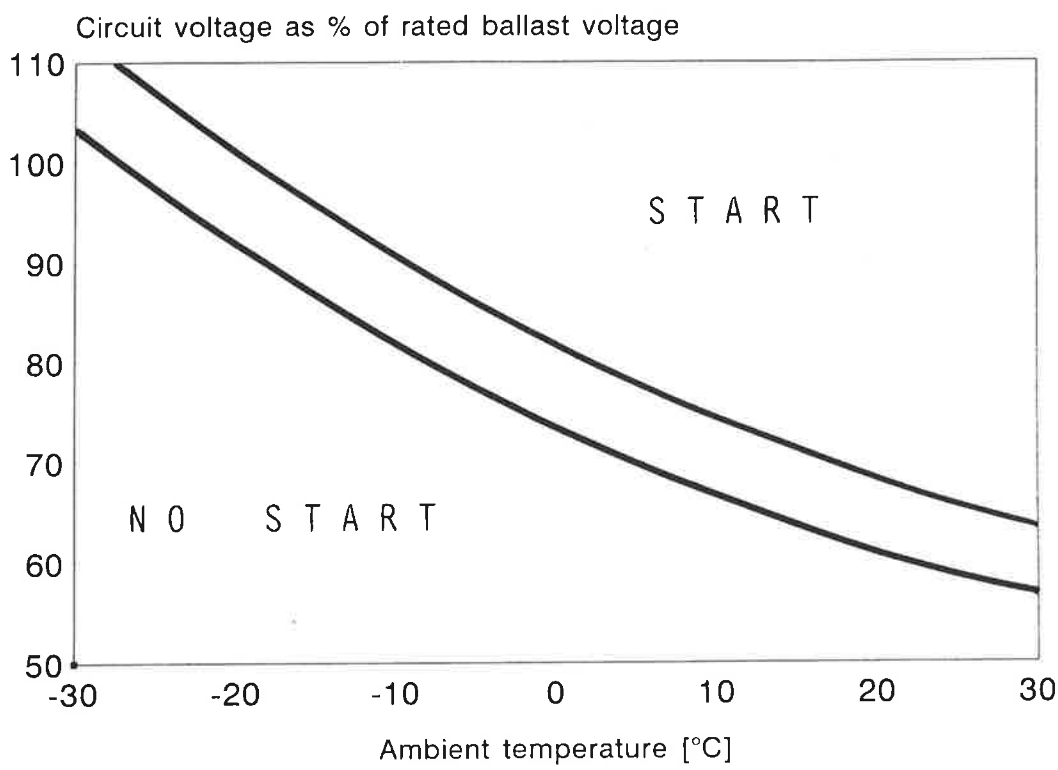


Disctance from ignitor to lamp

Superimposed-pulse ignitors should be positioned close to the lampholder.
The distance from ignitor to lamp depends on the maximum permitted load capacitance, which is listed in the technical data of the ignitor manufacturer.
Depending on the nature of the cable, its self-capacitance is 70 to 100 pF per metre.
Some of the fully electronic ignitors are also suitable for extremely high load capacitance.

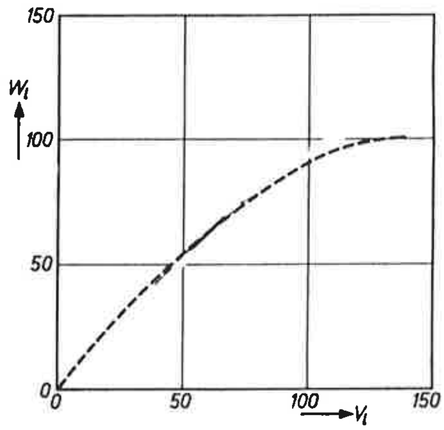
Mercury lamps are designed for a trouble free starting behaviour (see principles of operation). Although all lamps are 100 % on line started at 80 % of the rated ballast voltage, care should be taken when mercury lamps are used at low ambient temperatures. The diagram below shows the relation between the minimum starting voltage and the ambient temperature.

