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Electric light in historic interiors

Rob van Beek | Wout van Bommel | Henk van der Geest

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The Government Buildings Agency

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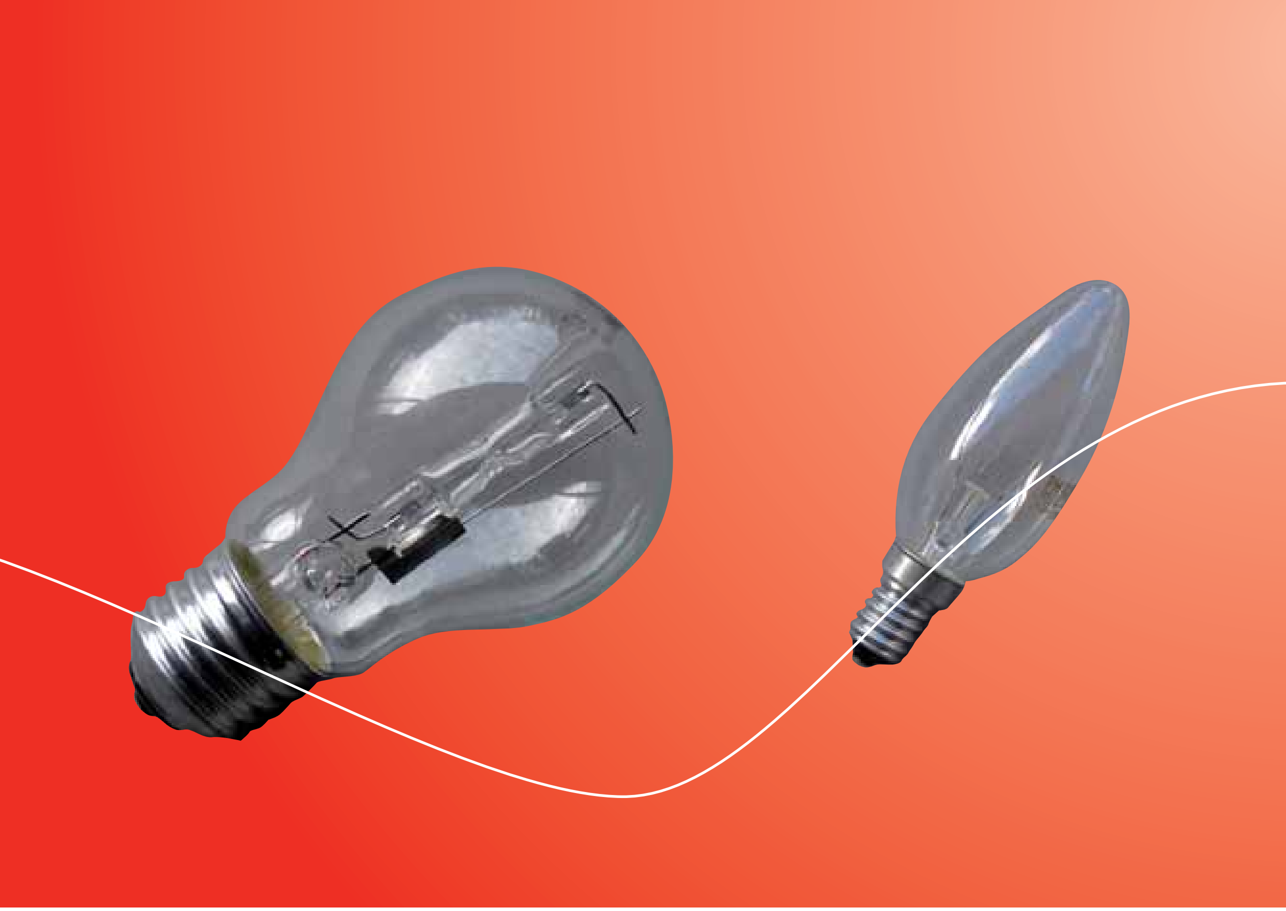
Foreword

To avoid having to depend on a limited number of daylight hours per day people have always sought ways to create their own sources of light. By way of torches, oil lamps, candles and petroleum lamps this quest led to the development of professional artificial lighting as recently as the early 19th century. After gas lighting and electric arc lighting, the development of the incandescent lamp in 1879 effectively signified a major step forward.

The incandescent lamp has been tremendously important to interior lighting for over 130 years but that is now coming to an end. The ban on the production of incandescent lamps has compelled us to start using other sources of light. Alternatives do indeed exist but are not suitable in all cases. A historic interior, for instance, requires specific lighting.

The Government Buildings Agency owns a large number of monuments. When the use of incandescent lamps in these buildings is inevitably phased out, alternatives must be available. This publication reflects the results of research and many years of experience. It offers insight into current possibilities and shows the available options, serving to guide all those engaged in the maintenance, operation or occupancy of historic buildings in their choice of new forms of lighting.

This publication simultaneously addresses the manufacturers of light sources. Our findings clarify which specific properties light sources require in order to ensure optimum use in historic interiors.



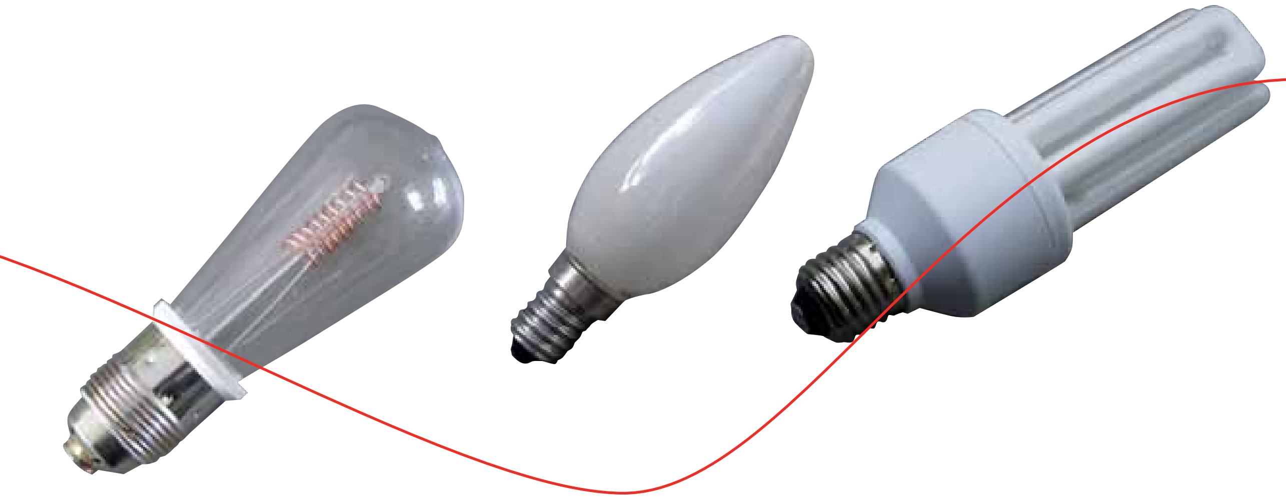
1. The end is near

The incandescent lamp has had its day. As a result of new European regulations, in a few years' time incandescent lamps will no longer be sold for household use. The gradual abolition of incandescent lamps began in 2009. Most standard incandescent lamps are already no longer available and the last lamp scheduled to disappear in 2016 is the halogen lamp.

Even though incandescent lamps do emit a warm and pleasant light, render perfect colour and are inexpensive on top of that, they must go neverthe-less. This is mainly because of their inefficiency. Comparatively speaking, an incandescent lamp consumes a great deal of energy but produces very little light in return. Over 90% of the energy is transformed into heat. Moreover, incandescent lamps have a relatively short life, and burn out after 1000 to 1200 hours of operation. Other sources of light achieve better performance in that area. For these reasons, incandescent lamps are hardly ever used in offices. Fluorescent tubes and low-energy lamps, which are known as fluorescent light sources, have formed a better alternative for many years now.

Monuments

Today incandescent lamps can also hardly be found in the buildings owned by the Government Buildings Agency any longer. Monuments form an exception. Monumental buildings often feature historic, and in some cases authentic light fittings, using incandescent lamps as the source of light. These light fittings are historically valuable, they form an intrinsic part of the Interior and their illumination is indispensable to the character of that particular room.
There are alternatives to incandescent lamps. Low-energy lamps have already been around for some time, LED lamps arrived later. The fittings of these alternatives fit into incandescent light fittings. But other issues also come into play.
The question is warranted as to whether, from a technical lighting and design perspective, these lamps are suited to specific use in monuments The halogen lamp has currently proven to be the best



alternative to the classic incandescent lamp but the halogen lamp too is an incandescent lamp and is scheduled for extinction on account of the same relatively low light output. While the light output of a halogen lamp indeed scores one and a half times better than that of the classic incandescent lamp, there is room for improvement, as LED and low-energy lamps have proven.

It has emerged from day-to-day practice that professional users have been working on replacing incandescent lamps with low-energy or halogen lamps in monuments for many years. This often is prompted by technical and maintenance reasons: other light sources do not need to be replaced as often as the standard bulb. The changeover sometimes stems from the desire for more light. While light output is higher compared to the incandescent lamp, a loss of light quality still applies to the low-energy and LED lamps currently available on the market. This will continue to be the case. The colour rendering of an incandescent lamp can never be matched by low-energy and LED lamps.

Emergence of LED lighting

The extinction of incandescent lamps and the emergence of LED lighting provide good reasons for conducting research into lighting in historic buildings. With knowledge of the current situation, it is possible to correct any errors made in the past and to apply new techniques.

There may be different reasons for changing an existing lighting system and implementing a new lighting plan. The abolition of incandescent lamps may be among these reasons. However, people may also be unhappy with the current lighting, or the function of a room may change, which will require adjusted lighting. A good schedule of requirements undoubtedly is essential if a new lighting plan is needed. The plan should clearly define the technical lighting requirements but the specific features of the relevant monumental Interior are equally important. Understanding these two issues is indispensable if a good final result is to be achieved.

In practice 1: Chandeliers in the Royal Palace on Dam Square, Amsterdam

All the chandeliers restored in the Royal Palace on Dam Square gained new halogen candle lighting. The lighting was advanced based on the experience gained at Paleis Het Loo. However, a problem was encountered with the vertical lighting which reduced visibility of the table below. The light was largely directed upward. A light fitting was therefore designed for two chandeliers. The fitting was trialled by suspending it to the frame of the chandelier and adding halogen lamps that cast light downward. These lights now shine downward, through the layer of crystal. The circular fitting is an inconspicuous added feature that renders the desired effect. Moreover, the complete light fitting is reversible because it is fastened to the chandelier without using any permanent connections. This solution marries the aesthetical aspects with the practical aspects without diminishing the historical value..

2. The use of artificial lighting

2.1 Artificial lighting in a monumental environment

The Government Buildings Agency owns some 360 monuments, which cover a total floor area of one million square metres. These monuments have a wide range of uses, but they can be broken down into three categories.

- Monuments, the use of which in principle is unrelated to their monument status. Upon completion, these buildings were often used as law courts, prisons or offices and at one time gained monument status based on their cultural and architectural value.
- Buildings the beauty of which also determines their current use. These buildings are used as representative accommodation by various ministries. Or, palaces and castles, for instance, used for hosting receptions and banquets.
- Monuments that primarily function as a museum. Such buildings have been preserved because of their immense architectural and historical value to ensure that they are conserved in the best possible condition, also for future generations. The building and its interior collectively form the collection.