Starting behaviour



4.3. Ballasts

Superimposed-pulse ignitors can be used with all normally available ballasts, provided these are designed and approved for the lamps in question. No special tappings are needed, and neither the ballastwinding insulation not the terminals have to meet any extra requirements because with superposed -pulse ignitors they are not exposed to the high voltage.
When starting aids of the impulsor type are used, the high voltage is applied to the ballast. With starters of this kind, use only ballasts specially approved by the manufacturer for this kind of operation.
Additional units, such as powerreduction devices, can only be used in conjunction with superposed-pulse ignitors. The ballast stabilizes the lamp power at higher lampvoltages (see V_l / W_l graph).



4.4. Lampholders

The holders supplied by the industry are so constructed that they can immediately be used for ignitors with impulse voltages of up to 5kV.
For instant restarting with impulse voltages above 5kV, use only holders that the holder supplier states are suitable. These holders must be appropriately insulated when fitted. To allow for thermal expansion of the lamps, it is advisable to mount at least one holder flexibly so as to take account of this expansion.

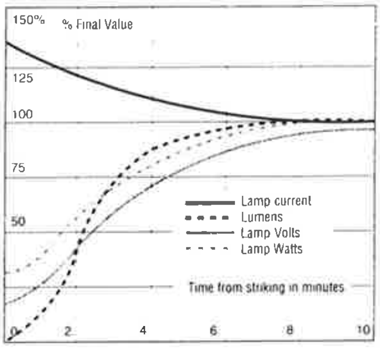
4.5. Run up conditions

Depending on the design of discharge lamps (dimensions, materials, chemicals, construction) the run up characteristics can differ. However, the electrical parameters all (except low pressure sodium) show the same trend during warm up. After the ignition the lamp current decreases and the lamp wattage -voltage and lumenoutput start to increase.

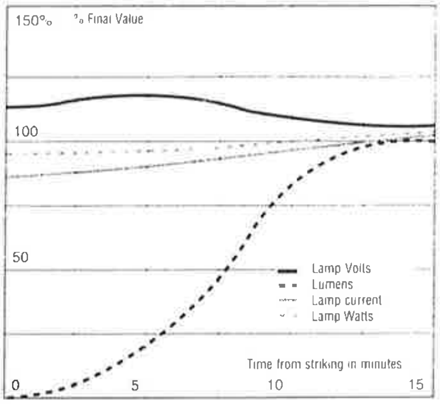
Because during warm up the chemicals start to evaporate and the arctube pressure increases, the arctube voltage starts to rise.

Below some of the typical warm up characteristics are shown:

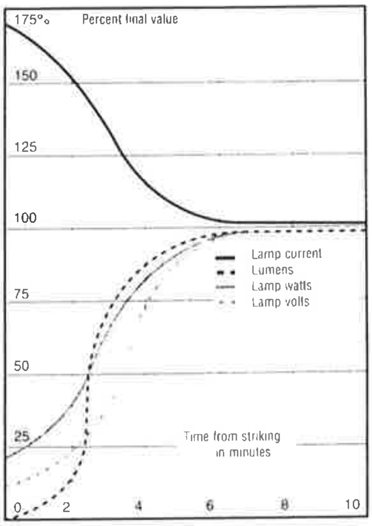
High pressure sodium



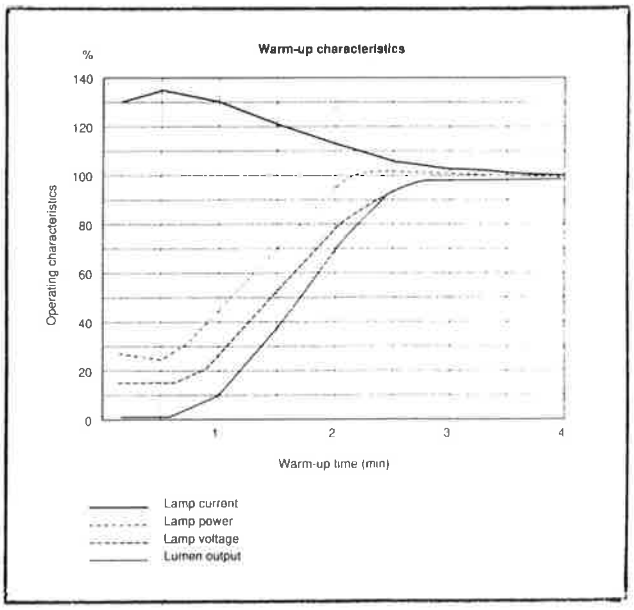
Low pressure sodium



Mercury



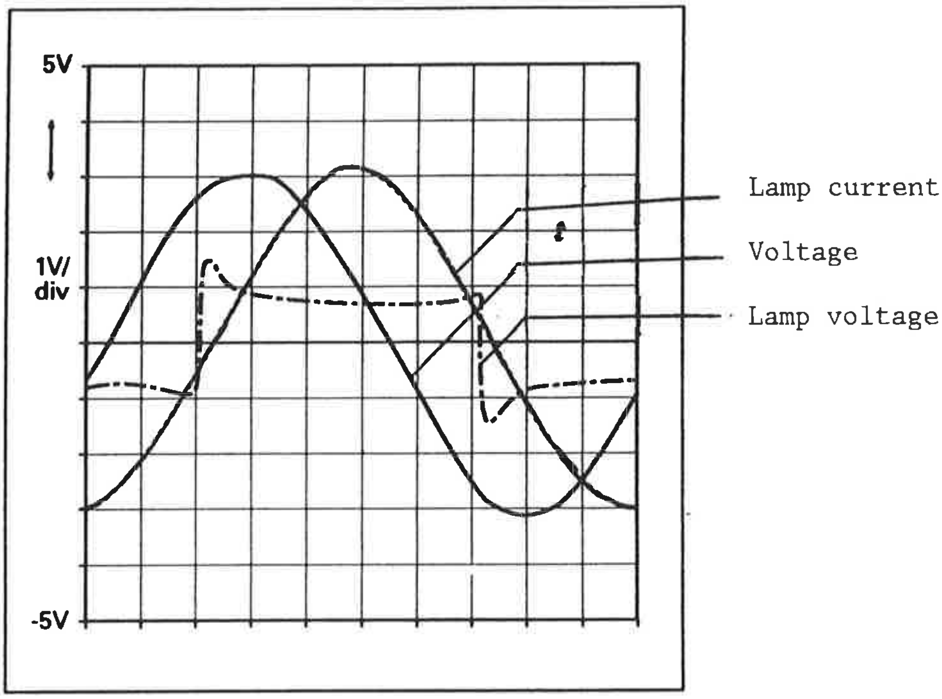
Metalarc



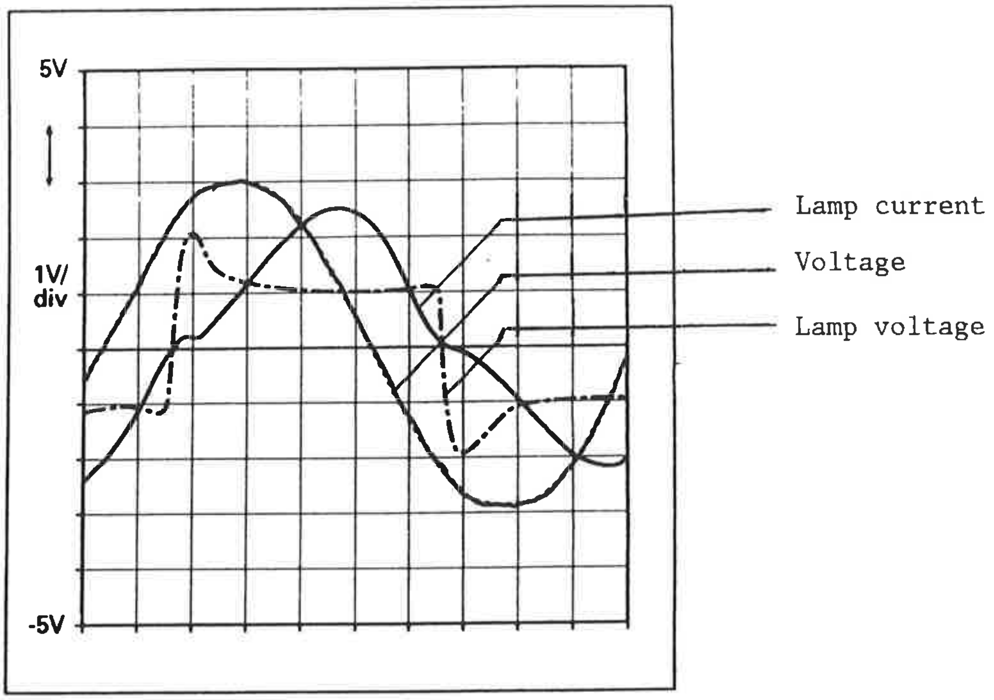
4.6. Lamp voltage and current

As we can see from the graphs below the lamp current and voltage is delayed in relation to the mains voltage because of the inductive characters of the ballast and the lamp.

Voltage and current of new SHP S 70W lamp



At the moment the lamp current goes through zero we also can see a re-ignition peak which is stimulated by the ballast. This peak is caused by the discharge which is temporary delayed. The re-ignition peak restarts the discharge 100 times per second.
The following graphs show the lamp voltage and current of an old (16000 hrs) SHP S 70W lamp.



Here it is shown that the re-ignition peak is increased. The reason for this is that emitter and chemicals are lost over life. This is the reason why SHP lamps show RMS lampvoltage increases over life (typical 1V/1000 hrs).
Once the re-ignition peak is higher than the mains voltage the lamp can not be restarted and the end of life is reached. This is often recognized by lamp cycling. A cold lamp has a lower re-ignition peak so it will operate untill warm up. After the lamp extinguished the process starts all over again.

5. Product Quality

5.1. Quality specifications

Attached are the quality and safety requirements which are used in the company as a reference and a tool to evaluate whether the products are conform to the customers expectations. All possible defects are classified in the following way:

a) Visual defects

* Critical defects:	- safety
AQL 0	- commercial conflicts
* Vital defects:	- inoperative products
AQL 0.4	- useless products
* Major defects:	- reduction of performance
AQL 1.5	- severe appearance defects
* Minot defects:	- cosmetic defects
AQL 4.0	

b) Qualitative defects

* Dimensions
* Electrical and Photometrical characteristics
* Life
* Strength: base torque

In this internal SLI document the international standards (IEC) requirements are incorporated.