Workplace lighting

The first category of monuments, which for instance serve as office accommodation, a law court or prison, require facilities that all too readily conflict with the historical value of the Interior. The statutory requirements imposed on a building also affect the lighting. The workplace lighting of an office space in a monument cannot be installed in the same way as in a contemporary building designed as an office. This therefore calls for a custom solution.

Before the advent of the incandescent lamp, by today's standards countless people were more or less enveloped in darkness. However, the requirements imposed on workspace lighting have also become more stringent over the course of the years. A value of 500 lux now applies to normal

Workplace lighting
An office dating from around1930. Fortunately, the space has enough windows to allow daylight to enter. The light fittings were unable to replace daylight if there was a lack of daylight. The spacing between each of the light fittings is such that the level of artificial lighting provided would not exceed the level of dimmed light.

Photograph made available by the Early Office Museum (Officemuseum.com).

office workspaces, which can be achieved in a standard 20m2 office with four 32-watt fluorescent tubes. Eighteen incandescent lamps are required to achieve the same level of lighting with 75-watt incandescent lamps. Before the advent of fluorescent tubes, in practice no more than four lamps were hung in the room: the level of lighting was a factor of 5 lower than is usual today. The lighting level is most likely to have been even lower because the light output from the current light fittings is far higher than in those days.

Specific requirements

Monuments with a highly representative function, such as palaces, form the next category. People live, work and sleep in palaces. Guests, among them dignitaries, occasionally stay there overnight. Meetings, receptions, banquets and parties are hosted requiring facilities such as catering and security.

All the various additional functions involve specific lighting requirements. When hosting representative functions, the room is arranged in the style of the period characteristic of the property. The permanent interior features still remain intact.
The furnishings of a monument are modernised less frequently today. A historicised alteration or renovation of historic features and qualities are more common. Each style of interior has a particular form of corresponding lighting. Light fittings must match the furniture, wall decorations and ceilings and floor finishing. On occasion non-electrified chandeliers, so those using candles, were hung from the ceiling. Yet these were unlikely to burn every evening. In such cases, a room was usually illuminated using temporary, flexible lighting, such as standard lamps.
Incidentally, the light fittings of such chandeliers would often have already been converted; this was a regular occurrence a century ago, when incandescent lamps - and power supply - had meanwhile become commonplace.

The Argand lamp

User friendly

The use and reuse of a monument requires analysis: what facilities are needed if a monument has a representative function, and what facilities should be user friendly, where applicable?

If more demands are made than solely the requirement for a historic ambience, the question is whether this is feasible with the original lighting. When using a monument as a residence, temporary accommodation, pied-à-terre or for offering accommodation to dignitaries, we impose greater demands on our environment and the way it is furnished. In a residential environment, lighting is required not only to aid reading but also to evoke a pleasant atmosphere. The interior must enable people to stay there in comfort and feel at home whether their visit be temporary or for a longer period of time. Both sanitary and kitchen facilities must satisfy the current levels of comfort and hygiene standards, while perhaps also maintaining the original, historical details. The lighting required for these functions should be adequate and installed in compliance with the prevailing standards.

Original situation

The third category of monuments, which function as a museological object in their own right, perhaps form the easiest group when it comes to lighting. In many cases, the illumination in these spaces emulates that of the original situation, possibly with electrified chandeliers and candelabra. The functional lighting requirements arising from the use of the room as a workplace do not apply in this case. Often the sought-after result is achieved in selecting a light source with the properties matching the original situation as closely as possible. Incidentally, in many cases this will mean a low level of lighting. This will indeed provide an accurate rendering of lighting in those days, but begs the question as to whether people were satisfied with this type of light in those days. Poor lighting was not a conscious choice but was created by the restric-

tions of the available light sources. People were used to it and did not know any better.

2.2 Artificial lighting in buildings throughout the years

Daylight provides perfect light but is only available for a limited part of the day. In the winter additional light certainly is required for a considerable number of hours per day. That need has grown strongly throughout the years. Industrialisation entailed that we increasingly began to work indoors. Artificial light enabled the standardisation of working hours - not only in factories but also in offices and at schools.

In their quest for artificial light our ancestors survived with all manner of aids, varying from torches and candles to oil and gas lamps. All of these sources of light offer a very limited amount of very local light. The advent of the electric arch lamp was a breakthrough. While the arch lamp emitted ample light, it also had its disadvantages. It was an extremely expensive form of lighting, the intensity of which was too bright for a home and the maintenance of these lamps was a complicated affair. For that reason the arc lamp was only used in public buildings. During the same period gas lamps proved to be a good alternative for homes.

Open fire

The first form of artificial light was open fire. Aside from the warmth generated by open fire, it also offered some light. However, it is a light source that is not easy to handle. Burning branches and torches, possibly immersed in inflammable substances, were more practical. The oil lamp was used all over the world from the fourth century BC with different kinds of oil used as fuel. The oil used was dependent on availability as well as price. Cheap oil emits fumes and smells, while expensive oil does so to a lesser degree. Candles long formed a main source of light but the amount of light emitted by one single candle was very limited: around 12 lumens, barely enough for reading.

Chandelier in the Royal Palace on Dam Square, Amsterdam
The chandelier was originally designed for candles but in 2009 was adapted for electric candles. The alteration was made without damaging the fitting, so without drilling any holes. The wiring runs along the outside of the fitting and is visible, in principle. The conversion of such light fittings must be performed meticulously and is a specialist domain.

A candle placed on a table right next to a book will produce a light level of around 6-7 lux on that book. The price was an added problem. Three hundred years ago candles were expensive, and having one single candle in a room was a luxury in itself for the average person.

The Argand lamp was invented in 1783, an oil lamp which, compared to the traditional oil lamp, achieves better burning performance when oxygen is added to the wick of the lamp. This produces quiet, even light.

The year 1800 marked the advent of the gaslight. From the end of the 19th century gas lamps with an incandescent mantle gradually superseded candle and gas lamp lighting.

In order to use the limited amount of light as efficiently as possible, candelabra and oil and gas lamp fittings gained mirrors and crystals. Mirrors transmit light to the desired location while crystals enable a single flame to replicate itself in these crystals as it were. This type of lighting was common until the end of the 19th century.

Edison then invented the incandescent lamp in 1879, and gas lamps were supplanted by the electric light.

Affordable artificial light

The incandescent lamp represented a major advancement, paving the way for reliable, safe, high-quality and affordable artificial light. While the light output produced by the first incandescent lamps was indeed little more than that of a good gas burner, they did in fact have tremendous advantages. The risk of explosion was small, and these new lamps did not produce smoke or poisonous gases. Compared with the lighting that had been used to date, they also scored highly on user friendliness. Electric lamps could easily be turned off at a distance with a switch. The electric light moreover underwent rapid qualitative development. Edison lamps used around 1885 emitted a luminous flux of around 100 lumens; a decade later this had already more than doubled. The light output of this carbon filament lamp rose in the same period from 3 to 7 lumens per watt. The first buildings in the Netherlands gained electric light around 1890 but it would take until after World War One before the incandescent lamp was used as a standard light source in homes. The fact that the changeover took over 25 years is attributable to the facilities required for electric light. Aside from incandescent lamps, an electric power plant was also needed. The electricity grid was very limited in those days and had to be expanded. This was first carried out in the cities, followed later by the rural areas. Some buildings had already acquired electric light in the early years despite the absence of an electricity grid. Power was generated locally with the aid of a generator.

No standard products

There are numerous pre-1890 monuments. Electric light therefore was often added to these buildings at a later date. Electric light fittings dating from the early years of electric light were often specially designed for the relevant building, particularly for prestigious buildings. There were no standard products as yet; a ‘lighting industry’ had yet to evolve.

In the early years, it was common practice to convert the light fittings that were present in the existing buildings. Gas or candle light fittings gained wiring and suitable fittings and could thus instantly accommodate the new type of light, the incandescent lamp. Incidentally, 130 years after the advent of the incandescent lamp, conversion still continues today. A number of the original candle light chandeliers in the Royal Palace Amsterdam, for example, recently gained new electric candle lighting. In a number of cases, this was because the light fittings had already been electrified on a previous occasion but the technique used no longer satisfied the more stringent technical or safety requirements. There are cases in which single-insulated cord was used at that time but today double insulation is required for 230V systems. Occasionally, feed-through protection also proved to be absent in places where a cord was fed through a metal component.

In the early years of electric light the aesthetic quality of a fitting took precedence over the technical aspects of lighting. Antique chandeliers are generally richly embellished. The points of light were often nothing more than standard light bulbs screwed into the light fittings without any protective covering. Artists created the designs of light fittings; the profession of lighting designer was unknown at that time. From a technical lighting point of view this did not present a major problem. The incandescent lamps dating from the early years were carbon filament lamps with low brightness. Even when used without a protective covering, these lamps do not glare if you look directly at the lamp. The development of the incandescent lamp meant that light output would indeed increase over the course of the years, but would later be associated with the risk of glare.

Tungsten filament

Introduced in incandescent lamps at around 1912 tungsten filament signified a major leap forward for light output. Tungsten lamps are still available today. They produce three to four times as much light as a carbon filament bulb and feature a more compact spiral filament. However, this meant that without appropriate covering they produce glare. Particularly the more compact spiral filament is relevant in this context: the total amount of light is emitted through a small surface with very high brightness. The light emitted by a carbon filament lamp, which was common until that period, was produced by a much longer incandescent filament.

The use of tungsten was important in designing light fittings in such a way that they would not produce glare. The light sources thus gained a protective covering and light was directed to the desired location through reflectors, diffusers and other optical devices. To avoid looking directly at the incandescent filament in open lamps, matt glass was used for incandescent bulbs. However, carbon filament lamps feature transparent glass. Such bright, low-power incandescent lamps are still in vogue: their distinct sparkle evokes a convivial atmosphere.