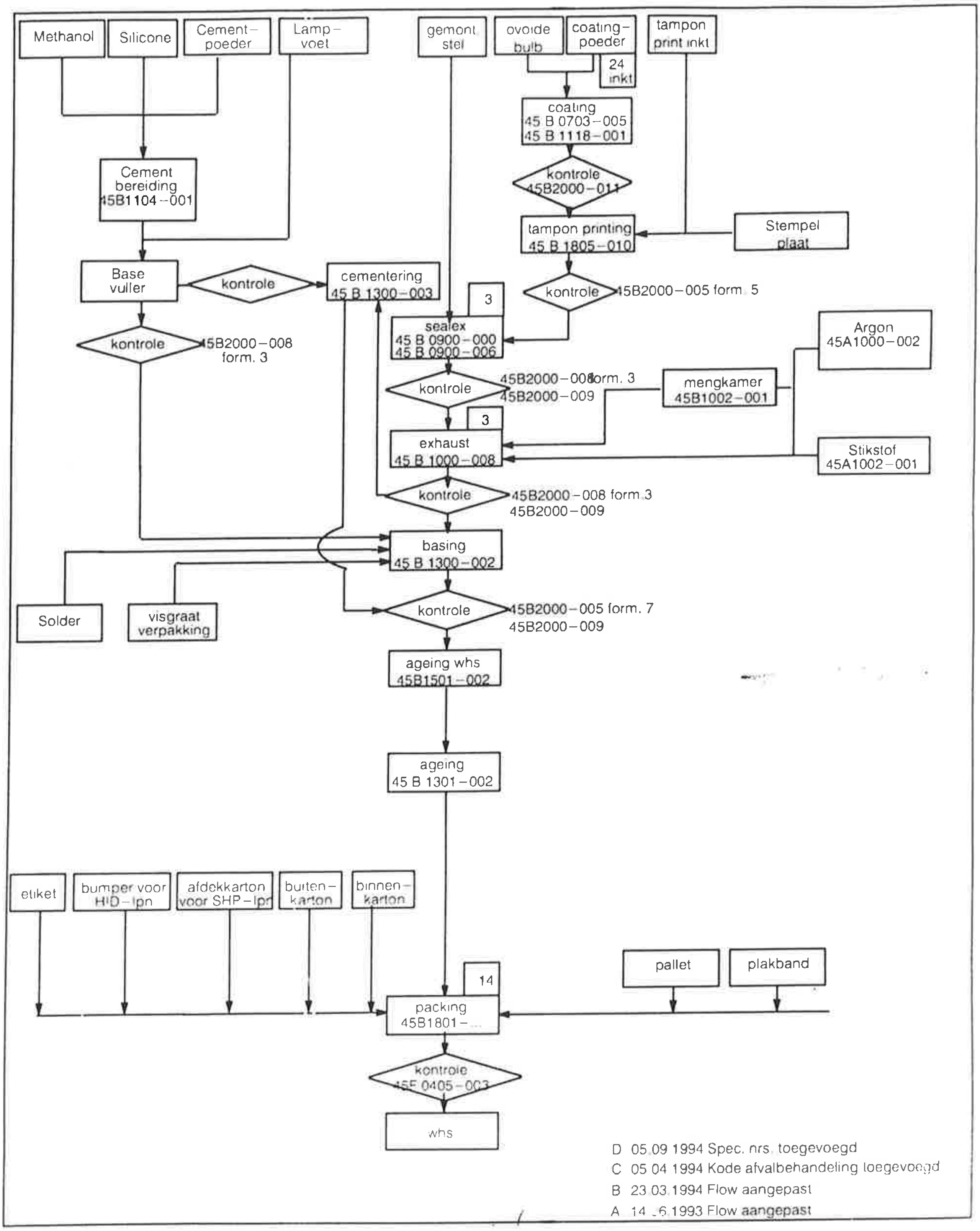
IEC 188	:	Mercury Lamps
IEC 662	:	High Pressure Sodium Lamps
IEC 1167	:	Metalhalide Lamps

5.2. Quality and process inspection

The strategy in quality management should always be preventive instead of corrective. In other words possible problems should be avoided in the first place. This is of course achieved by a lot of factors like (ref. 4 M model):

Men
Machines
Methods
Materials

Quality inspections should also be done in the earliest phase of the process. Below a process flow sheet with the various checkpoints is shown:


Methanol
Silicone
Cement-poeder
Lamp-voet
gemont. stel
ovoide bulb
coating-poeder
24 inkt
tampon print inkt
coating 45 B 0703-005 45 B 1118-001
kontrole 45B2000-011
tampon printing 45 B 1805-010
Stempel plaat
Cement bereiding 45B1104-001
Base vuller
kontrole
cementering 45 B 1300-003
kontrole 45B2000-005 form. 5
3
sealex 45 B 0900-000 45 B 0900-006
kontrole 45B2000-008 form. 3
Argon 45A1000-002
kontrole 45B2000-008 form. 3 45B2000-009
mengkamer 45B1002-001
3
exhaust 45 B 1000-008
Stikstof 45A1002-001
kontrole 45B2000-008 form.3 45B2000-009
basing 45 B 1300-002
Solder
visgraat verpakking
kontrole 45B2000-005 form. 7 45B2000-009
ageing whs 45B1501-002
ageing 45 B 1301-002
etiket
bumper voor HID-lpn
afdekkarton voor SHP-lpn
buiten-karton
binnen-karton
pallet
plakband
14
packing 45B1801-...
kontrole 45E 0405-003
whs
D 05.09.1994 Spec. nrs. toegevoegd
C 05.04.1994 Kode afvalbehandeling toegevoegd
B 23.03.1994 Flow aangepast
A 14.06.1993 Flow aangepast

5.3. Quality complaints

In attachment the revised quality complaint procedure can be found. It includes the forms, responsibilities and a practical guide on the information flow.