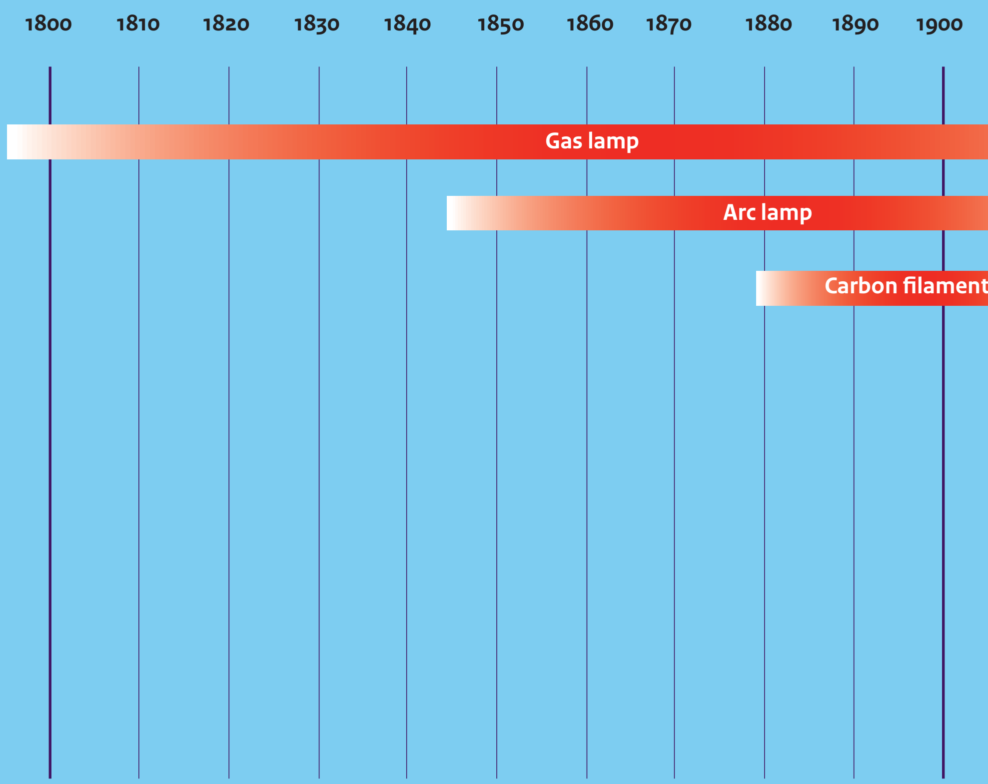
Crystal chandeliers

Light fittings are designed for specific light sources. Not only does this apply to the incandescent lamp but also to its predecessors: candle, gas and oil lamps. The look of an antique light fitting is determined by light but always in combination with the materials used. The reflection of that light on the material creates a total image. Bright light glitters in a crystal chandelier making the crystals sparkle like miniature sources of light.

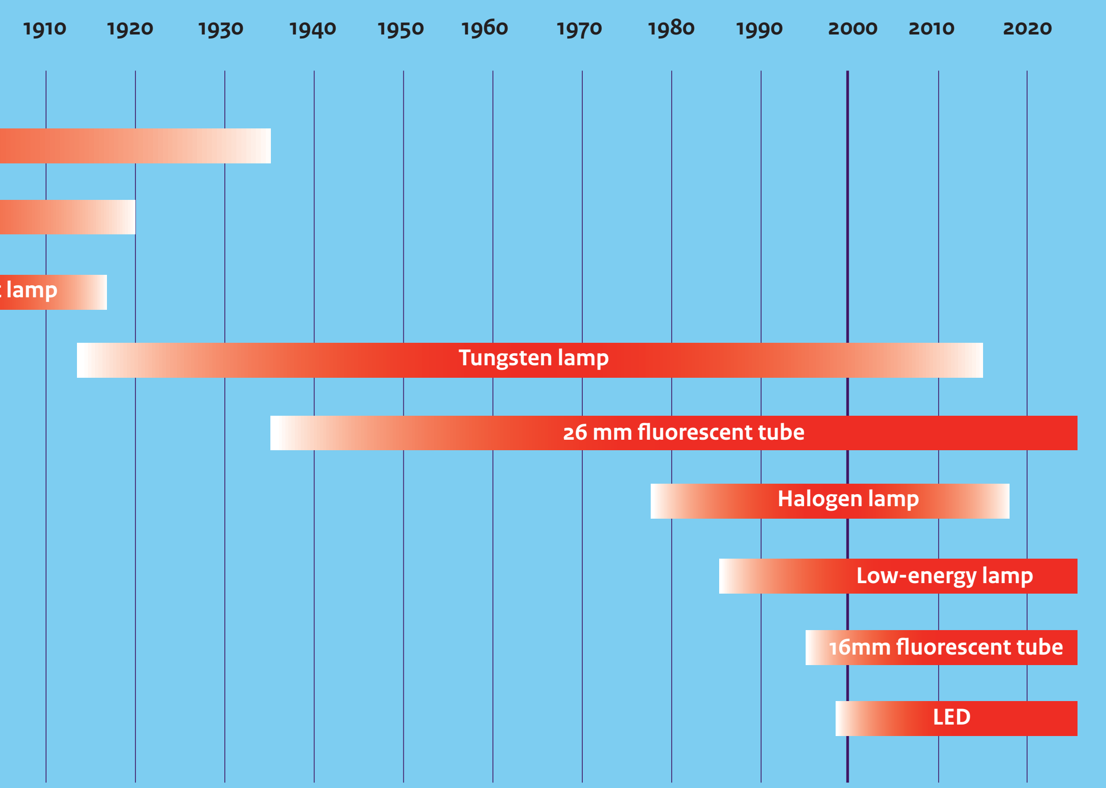
Aesthetics

It would take some time before light fittings could derive full advantage from the new light sources in terms of functionality and aesthetics.

This applied to the incandescent lamp in those days. Today, this applies to low-energy as well as LED lamps. In the early years of the incandescent lamp, light fitting designers reverted to existing and familiar designs. Even though the incandescent lamp already offered designers great freedom in installing light sources, it would take some time before they discovered these possibilities and actually began to take advantage of them. In both gas and candle light fittings, the flame was always an important, restrictive and thus determining factor for the design of the light fitting. The light source had to be placed in a vertical position facing upward, while the heat emitted by the flame had to be taken into account. This was no longer required for the incandescent lamp. Pear-shaped light bulbs can burn in any direction. It took some time for designers to fully comprehend this.



Architects of prestigious and talked-about buildings were eager to engage renowned artists to design suitable furniture and lighting for their buildings. During the period when the electrification of light began making inroads, artists initially routinely chose designs that partially recalled the historical use of light. The new opportunities offered by electrification, however, were soon utilised to the full. It represented a tremendous boost to aesthetics and design. Since traditional craftsmanship primarily applied at that time, countless specially designed light fittings dating from the early years of new lighting are unique models. These light fittings are of immense beauty, high quality, and high historical value.



1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
lamp
Tungsten lamp
26 mm fluorescent tube
Halogen lamp
Low-energy lamp
16mm fluorescent tube
LED

Stairwell in the NIOD Institute for War, Holocaust and Genocide Studies
During the restoration of Herengracht 380 in Amsterdam in 1997 halogen spotlights were installed in the stairwell. These cast direct light, creating large local areas of brightness (light spots) on walls and ceilings. These halogen spotlights only came into vogue in the eighties. Originally the space would have been more evenly illuminated. By replacing the halogen light fittings with those emitting multi-directional light, the even distribution of light has been restored. A replica of a lamp designed by W. Wissmann was chosen. The lamp dates from 1921 and is fitted with a LED lamp.

In practice 2: Herengracht 380, Amsterdam

Herengracht 380 was built between 1888 and 1890 for the wealthy tobacco grower Jan Nienhuys. The property was designed by the architect Abraham Salm, and was one of the first buildings in Amsterdam to use electric light. Since there was no electricity grid at that time, energy was generated locally by a generator in the back garden.

The original lighting consisted of chandeliers and wall fittings, designed specifically for incandescent lamps. The majority of the original light fittings still existed but at around 2007 it was apparent that they were in need of a serious overhaul. The light fittings were in such poor technical condition that they were designated a fire hazard.

In addition to the original lighting still existing in the building, while the property was undergoing major restoration in 1997 a considerable amount of 'new light' was added, primarily to the monumental stairwell. The choice for these new halogen light fittings was later found to be less fortunate in terms of their look and lighting effect. The property had originally been built as a home and now houses the NIOD Institute for War, Holocaust and Genocide Studies. The building offers office and meeting rooms. These spaces were originally illuminated by chandeliers, supplemented with wall fittings. The light provided by these fittings housing the incandescent lamps, for which they were designed, was far below the level required for office work. The user endeavoured to increase the level of light by using low-energy as well as halogen lamps in the existing light fittings

NIOD light fitting
During the design phase of the new office space lighting it was clear that additional light would be needed once the historic chandeliers had been restored. The value of the monument dictated that the lighting used should preferably be unattached to the building. In other words, nothing in fact was allowed to be mounted to the ceilings or walls. It was decided to develop a light fitting that could be placed close to the wall, a hybrid lamp combining a wall lamp with a floor lamp. The fitting is powered by a cord that runs along the skirting board and is furthermore fastened to the wall with a small, single steel wire. These light fittings provide general lighting together with the restored chandelier. Floor lamps have been added to the workspace and serve as supplementary workplace lighting.

but these lights created glare. The brightness of the light sources visible in the light fittings was too high. Standard lamps were also added to the office spaces. Energy saving lamps were used to light the traffic spaces, mainly the stairway. Aside from higher light output, long life formed a key aspect. The light sources are situated in places that are difficult to reach and replacement costs are high as a result.

In 2008 the Government Buildings Agency undertook to seek a solution for the various lighting problems, a project in which the National Cultural Heritage Agency (RCE) was also involved. The first aim was to rectify the unsafe situation and the second to create a total lighting plan for the building, and restore the technical features and materials used in the original light fittings.

It was elected to restore the chandeliers and wall lamps to their former condition as far as possible, including the accompanying low level of light. The question arose as to which light sources should be used. An alternative had to be found for the original carbon filament lamps which were no longer available. In the period in which this took place no suitable alternative light sources were available, according to the project team. The only solution was to develop a lamp ourselves. This led to the creation of a clear glass LED-based ‘balloon’ lamp. The glass was blown in the shape of 19th-century incandescent lamps. This shape was traced back to literature and old photographs of the property. A double, vertical rod-shaped LED with a colour temperature of 2700K was placed

NIOD LED ‘carbon filament lamp’
The LED lamp designed for Herengracht 380 in Amsterdam. The light fittings in the building date from 1890 and were originally designed for the Edison lamp. These light sources are distinctly recognisable in old photographs. We endeavoured to emulate the light emitted by the carbon filament lamp as closely as possible using the latest techniques.

inside the glass ball. The dim level of the LEDs was reduced to the level matching that of the original carbon filament lamp. A spiral copper wire was coiled around the LEDs. Using this light source, the original light fittings closely emulate the level of illumination they produced 120 years ago. In all fairness, we must admit that while the design of the lamp and lighting level thus closely resemble the original lamps, this does not apply to colour rendering and colour temperature.
In order to achieve the desired functional lighting level in the various rooms - this had proven unfeasible with the existing light fittings - further light fittings needed to be installed. A situation had to be created enabling office work to be performed in compliance with the relevant applicable statutory requirements.

A prototype of the NIOD lamp in its setting

3. Light and light sources

3.1 What is light

Scientists not only define light as electromagnetic radiation that has a wavelength from 380 to about 780 nm, but also as a particle, the photon (Max Planck, German physicist, 1899). We see this radiation the moment it is reflected through a material or a substance causing our eyes to react. The human eye sends the stimuli it receives to the brain which, in turn, interprets these. This process is called visual perception. This information triggers us to act. Vision has a visual as well as a neurological aspect. It provides direction to our daily life.

Rainbow

An analysis of white light shows that it is made up of all colours of the rainbow. This is the full light spectrum. The human eye sees coloured light by not transmitting all colours of the light spectrum; we can block specific colours. The colour removed is complementary to the colour we are able to see. A red filter removes all blue and green colours from white light. Everything it exposes is red. Colour theory is based on three primary colours, which, in turn, collectively form the colour white: red, blue and green. Colour television uses these three primary colours, and we indeed perceive all colours through these. The colours may vary in reality but our brain corrects general errors. We adapt our perception to the prevailing light situation.

Daylight is cooler (bluer) than the light emitted by an incandescent lamp, yet we perceive colours 'naturally' through our own white balance in both cases. All colours in the colour spectrum are represented in white light, albeit in varying proportions. We regard daylight as the most beautiful light, even though it is usually perceived as self-evident. It is ideally suited to sight and perception due to the even and regular distribution of the colour spectrum. If there is no daylight, we appreciate warm artificial light more than bright, cool artificial light.

Daylight is caused by the sun's glow and all atmospheric conditions the sun encounters on its orbit. Our visual system was designed to see that light from prehistoric times. We attempt to replicate it but have not yet been entirely successful: something is always missing.

Biological clock

Light is a biological necessity and is indispensable to every form of life. The change of seasons may determine our outlook on life. There are people that react violently, such as those suffering from a winter depression. Our body clock has a cycle of approximately 24.5 hours. A sufficient dose of light/daylight synchronises our body clock with the 24-hour rhythm of nature. Without sufficient light - so, without synchronisation - the rhythm of man and nature will start to diverge widely day by day. This will lead to jetlag-type complaints. Only in 2002 was it discovered that our eyes have an extra receptor that is particularly sensitive to light around 460 nm. This is light with blue characteristics. The production and breakdown of the hormones melatonin (the hormone of sleep) and cortisol (the hormone that leads to the release of energy) which determine our sleeping and waking pattern, depend on blue light.

3.2 Experiencing light

Light forms an important part of what is termed as the experience industry or experience architecture. Light can induce people to be alert and active and make them feel good. It creates atmosphere and conviviality. But if light is poor, it may have a harmful effect. Light has a tremendous effect on people and this includes experiencing colour. Just as the colour of an interior has a psychological effect on people, so too has the colour of light. Light is made up of colour. We often immediately think of colour as bright, saturated colours but the subtle nuances in particular can create a major and unexpected effect. Their impact is huge, because we often only subconsciously perceive these subtle nuances.

Architecture

With the advent of technical means, which easily enabled coloured light to be incorporated in architecture and indoors, this means was regularly (and sometimes simplistically) used to create atmosphere. While on occasion the effects were colourful, they were highly appealing at informal gatherings. This was quite acceptable for festivities, music and other unofficial occasions. This is not what we usually want to use for daily life at home, and we mainly need white light for work as well.

White light in energy-efficient light sources is made up of a combination of colours known as a discontinuous spectrum. It looks like white light but the effect is achieved synthetically. Our brain perceives it as white. The outcome may be that not all colours in the environment are accurately reflected through it. This is not an issue if that light is used as additional lighting if daylight is also present. It is a bigger problem in the evening.

As discussed earlier daylight has a higher share of blue than incandescent lamps, which contain more red. When daylight has disappeared, in our culture we appreciate the warm light of an incandescent lamp more. We enjoy lighting candles, which have an even warmer colour than incandescent lamps. If incandescent lamps, with their colour temperature of 2700K, are dimmed, the colour of light resembles that of candlelight. Candles have a colour temperature of around 1900K. From a biological perspective, this is a correct value. It is important to our biorhythm. The warm light does not affect the production of the energy hormone, cortisol, but more melatonin is actually produced causing sleepiness.

Daylight, incandescent lamps and candles have a continuous spectrum in common; they radiate all colours, but their proportions are slightly different. This does not apply to low-energy lamps and other gas-discharge lamps.

Distinct views

Countless people hold distinct views about low-energy lamps and LED lights. They either love them or hate them. The environment where the lighting is used also plays a role. Fluorescent lighting is generally accepted in offices but not in a residential environment. When purely looking at the experience and not at the underlying aspects, such as energy consumption, people experience halogen and incandescent lighting as pleasant light. This does not apply to low-energy lamps and LED lights, which are also referred to as synthetic lighting. Many people experience this type of light as ‘awful’. When actually taking the energy aspect into account, some people suddenly find the incandescent lamp dreadful. These aspects relate to experience and perception. In further developing low-energy and LED lamps, there clearly is room for improvement in this area. It was found that people appreciate incandescent light, including the halogen light, more in their daily environment when daylight has ended - when seeking peace and quiet, or when socialising and having a good time, enjoying food and wine. This particular lighting makes a positive contribution to how people feel and behave. A cosy pub, with incandescent lighting and candles will soon be void of clientele once the fluorescent lights are turned on.

3.3 Definition and quality aspects of daylight and artificial light

This section defines and explains the key qualities of the various types of light and light sources. The quality aspects of the various light sources are subsequently quantified in section 3.4.

3.3.1 Quantity of light

Depending on the weather conditions and season, the amount of daylight on a horizontal surface in an open field outdoors varies between 100,000 and 3000 lux. The percentage of daylight that contributes to the horizontal luminous intensity on the working surface in buildings through windows (known as the daylight factor) depends on the geometry and orientation (NSEW), as well as the location of the windows and depth of the room. Assuming that this factor is still achieved for up to 80% of the horizontal surface in the building, a typical example of the daylight factor for a home is around 1.5%. That percentage is between 2-5% for offices, which generally have larger window surfaces. The required average horizontal lighting intensity in buildings is 500 lux for normal office work. Artificial lighting clearly needs to supplement the daylight that enters large sections of buildings for a part of the day, and in winter for a larger part of the day. Depending on their wattage, the various light sources produce different levels of light output. The light output, officially referred to as luminous flux, is expressed in lumens. Here is an example: a 75-watt light bulb has a luminous flux of around 900 lumens, while a thin, 50-watt fluorescent lamp (fluorescent tube) has around 5000 lumens. The availability of the range of luminous flux differs per lamp type. Incandescent lamps, for instance, are only available in a lower luminous flux while fluorescent lamps (and incidentally, other gas-discharge lamps in particular) are available in a higher luminous flux.

3.3.2 Luminous efficacy

The luminous efficacy of a light source is determined by the light output in relation to the required energy: lumen/watt (lm/W). The official name for this term is 'specific luminous flux'. The incandescent lamp above has a luminous efficacy of 900/75 lm/W. The fluorescent lamp is slightly more complex because the required ballast device (see also section 3.3.10) also consumes energy. This energy consumption is published in the manufacturer's literature, and therefore is known. The fluorescent lamp above has a luminous efficacy of around 95 lm/W. Smaller versions (with a lower wattage) of the same type of lamp usually have a lower luminous efficacy. For instance, the luminous efficacy of a 25-watt light bulb does not have 12 lm/W but around 8 lm/W while a thin 16-watt fluorescent lamp has around 85 lm/W instead of 95 lm/W.

3.3.3 Average life

The average life of the various light sources varies widely. Incandescent lamps and halogen lamps have a shorter average life. LED lamps, at the other end of the spectrum, have an extremely long average life. The term commonly used is 'economic life'. This is the life after which it is wise to replace all lamps for economic reasons. This applies to the actual life of incandescent lamps and halogen lamps (so 'when the lamp burns out'), while in the case of gas-discharge lamps and solid state p-n junction devices, this could be when the lamp no longer provides adequate light or when it is expected to be too expensive to replace each individual lamp because of the rapid increase in failures.

3.3.4 Colour appearance of light

Different types of light produce a different colour appearance. Actual coloured light is accurately characterised by the name of the colour itself, such as red, green, yellow or blue light. Yet there are also different hues of white light and these are more difficult to characterise. White light containing a relatively large amount of red is called 'warm white light' (examples are candles and incandescent lamps), and white light containing a relatively large amount of blue is called 'cool white light' or 'daylight' (such as a number of fluorescent lamps). A more accurate characterisation of the hue of white light produces the 'correlated colour temperature', Tk measured in Kelvin. Warm white light has a relatively low colour temperature while cool white light has a high colour temperature. Colour temperature can be determined accurately by measurements or calculations based on the spectrum published by the manufacturer. Here is an example: the colour temperature of daylight may vary between around 4000 to 20,000K, an incandescent lamp produces light of around 2700K, halogen lamps 3000K to 3200K and fluorescent lamps are available in the range of 2700K to 17,000K.

3.3.5 Colour rendering of light

Another aspect of the colour properties of light is the degree to which colours of objects are accurately reproduced in that light. There are artificial light sources which make the colours of objects disappear entirely, such as the low pressure sodium lamp used - incidentally, increasingly less - in motorway illumination. Incandescent lamps and halogen lamps provide the best colour rendering. The Colour Rendering Index denoted by Ra, a number between 0 and 100, defines the colour rendering of light sources. These numbers can also be accurately calculated based on the light spectrum. The low pressure sodium lamp has a Ra of 0, while incandescent lamps have a Ra of 100. All other light sources have values somewhere in between. The Colour Rendering Index should be looked at in conjunction with the colour temperature. High colour temperature lamps will reproduce a slightly 'cooler' colour rendering while low colour temperature lamps will reproduce a slightly 'warmer' colour rendering. This similarly applies to daylight. The variation in the colour temperature of daylight from minute to minute will therefore also slightly change the colour of objects: the 'natural' colour of objects does not exist.

3.3.6 Dynamics of light

The colour appearance and quantity of daylight constantly changes. As stated above, colour temperature varies from around 4000K to 20,000K, in other words from red/sunset red to bright blue and everything in between. The quantity of daylight varies from 100,000 lux on a clear, sunny day to 15,000 to 3000 lux on a grey, cloudy day. The dynamics of daylight are generally experienced as favourable. Until recently, the majority of light sources provided an almost consistent colour rendering. The availability of LEDs created the opportunity to adjust the colour of this artificial light electronically (dynamic adjustment). In the past, this could only be achieved by dimming the various hues of lamps individually and at different dimming levels (often using a dual lamp fitting). Many - but not all - sources of artificial light can be dimmed properly to enable variation in the quantity of light. Incandescent lamps and halogen lamps are easy to dim. By dimming the light, the colour slowly becomes warmer; this process is known as amber drift. The colour change when light is dimmed is experienced as entirely natural.

3.3.7 Direction of light

The direction of daylight is usually determined by the vertical windows in buildings: the light streams into the buildings more horizontally than vertically. This frequently results in relatively higher vertical lighting intensities than horizontal lighting intensities. This differs for artificial light that enters buildings from the ceiling, in which case the horizontal lighting intensity is relatively higher than the vertical lighting intensity. The exact proportion of these components depends on the light distribution, which in turn relates to the optics applied in the light fittings.

3.3.8 Biological dose

Studies have shown that, particularly during the winter months, insufficient daylight enters most offices to ensure the required level of alertness. There is not enough daylight to create the natural biological effects we need for our well-being. This means that artificial light must supplement the lack of daylight, largely in the morning hours because the biological effect of light is the most important at that time. Studies have revealed that light containing a relatively large blue component is more effective: it provides a larger biological dose. A large biological dose of light therefore is effective in the morning but could indeed disrupt our natural biological rhythm in the afternoon and particularly in the evening, causing us to sleep poorly. For that reason it is worthwhile comparing the biological dose of light sources combined with the time of day, evening and night. The total biological dose of a light source with a specific luminous flux (lumen) can be calculated based on the biological action spectrum which has meanwhile emerged from recent studies.