5.4. Information on lamp life:

5.4.1. *Definition of terms*:

To define and quantify lamp life, various terms are being used, which are explained below:

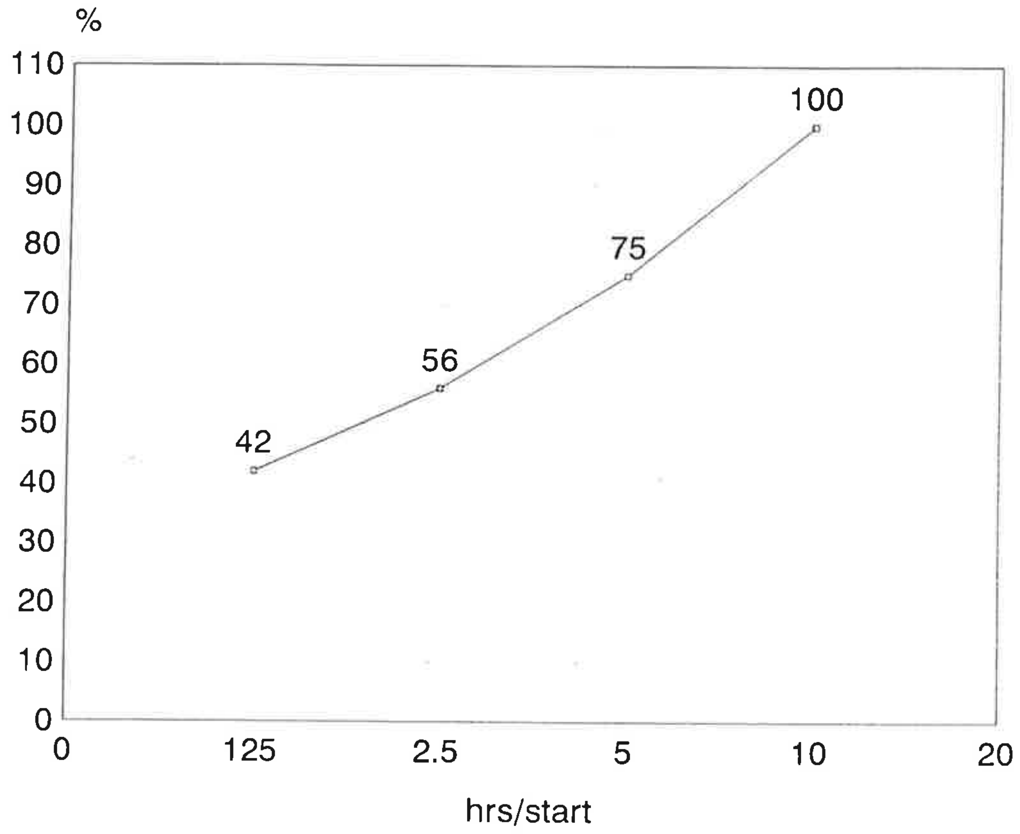
- **Lamp life** is the time period during which an individual lamp is functional, or the time period after which a percentage x of a group of not less than 50 lamps having the same product code is still functional.
- **Average Lamp Life** refers to a group of lamps with the same wattage, voltage and construction. It is the time period after which 50 % of the lamps belonging to a group have failed. The minimum number of lamps per group should not be less than 10.
- **Individual Life** is the burning period of an individual lamp.
- **Survival Rate** is the percentage of lamps from one group which have survived a specific time period.
- **Service Life** refers to a group of lamps. It defines the burning period after which the % luminous flux multiplied with the % surviving lamps of an installation has decreased to 70 %.

The service life determines the group replacement period for an installation.

5.4.2. *The effect of switching on lamp life*

Due to the fact that during start up of a discharge lamp the load on the electrodes is the highest, the average iife is depending on the switching cycle frequency. Although the data below can not be used as 100 % exact information, because it is too general, it provides an idea about the life dependence of a discharge lamp.

On the Y-axis the average rated life in % is indicated.
On the X-axis we can find the number of operating hours between 2 starts.



When discharge lamps are operated continuously the effect on lamp life is minimal. However in these conditions Sylvania recommends to use thermal protected ballasts. In case of non protected metalhalide lamps it is recommended to switch off the lamps at least once a week.