3.3.9 Design, weight and luminous surface of the light source

The design and weight of a lamp often determine their use in a particular situation or in a particular fitting. Incandescent lamps, and to a greater extent halogen lamps, are compact and light. Fluorescent lamps are much larger and elongated while compact fluorescent lamps are available in various designs and weights. LEDS are extremely compact and are sometimes ‘packaged’ in a pear-shaped light bulb to give them the same shape as an incandescent lamp. These are known as LED lamps.

The luminous surface of the light source or in popular terms ‘ the heart where the light source originates’ determines the possibility of directing light with optics. The smaller the surface, the more accurately the light can be directed but with an increased risk of glare as well. If the luminous surface changes, optics designed for a particular luminous surface will direct the light in other directions, perhaps even those that could prove disturbing. This occurs when one type of lamp is replaced by another type of lamp using the same optics. In transparent incandescent lamps the luminous surface - the incandescent spiral filament - is very small. The luminous surface in matt incandescent lamps is much larger: the whole lamp housing has become the luminous surface. The luminous surface of LEDs is very small and almost tapered. Power LEDs with a high brightness level could damage the eyes if the source is looked at repeatedly and/or for a long time. Fortunately, human beings have a natural reflex mechanism to prevent them from looking at high levels of brightness (similar to our inability to look at the sun for any length of time). Fluorescent and compact fluorescent lamps (CFLs) have an extremely large luminous surface. The brightness is distributed across the whole tube surface as a result of which a single point is less bright.

The brightness of luminous surfaces is expressed in candela per square metre or cd/m2, the formal term of which is luminance.

3.3.10 Ballast device

A ballast device in the electrical circuit, with a starter if necessary, is required to use gas-discharge lamps while LED lamps need a driver. A ballast device and a driver also consume energy. In the past ballast devices were heavy but today electronic ballast devices, which are more energy efficient and weigh less, are almost only used. The light fittings need room to accommodate an in-built ballast device. Since this is a problem in existing light fittings, compact fluorescent lamps are available with an in-built ballast device (integrated CFL, called low-energy lamps in the Netherlands). These have been designed to replace the incandescent lamp. LED lamps are also available with in-built drivers. Low- voltage halogen lamps, commonly 12V lamps for household use, require a transformer to reduce the power voltage.

Non-integrated CFL

FL (fluorescent tube)

GLS incandescent lamp

LED lamp

3.4 Qualities of the incandescent lamp, fluorescent lamp, compact fluorescent lamp (low-energy lamp) and LED

3.4.1 Overview

Table 3.1.1 provides an overview of the various qualities of the different types of lamps (white light), expressed by quantity (luminous flux, lm), luminous efficacy (lm/W), colour appearance (colour temperature, Tk), colour rendering (Colour Rendering Index denoted in Ra),dynamic use options (dimming), biological dose, design, luminous surface and an external ballast device that may possibly be required. The range given is based on lamps used for home and office lighting.

3.4.2 Relation between luminous efficacy and colour quality

There is a negative relationship between the luminous efficacy and colour quality of the lamp in gas discharge lamps (fluorescent and compact fluorescent lamps) and in solid state p-n junction devices (LEDs): the higher the colour quality, the lower the luminous efficacy. For that reason, on the one hand fluorescent lamps are available with good colour quality (around Ra 80) and a high luminous efficacy (800 series) and, on the other, in extremely good colour quality (around Ra 90) and a lower luminous efficacy (900 series). The 800 series is adequate for normal office use. This negative relationship similarly applies to LEDs. With the luminous efficacy of white LEDs still at a fundamentally low level a few years ago, they had little appeal from an economical point of view. LED products, however, were chosen with a low colour rendering, i.e. around 65, to achieve a reasonable luminous efficacy nevertheless. The low colour rendering of LEDs (and greater luminous efficacy) was often coupled with a relatively high colour

Halogen

Integrated CFL

	GLS	Halogen	FL	CFL		LED	
				Non-inte-grated	Integrated low-energy lamp	LED lamp	LED system
Luminous flux (lm)	200-1200	200-3000	1000-6000	250-4000	250- 1200	100-500	1000-6000
Luminous efficacy (lm/W)	8-12	15-25	80-100	40-70	40-60	45-65	45-70
Average life	1000	2000-4000	17000	8000-12000	8000-10000	35000	35000
Colour temperature (Tk)	2700	3000	2700-4000[1]	2700-4000	2700	2700-5000	2700-5000
Colour rendering (Ra)	100	100	80-90	80	80-90	65-90	50-90
Quantity dynamics	Dim[2]	Dim[2]	Dim[2]	No	Dim[2,3]	Dim[2,3]	Dim
Colour dynamics	No	No	Mix dimmable lamps	No	No	No[4]	Mix colours of LEDs
Biological dose (%)[5]	100	130	100-135	100-135	100-135	90-135	Dependent on colours
Design	Pear-shaped	Compact	Oblong	Compact Oblong	Pear-shaped and other designs	Pear-shaped	Various
Luminous surface	Small spiral or balloon	Small spiral	Large	Large	Balloon	Balloon	Very small to a wide range
Ballast device/ driver required	No	No, low-voltage transformer	Ballast device	Ballast device	No	No	Driver

Table 3.1.1 Qualities of the various light sources

1) Special versions are available with a colour temperature of up to 17000K
2) When incandescent or halogen lamps are dimmed they acquire a warmer colour (the colour temperature becomes lower). This is often regarded as a pleasant natural effect. Dimmed gas-discharge (fluorescent and compact fluorescent) lamps and solid state p-n junction devices (LEDs) themselves do not produce this effect: the colour temperature remains constant during dimming.
3) Special dimmable version.
4) Can be developed, in principle.
5) Relative compared to an incandescent lamp, based on the same level of light. The first number in a range refers to a 2700K version, the last number to a 4000K version.

temperature (much cooler than incandescent light). In terms of use, the outcome therefore was a double negative: poor colour rendering and cool unpleasant light compared with an incandescent lamp in a home environment.

3.4.3 Improved luminous efficacy of LEDs and choice of colour quality

The luminous efficacy of LEDs has improved to such an extent that a reasonable luminous efficacy (around 55-65 lm/W) can be combined with good colour quality (of around Ra 80 and a colour temperature of around 2700K). In view of the expected developments in the luminous efficacy of white LEDs (the forecast improvement factor is 2 in a few years' time), the LED standard for household lighting should have a Colour Rendering Index of around

Ra 90 with a colour temperature of around 2700K. It has emerged that the use of compact fluorescent lamps (low-energy lamps) in the household environment with a Ra of around 80 in the past 25 years has led to complaints. In the event of the forecast higher luminous efficacy, the required "loss" of luminous efficacy will no longer make that much difference (perhaps a 6W rather instead of a 5.5W LED lamp for a 60W incandescent lamp equivalent).

3.5 Pros and cons of lamps based on area of application

3.5.1 Offices

Thin (ø16mm) fluorescent lamps are the most economical and energy-efficient form of office lighting. The functional quality of well-designed office lighting using these types of lamps is excellent. This is mainly because these fluorescent lamps easily produce non-glare lighting in the appropriate light fittings with the right balance between the diffuse and directional component (directed towards the working surface). Solutions using the compact fluorescent lamp (the non-integrated, long version) are less efficient but offer the option of applying smaller, square light fittings rather than small oblong fittings. LED cluster light fittings, often in the form of a fluorescent lamp, are becoming more widely available. On account of the current luminous efficacy of LEDs, such solutions are far less economical and energy-efficient than fluorescent lamps. The tapered luminous surface of each small LED element makes it difficult to reduce glare and achieve the right balance between the diffuse and directional component. These properties need to be acquired by optical means in the light fitting and that adversely affects the luminous efficacy of the system. LEDs still therefore need to undergo major improvement in order to compete with the luminous efficacy of today's fluorescent lamps. A more attractive design can be created for custom-made LED office lighting fittings (for instance, using curved and flatter forms).

Dynamic rhythm

Multi-lamp fluorescent light fittings can be applied to dynamic office lighting to produce 'natural non-visual biological effects'. The lamps emit various colours of light, possibly up to 17000K, and are dimmed differently at different times (in the morning or afternoon) to generate a dynamic rhythm. LED systems are definitely also set to be used for these types of applications, either combined with normal fluorescent lighting or otherwise.

3.5.2 Special spaces

In terms of functionality, fluorescent lamps are ideal for illuminating conference rooms and reception areas. To increase their level of illumination in these spaces, LED systems offer advantages, possibly combined with fluorescent lamps, or used entirely on their own. The decisive factors of LED systems are their easy dimmability, colour match and directionality. The ambience in the room can easily be adapted to the alternating functions of the room using a system that can be controlled as above.

3.5.3 Monuments serving as offices

The above 'normal' office lighting solutions can occasionally also be applied in historic interiors, but this certainly does not apply in all cases. In cases where large light fittings in or mounted to the ceiling are undesirable, special LED light fittings can be used as 'miniature floodlights' to illuminate the ceiling from the sides of the room to produce indirect lighting for the workspace. In certain cases, it is also possible to create more direct lighting for the workspace in the same fashion. Combinations of these options may form an acceptable solution. The ideal solution is not always at hand and requires a custom approach at all times. In monuments with a homely character it is important to choose 2700 or 3000K as the colour of light for incandescent or halogen lamps.

In monuments where light fittings housing incandescent lamps form an essential part of the monumental interior, depending on the situation compact low-energy lamps, LED lamps or custom-made LED systems can be applied. A colour temperature of 2700 or 3000K should be used in such cases. Yet, situations are conceivable for which an appropriate alternative does not exist. If matt incandescent lamps are replaced with low-energy lamps, the design and size of the latter lamps may not be appropriate for the fitting. Moreover, these low-energy lamps are non-dimmable. An alternative - dimmable LED lamps - is emerging. However, it is important to bear in mind that they should not only be chosen in the correct colour temperature (2700-3000K) but also in the correct colour rendering (Ra 80 but preferably Ra 90). When dimmed, however, their colour will not grow warmer as is the case with incandescent lamps. As stated earlier, the luminous efficacy of LED lamps is soon expected to improve, which means that acceptable solutions will be possible in the long term using LED lamps. Small custom-made LED lamps will need to be used as an alternative for various forms of clear incandescent lamps. The luminous surface is the LED itself, which has been placed as close as possible to the original position of the spiral filament.
The design of the lighting system clearly requires

more attention. Further information on this topic can be found in section 5.2 and in the section entitled ‘In Practice 2’.

In practice 3: New location for Delft University of Technology’s Faculty of Architecture

After the fire that devastated the entire Faculty of Architecture at the Delft University of Technology in May 2008, the faculty moved to a new location. The faculty canteen gained a work of art entitled the ‘Rollercoaster’ by Bertjan Pot. The work comprises a ribbon of 480 lamps meandering through the upper space. For sustainability reasons 7W low-energy lamps were chosen as lighting.
The effect was experienced as cold and dismal; a disappointing result.

Ultimately it seemed sensible to replace the low-energy lamps with incandescent lamps. This obviously met with objection from a number of people. After having experimented with LED lamps, however, incandescent lamps were incorporated in the work of art for the reasons outlined below.

In the new situation 15W incandescent lamps were used having twice as much power as low-energy lamps but dimmed at 50%. This means that they use the same amount of power.
By dimming the incandescent lamps to half capacity, their average life increases tenfold, to 10,000 hours. This is longer than that of low-energy lamps which have an average life of 6,500 hours.
In addition, at the time the lamps were replaced only 100W lamps were banned while lower wattage lamps were still available as usual.

As a result of the change users feel more comfortable in the canteen, consume more food and also meet up in the canteen outside the official canteen hours. No one has complained about the change in lamp type. The low-energy lamps are also used at other locations.

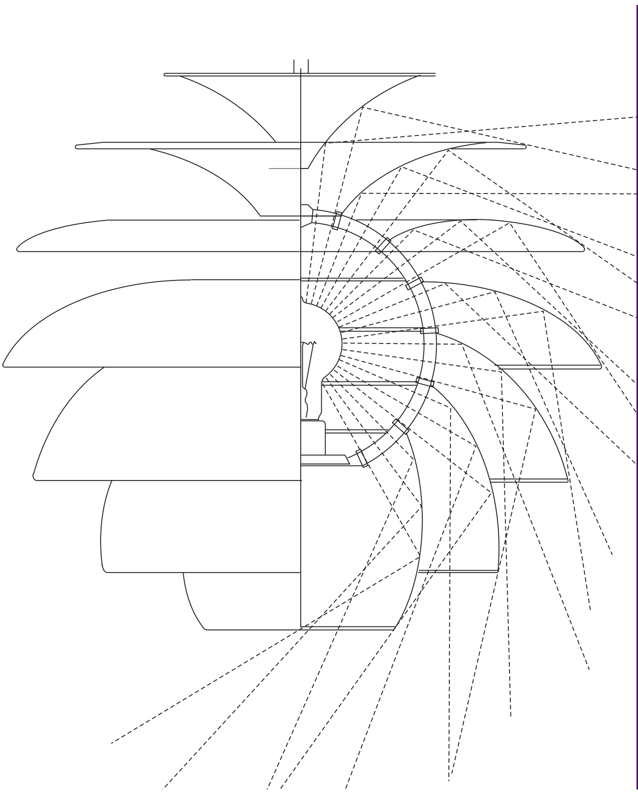
In terms of sustainability incandescent lamps do not have any disadvantages aside from consuming a relatively large amount of energy in order to produce light. Low-energy lamps on the other hand are reduced to chemical waste at the end of their life.

4. Value and technical assessment of lighting in historic interiors

If anything is to be altered in a historic environment, it is essential to understand the background of the interior itself and the objects located in the room; to that end research is required. This applies to any intervention within a historic environment. It involves an understanding of the historical value of the existing situation. Not only is the lighting present important but also the room where this is located. These two factors combined determine the cultural value. Examination of the existing situation will yield essential starting points for the design phase. The questions that should be asked in this context include the following: Is the situation unique from a historical perspective, and should it definitely be conserved, or is the relevant object of lesser importance? Are the light fittings present authentic or were they added later? Are they a determinant for the oeuvre of the architect or artist? Are the products serial products or are they unique?

Candle fittings

Originally, the light fittings present may have been designed for incandescent lamps. Electrified candelabra or gas light fittings may also have been used. In the past, light fittings were adapted for the incandescent lamp by mounting large E27 or small E14 fittings at the point of the original candle or gas jet. People often chose to use E14 candle fittings in combination with a candle lamp. The candle fitting consists of a fitting located at the top end of a white tube. The tube resembles a candle, either with or without imitation candle wax dripping from the upper edge. Occasionally, light fittings were damaged during the conversion process, for example when drilling holes to mount the fittings and attach wiring. Candles were replaced by incandescent lamps during the above electrification process but the lamps were not a visual substitute for candles. Relative to the candle, from a technical lighting point of view this approach marked a fundamental change. The position of the point of light of the candle indeed alters as the candle burns up while the point of



Poul Henningsen
Type II A. Design drawing by Poul Henningsen dating from 1924. From the early twenties Danish designer Poul Henningsen (1894-1967) designed countless light fittings for the Louis Poulsen company in Copenhagen. The drawing shows that the incandescent lamp was the starting point for the design. The light emitted determines the design of the various elements of the shade. A light source with different dimensions and characteristics to those of an incandescent lamp will have a detrimental effect on the quality of the light fitting. The light fitting will only emit indirect light, implying that the output will not be that high. To ensure that a sufficient amount of light is emitted nonetheless, a high-voltage lamp must be used. These particular types of light sources are difficult to emulate, or cannot even be emulated, by LEDs.

light of the incandescent lamp remains static. The traditional candle lamp was also considerably larger than a candle flame, not only in terms of size but also in terms of light output. A light source of 15 to 60 watts which has an output of 120 to 600 lm, depending on the selected power, and therefore is comparable to 8 to 50 candle flames, was placed at the point where a candle flame originally burned with a luminous flux of 12 lm. This is basically the same for the 18 to 42-watt halogen versions that are available nowadays. If too much light is installed in historic light fittings, that can cause the risk of glare, reducing the beauty of the light fitting. Moreover, a high output incandescent lamp and a high temperature could also physically damage the light fitting. The material could also be tainted by a higher UV load. A wide range of LED alternatives for the candle lamp have recently been put on the market. These lamps are available in myriad versions and wattages, and thus entail a huge variation in light output.

Nowadays, low-voltage electric halogen candles are used as a substitute for candles instead of high-voltage incandescent lamps. The examples highlighted in the sections entitled ‘In practice’ describe a few projects where this was recently carried out.

Alternatives

The value of a monument will determine whether a new lighting plan should be based on the existing light fittings or whether there is leeway for alternatives. In addition to a historical valuation of the light fittings, their technical condition too is an important aspect. The light fittings may be in need of a technical overhaul. Light fittings are regularly found to be in such poor electro-technical condition that they are declared unusable. Poor wiring involves a high risk of overheating, and this may cause fire. In order to obtain a clear view of the technical condition of the light fittings, they are required to be dismantled. Examining the authenticity of the electrical components, wiring and fittings (lamp holders) usually is reasonably easy. The material from which they are made often provides an adequate amount of information about the period in which they were added to the light fitting and thus the possible historical value. Dismantling a light fitting may perhaps also offer a good opportunity to restore the metal. Layers of paint or other surface treatments can be repaired, removed or replaced and the light fittings will be cleaned thoroughly.

New lighting plan

The cultural and historical value of the room where the light fittings hang provides key preconditions for the design phase of a new lighting plan. Valuable ceilings and walls make it unacceptable or impossible to mount anything or lead wiring to these areas. This therefore makes it virtually impossible to use new supplementary hanging or wall light fittings.

An examination of the present situation will reveal whether largely authentic lighting is present or whether a situation applies in which alterations have been made over the course of the years. The latter is often the case. The wiring and fittings will, for instance, have been replaced at one stage for technical reasons. Often light sources other than the original light source will have been used. In the early years of the incandescent lamp and definitely the carbon filament lamp, the lighting intensity was extremely limited and did not provide the lighting level required today. Carbon filament lamps are rarely seen these days as opposed to tungsten lamps, which abound. In past decades, when more light was needed in a room than the light provided by the existing light fittings it seemed logical to replace the light sources with a higher-output version. Light fittings were originally designed for a lamp with a specific output in mind. As stated earlier, increasing the output can result in glare. The characteristics of the light emitted by the light fitting could change completely.

Light quality

Light fittings designed for incandescent lamps and fitted with low-energy or halogen lamps lose some

Classic basket-chandelier
lThe original candles are in direct view, without any form of covering. Not only must a substitute light source have the appropriate technical lighting characteristics but also a shape that aesthetically fits in the luminaire.

of their light quality. The same is true when replacing incandescent lamps with today's LED lamps.

Light fittings are always designed for a specific light source. Each type of light source has a unique design, coupled with technical lighting characteristics. Countless existing light fittings are based on incandescent lamps because these were used for decades. The shape of the classic incandescent lamp (dating from around 1915) has not changed dramatically over the years. This implies that until recently light sources were still available to match the design of the light fitting. This is no longer the case. Clear 40W lamps will cease to be manufactured after September 2011, while higher wattages and matt lamps are now already no longer available. The year 2012 will see the production of the last incandescent lamp (see 8.2).

Light fitting categories

We therefore need to seek alternatives. But how do we choose the most suitable light source for a specific light fitting from among these? It is possible to distinguish between three different light fitting categories as follows:

- Light fittings, the light source of which is in direct view and therefore forms a visual aspect of the design.
- Light fittings which do not reveal the incandescent lamp but do determine the design, and for that reason are irreplaceable unless the other light source features identical characteristics.
- Light fittings which completely surround the incandescent lamp making it only the light source but not a determinant of the light fitting design.

Chandeliers with clear incandescent lamps fall in the first group. Chandeliers are available with light sources that are largely masked from direct view by the crystal. However, a clear lamp is the only lamp that does justice to the effect of the crystal. This contrasts with matt lamps and low-energy lamps, which are definitely alien to a chandelier. Chandeliers were never designed as a work light. Historically, these light fittings were found in

representative interiors. When substituting light sources, the light as well as the design of the substitute light sources should be taken into account for these types of light fittings.

The designs created by Danish designer Poul Henningsen are illustrative of the second group of light fittings. His designs are based entirely on the technical lighting and physical characteristics of the incandescent lamp. If light sources with different characteristics are used in these types of light fittings, this will have a detrimental effect on the quality of the light fitting, from both a technical lighting and aesthetical point of view. The third category comprises light fittings that were indeed designed for incandescent lamps but the final design of which is not determined, or scarcely determined by the incandescent lamp. An alternative light source is quite easy to find for the latter category; if it fits then it is fine. A closed opal glass ball is illustrative of a light fitting in this group.

Enrichment?

Old, original light fittings in themselves may be valuable, yet are out of place in the room in which they have always hung. When incandescent lamps were introduced in existing buildings, the accompanying light fittings were an essential, functional addition to the interior but they were not integral to the original design. The candle or gas fittings, which indeed formed part of the ensemble, were often converted and adapted for the incandescent lamp. Obviously existing light fittings were also substituted by new light fittings, which originally featured electric light bulbs. In those days people perhaps also considered creating more light using completely new methods. When converting existing light fittings proved unfeasible, people opted for new light fittings. The new addition to the room sometimes was aesthetically acceptable or even an enrichment, but sometimes the opposite was true.

This even offered the opportunity to remove (and conserve) authentic light fittings from a certain

Jachthuis St. Hubertus.
Original light fitting in Jachthuis St. Hubertus. St. Hubertus was designed by Dutch architect H.P. Berlage and constructed between 1915-1920. The light fitting design is also presumed to be the work of Berlage. Aside from buildings, Berlage designed furniture and other interior furnishings. The light fitting was designed for the incandescent lamp. In this particular case it will not be difficult to find an appropriate substitute. The light source itself is not in view and the lighting characteristics of the substitute light source are not critical.

period now that better alternatives were available. The decision to do so related to the new function of, and different furnishings in the room. However, a key aspect was to ensure that the adjustments could be reversed to enable future generations to restore the previous situation easily, if desired. If the assessment has revealed that the light fittings in the room do not have any historical value and moreover do not meet the technical lighting requirements, the option exists to create a lighting design based on the new light fittings. Sadly, in numerous cases, little remains of the authentic lighting in what once was a valuable interior. The authentic lighting has made way for standard lighting incorporated in ceiling systems. This is regrettable. We must endeavour to rectify errors made in the past. The interior can once again be given a fitting character with a new lighting design reminiscent of its historical origins.

'Modern classics'

Apart from the antique light fittings dating from the early years of the incandescent lamp, there is another large, more recent group of light fittings which are threatening to become virtually worthless due to the extinction of the incandes-cent lamp. Just as light fitting design in the early years of the incandescent light bulb often was based on existing candle and gas fittings, a new generation of designers were particularly inspired by the unique characteristics of the incandescent lamp. This has yielded high-quality light fitting designs, those which make optimum use of the favourable characteristics of the incandescent lamp while eliminating its unfavourable characteristics.

Multiple examples of such meticulous light fitting designs can be found within the oeuvre of Danish architect

Poul Henningsen. Light fittings have even had a design focus on the physical features of a specific light source, an example of which is a light fitting designed by Dutch architect Gerrit Rietveld. History later repeated itself, with the advent of the

PH 5 1958
A 1958 design classic by Poul Henningsen based on an incandescent lamp and still being manufactured by Louis Poulsen. This particular light fitting is suitable for an incandescent light bulb of up to 200 watts with a luminous flux of 3000 lm. The light fitting requires a high-output light source. All of the light emitted is indirect. A considerable amount of light therefore is lost. As an incandescent lamp alternative, the manufacturer is currently proposing two types of low-energy lamps with a luminous flux of 1500 and 2000 lm respectively. Aside from poorer colour rendering these alternatives also emit a significantly lower amount of light. Low-energy lamps with higher output do not physically fit in the light fitting. Whether or not the quality of the light fitting has considerably diminished and been rendered practically unusable on account of the reduced light output, remains to be seen.

halogen lamp. The unique characteristics of the tiny halogen lamp served to inspire designers and engendered a series of design classics. If no genuine substitutes for incandescent light bulbs and halogen lamps become available, the unique features of these light fittings will cease to be appreciated. Many of these light fittings are still in full production, and a number have been incorporated in the collections of prominent museums. It should remain possible to experience the light fittings as the designer once had in mind. This is cultural heritage that must not be forsaken. It is vital that a number of incandescent lamps remain available for this purpose. The likelihood of finding equivalent alternatives in that area seems to be out of the question.

Rietveld lamp
1920's hanging lamp designed by Gerrit Rietveld. The light sources are integral to the design. Without this light source, this light fitting will cease to exist.

In practice 4: Paleis Het Loo, Apeldoorn

Around 2005 it was found that the existing lighting in Paleis Het Loo no longer satisfied the safety requirements. 'Electric candles' were used as the light source for most of the light fittings, chandeliers, wall fittings as well as the standing candelabra. In the past these light fittings had all been converted from candles to electric lighting. The lamp used was a small 7W 230V lamp in a 10mm screw fitting. These fittings had in fact never been intended for 230 volts and the person exchanging the lamps ran the risk of electrification. It was decided to develop a safe low-voltage version of the electric candle. The starting point was to emulate the original character and technical lighting features of the candle as accurately as possible. The light source was required to have an operating life of 2,000 hours for user-friendliness reasons. Experiments were carried out with LED lighting, which was an attractive light source particularly in terms of average life. However, in those days the technical lighting characteristics of LED, such as colour temperature and colour rendering, had not achieved the level of the candle and incandescent lamp. A significant improvement has meanwhile been seen in this area.

Candle in Paleis Het Loo
A light fitting in Paleis Het Loo in Apeldoorn. This light fitting and the chandeliers, wall lamps and other table candelabra gained electric candles in 2008. Thousands of light sources were involved. The light source is a tiny 10W halogen lamp. This light source is also doomed to extinction. A LED version will have to be found.

Paleis Het Loo
The e-candle developed for Paleis Het Loo and later adopted in monuments such as the Royal Palace Amsterdam.

A tiny 10W pin-based halogen lamp was ultimately selected. The lamp is dimmed, depending on the light fitting and location in which it is used usually to around 70% of its full capacity. The disadvantage of this light source is its small point of light, which is much smaller than that of a candle. The problem was resolved by placing a matt glass, flame-shaped housing around the halogen bulb.

Finding the correct surface treatment for the glass housing was a lengthy process. It takes a great deal of time and money to develop such a new product and this is unfeasible for smaller objects. In total several thousand units were required for Paleis Het Loo. The candle that was developed moreover became a standard product and has meanwhile been adopted in several buildings, such as the Royal Palace on Dam Square in Amsterdam. The light source, the 10W halogen lamp, is currently expected to remain available until at least 2016. By that time an alternative must be made available, based on LED, for instance.

5. The design of artificial lighting systems in historic interiors

5.1 Design principles

Clear design principles are vital in order to create a good lighting design. What is the quality of the room and what function will it fulfil? The quality of the interior is determined by establishing the value. The function of the room determines the requirements imposed on light. Each function requires specific lighting. Monuments in fact incorporate all functions that are also found in other buildings. Monuments house museums, law courts, offices, homes, churches, archives, theatres as well as prisons. Each building features characteristic architecture, offering opportunities yet also imposing restrictions. The lighting design should be based on the use of the space and the monumental or historic character of the interior.

In monuments, office lighting requirements are identical to those in other buildings. The essence is the efficiency of the tasks that must be performed, including the level of comfort for the user. A workplace must function properly and the correct lighting is required to do so. For standard office work, the average level of light on the working surface is 500 lux. Different values apply to other tasks. A number of functions and the required levels of light can be found in Appendix 7.1.

Standard situation

Contemporary offices often have white walls and a white ceiling. Generally, ceilings are not high but offer the option of incorporating recessed luminaires. The lighting industry has a wide range of available light fittings that easily fulfil the lighting requirements imposed on a standard situation.

This differs for monuments. There is no standard ceiling height and recessed lighting in a ceiling often is out of the question. Added to that, ceilings, like walls, are usually embellished. This means that they have other reflective characteris-tics. The design and installation of a lighting system can sometimes be an impossible feat if all technical lighting requirements arising from the restrictions associated with the space are to be taken into account. In such cases it is doubtful whether the light will satisfy all the preconditions. The starting point is to provide the correct level of lighting, rather than being able to install certain light fittings. Yet light fittings are needed in order to facilitate the required amount of light. If it is unfeasible to add light fittings in order to create the correct level of light, it will be difficult to give shape to the new function in the room.

More daylight

If an office function is to be created inside a monument, it should be examined whether the supplementary requirements for artificial lighting can perhaps be less strictly adhered to than for normal offices. For one thing, the office function may possibly not be a 24-hour operation. The height of the ceiling and windows in a monument often exceeds the standard height. This means that more daylight will enter and penetrate more deeply into the building. As a result, a sufficient amount of daylight will nevertheless permeate through workplaces located at some distance from a façade or outer wall.

In this context it is important to find out whether window film has been applied to the windows. Window film, which was originally intended to limit the harmful elements of daylight, such as ultraviolet and infrared radiation, will affect the quality and intensity of daylight. More information on this topic can be found in section 5.2. The design of an artificial lighting system normally does not take account of daylight entry. After all, the amount of daylight depends on the season of the year, the time of day and weather conditions, and varies from ample to zero.

When calculating light for an office environment, the strongly fluctuating amount of daylight is therefore not taken into the equation. Yet, particularly for monuments, which often have divergent spatial dimensions, it is worthwhile

estimating the daylight situation prior to the design phase and incorporating the results in the design principles. In specific situations people may opt to deviate from the prevailing artificial lighting standards.

5.2 The design phase

If a lighting system is to be altered in a room which has no historical significance, this can be accomplished either by replacing the light fittings or renewing the complete lighting system. This is not an option for historically valuable interiors. After all, the light fittings belong in the interior and perhaps may even have been custom designed for that room. They form part of an ensemble which is considered valuable. When opting to maintain the existing, original electric light fittings, it is important to use these in their original state, complete with the appropriate light sources in terms of technical lighting features and aesthetics. If the original light sources - incandescent lamps - are no longer available, alternatives should be sought.

The current substitutes for incandescent lamps are not equivalent substitutes. Replacements for incandescent lamps, such as energy saving bulbs and LED lamps have the same fittings and therefore physically fit in these fittings. However, they differ from each other in respect of lighting characteristics and visual suitability. An incandescent lamp produced by Company A was virtually identical to that of provider B. This does not apply to incandescent lamp substitutes. The technical lighting characteristics and design of energy-efficient alternatives may differ.

The only way to find out whether the alternative light source can be used is by testing it. Select a number of light sources which should in theory be acceptable and assess the lighting effect. See what they look like in the light fitting. Include in your assessment the option of dimming the light. Be aware that a chandelier was designed as lighting for festive occasions and not as a work light.

Light characteristics
Incandescent lamps, low-energy lamps and LED lamps all have their own specific light characteristics. Apart from luminous intensity, light colour and colour rendering, this concerns the way in which light is emitted. Incandescent lamps emit light virtually all around, in both a horizontal and vertical direction. Energy saving lamps emit light in a very similar manner, depending on the type .

The majority of LED lamps have a clear direction when emitting light. Light characteristics play a key role when choosing a light source. A LED lamp will illuminate fifty per cent of an opal glass ball, while a low-energy lamp in the same housing will achieve better performance.

A wide array of light fittings exists and the variety of light sources is even more extensive. This makes it difficult to choose a specific light source as the most suitable alternative for a particular type of light fitting. The light source that works well in a certain light fitting may be a less fortunate choice in a different light fitting. Added to that, the - subjective - experience is pivotal.

Alternatives

No matter what the final choice may be, none of the incandescent lamp alternatives have a colour rendering of 100. This means that in the new situation the colours in the room will always be reproduced less accurately than customary. An assessment can be made of the colour of the light itself, whether the colours of the room are reproduced accurately and whether the light glares. Is this acceptable? Energy-efficient lighting to date in any case implies reduced technical lighting quality. This diminishes the experiential value of the interior.

The extinction of the incandescent lamp does not carry disadvantages alone. Incandescent lamps produce a great deal of heat. The spiral filament reaches a temperature of around 2500°C, and the glass ball a temperature of around 200-260°C. The high surface temperature causes the dust particles present in the air that come into contact with the lamp to be converted into soot. The soot settles as pollution around the light source. This shortcoming is reduced by using light sources producing less heat.

After the empirical phase and the choice for the most suitable light source, come the lighting characteristics of the light fitting. We know what lighting effect and what levels of light the existing light fittings produce in the room. In most cases, in their 'original' state the light fittings will emit an insufficient amount of light to illuminate the room functionally. Except when used in museums to create an authentic ambience, nowadays the desired levels of light are much higher than in the past. Supplementary lighting will have to be created by adding other, precisely positioned light sources. These light fittings coupled with their light sources must provide the required level of light and moreover must be fitted in, in an aesthetically pleasing manner. Furthermore, the monument or the existing light fittings must not sustain any damage when light fittings are added.

Differing views

Based on the use of the room, the functional, technical lighting requirements are easy to define in accordance with the applicable guidelines. This is more complicated in terms of the aesthetical aspects of the lighting plan: the choice of the luminaire, its position, and the intended and unintended lighting effects it renders. Appropriate, beautiful and acceptable; people will hold different views on these aspects. A light fitting may be unacceptable to some while others may even feel that it enriches the interior.

When a higher level of light is primarily required, it may be an option to replicate the light fittings present and to add them to the room. To some, this may be considered a good solution while others may view this as the falsification of history.

Yet, it is possible to seek a contrast: a modern light fitting may well be highly appropriate in a historic environment, particularly if new furniture is added as well. But this may also meet with opposition. In short, there are no guidelines. Every situation is unique and requires custom work.

Anonymous

One design principle could entail integrating a new light fitting into the architecture. Or, to make the new addition anonymous and invisible as far as possible. The latter solution is often chosen because the primary aim after all is to provide supplementary lighting and not to add new ornamental light fittings.

For decorative purposes, LEDs in particular offer a wide range of new options. LEDs in themselves are tiny and measure but a few square millimetres

LED profile
LEDs can be mounted inside aluminium profiles. Cooling and light create an ultra-slim line of light, with a diameter of around 22mm in this example.

(these should not be confused with the incandescent lamp substitutes based on LED, which always contain multiple LEDs). A row of LEDs together form a very slim line of light, which for instance combined with an existing wall or ceiling profile can create an 'invisible' light source.

A newly designed, functional lighting plan affects the total quality of the room. The light may suffice from a functional perspective but may create problems from an aesthetical perspective. For example, profiles could create unwanted shadows on the wall or ceiling. The luminous intensity on certain elements in the room may also be too high and could damage the materials located there.

Not only should the design embody the situation inside the building but the illumination viewed from outside the building too is a key aspect. A level or colour of light that is not in harmony with the environment could produce an unwelcome effect on the façade in the evening.

Authentic

In a museum environment the lighting will endeavour to emulate the original illumination to make the space look as authentic as possible. Candle or gas light would have originally been used to illuminate many of these spaces. These light sources can occasionally be used, like candle light in castles for special occasions. These light sources are impractical for day-to-day use. Many candle and gas light fittings were electrified over the course of the years and adapted for incandescent lamps. The effects of the extinction of incandescent lamps will be felt in these buildings and, as is the case with non-museum situations, appropriate substitutes will need to be found. If the conclusion has now been drawn that the result of formerly adapting candle or gas light to incandescent lighting was unsatisfactory, and if similarly concluding that incandescent lamp substitutes do not represent a proper alternative, the option may be reconvert the light fittings to suit electric candles. These candles, which are based on a tiny 10W halogen lamp, form an excellent substitute for actual candles. Electric candles based on LED technology will certainly also need to be put on the market. This is a must: after all, the halogen lamp too is doomed to extinction. In exceptional cases, an option may be to go a step further rather than choosing incandescent lamp alternatives from among the alternatives available on the market. Special lamps can be developed. The section entitled 'In practice 2' describes where such a project was undertaken.

Harmful radiation

Daylight also contains ultraviolet radiation, which is harmful to objects, breaks down molecules and causes materials to fade and discolour, even if the dosage is low. The damage sustained is cumulative and irrevocable. The majority of artificial light sources even contain UV radiation but this can largely be reduced by filters. Only LEDs can be manufactured in such a way that they do not contain any UV rays. If the space contains materials that require protection against UV radiation, the lighting design must take this into account. Sunlight must be filtered and/or protected and the use of artificial light must be kept to a minimum value. Window film can be applied for this purpose but UV-resistant film on windows at times seriously affects the image of the façade, completely changing the appearance of the glass panes. For that reason, the use of window film is undesirable.

Smart switch systems

There are other ways to reduce the UV load. With smart switch systems artificial lighting can be turned on just before a person enters a room in a museum environment, and turned off after that person has left the room. The total UV load is the product of the quantity of radiation and the length of time objects are exposed to it. The maximum quantity of radiation can be reduced by using filters or by selecting an appropriate light source. With a smart electronic switch the factor time can be minimised causing the ultimate total UV load to be reduced.

Restorable interventions

We should be aware that the choices we make today will no longer be understood in a number of years. This may be attributable to the taste and aesthetics prevailing at the relevant period of time but technical developments too come into play. LED technology in particular has not yet reached its full development potential. The expectation is that in a few years' time energy-efficient light fittings will be available that do provide the required level of light yet are inconspicuous in a room. It is important that an intervention in monuments be performed such that it can be reversed, and is therefore restorable. This currently is true for lighting. We do not yet have any notion of the technical and aesthetical possibilities in the area of lighting in the next ten years. For that reason it is advisable to ensure that a new system, including the wiring, is designed as flexibly and multi-functional as possible.

Identical requirements

As stated before, the requirements imposed on the workplace in a historic environment are identical to those of a standard office workplace. These requirements relate not only to the lighting but similarly to the furniture, for example. Few office chairs satisfy the prevailing requirements while at the same time befitting an 18th century interior. Yet contemporary chairs, desks and cabinets are often placed in a classic interior in the knowledge that they can be removed easily, without defacing the interior. They are, after all, unattached to the room. Light is a different story: additional electrics are required for lamps and that could pose a problem.

A chair is a separate and independent element having a clear function: it should be comfortable to sit on. Functional light in historic spaces generally blends what there was with what should be added to satisfy the functional requirements and wishes. Additions can be installed entirely unattached to the room, via office desks or floor lamps but solutions can also be chosen that are more attached to the building. Occasionally this may yield more pleasing aesthetical results. Among the LED solutions available are those that provide excellent light from small openings of some four centimetres in the ceiling. This does, however, entail a number of structural interventions with the required technology concealed behind the small four-centimetre hole in the ceiling, mainly in the form of LED cooling.

An acceptable solution cannot be found

Even after having undergone a meticulous design procedure, at times we will need to draw the conclusion that an acceptable solution cannot be found. Suitable light fittings, for instance, are not on the market and custom-designed light fittings do not offer a solution. There may be times when a functional office space can be well-illuminated using fluorescent lighting, and the required level of light and uniformity thereof can be achieved using light fittings that even do not look out of place in the interior. This may seem to be a solution. However, the new light may have such a detrimental effect on the image of the wall coverings that it nonetheless will be decided to seek an alternative. Occasionally higher requirements need to be imposed on colour rendering in a monumental environment than in a standard office environment. Not for functional reasons, but to enhance the architecture of the room.

In respect of the technical lighting requirements, not only is visual functionality important in a historic environment so too are the aesthetical aspects of light, such as the effects of shadow and colour rendering. Should a satisfactory design not be created, we might consider using the room in a different manner. Or, a temporary system may be agreed out of necessity, which is far from ideal in terms of aesthetics and technical lighting factors. We should endeavour to avoid the latter option. Temporary solutions often last longer than ever intended.

In practice 5: De Ridderzaal, The Hague

After the Ridderzaal, the Great Hall, literally translated as Knights' Hall (which forms part of a complex of buildings housing the Dutch Parliament) at the Binnenhof or Inner Court in The Hague, had been restored in 2006 it emerged that the lighting installed did not blend in with the quality of the new, custom-designed carpets, tapestries and fabric of the throne. A green haze enveloped the energy-efficient lighting, the colours of the new textile art works were not reproduced accurately, the lighting was qualified as lacklustre and all 'life' had ebbed away from the hall. An evaluation focusing on improvements revealed that the lighting solely comprised dimmable compact fluorescent lamps (CFL) with external ballast devices. These lamps have a colour rendering of Ra 80. This colour rendering index is further reduced when the light is dimmed.

When the new meticulously manufactured tapestries and carpets were installed in the hall, colour perception began to play a more important role in the Knights' Hall. And, as we know the colour perceived depends on the light.

To resolve this issue the inner circle of the hanging light fittings was substituted by 35W metal halogenide lamps with a colour rendering of Ra 90. These lamps are non-dimmable and it takes a while for the lamps to achieve their correct colour. For that reason they cannot be used everywhere.

The lamps were mounted in uniform directable light fittings which emit different beams of light to create more life in the lighting effect. The current combination of two different kinds of gas-discharge lamps, the colour rendering of one of which was improved, greatly enhances the colours of the fabric in the hall. Incidentally, the CDM lamp also enjoys popularity in the retail sector on account of its better colour rendering features. The installed wattage was increased slightly from 28W to 35W per light fitting. This has created a more pleasant ambience which does justice to the design focus.

The above is a case in point which indeed proves that it is unwise to pursue only the goal of energy efficiency in renovating a historic interior. Since energy-efficient lamps do not emit all colours of the spectrum, some colours are not reproduced accurately. Light quality likewise plays a major role.

6. Potential developments in artificial light sources in the near future

LED is regarded as the light source of the future. Both incandescent, energy saving and LED lamps will be available during the transition period. The role of the incandescent lamp has largely been played out on account of its total ban in the future. Its designated substitutes are energy saving lamp and the LED lamps. The LED lamp is predicted to supersede the quality of the energy saving lamp within the near future. This already applies to luminous efficacy and is not expected to take much longer in terms of the technical lighting aspects. As a result of the advancement of the LED, it is not inconceivable that the energy saving lamp too will suffer extinction.

The market is endeavouring to imitate the specific characteristics of incandescent lamps by using LEDS in the transition period to energy-efficient light. However, these LED solutions are not adequate for all purposes. A LED version for the higher luminous flux emitted by incandescent lamps of 75W and above will most likely never be produced because it is unfeasible within the physical dimensions of a current standard incandescent lamp. Heat dissipation via the current lamp base is inadequate for such a high output LED lamp.

Two types of LED products are set to become available in the long term. The largest group comprises complete LED devices optimised for LED use, which have eliminated as many of the disadvantages as possible. In short, these devices have a LED design focus. This likewise applied at the time specific light fittings were designed for incandescent light bulbs. The other group comprises LED-based copies of the different types of light sources with which we are familiar today. Incandescent lamp substitutes called 'retrofits' are entering the market at a rapid pace and in countless versions. However, the lion's share thereof does not have the same light emitting capability as an incandescent lamp. For instance, they provide a light beam instead of emitting light all around (330°).

Single unit

LED light fittings are a new type of 'light device.' Traditional lighting consists of a light fitting and a light source. The consumer can easily replace the light source in the light fitting. A light fitting and a light source form a single unit in LED light devices. The light source in the light fitting is irreplaceable, it is a single unit. These 'LED light devices' are expected to supersede LED lamps in their conventional form in the long term. The speed at which this process of supersession is set to occur depends not only on the industry, light fitting designers and LED manufacturers, but also on the consumer. This will be a difficult period for luminaire design and development. Light fitting manufacturers and designers were accustomed to developing light fittings based on a standardised light source. No matter whether the product was an incandescent lamp or a fluorescent tube, all providers of light sources supplied interchangeable products. A LED chip in itself is not a complete, usable light source. Several LEDs are needed to generate the desired quantity of light. LEDs are bundled into a usable device with a cooling fin and either in-built or external driver. Due to the absence of a standard LED light source (just as the standard CD in the field of music), the lighting industry must also develop the different specifications for installing the light source itself, in addition to the light fitting. The Zhaga consortium, a large consortium of international LED and light fitting manufacturers, recently took the initiative to begin standardising LED light sources and modules. Light fittings based on these standard LED units are set to appear on the market before long.

Niche

To date, we have not seen any new incandescent light fitting designs appear on the market. Products are mainly ceasing to be sold. The moment specific LED light fittings become available at a reasonable price, they are expected to supersede the traditional light fittings. If the demand for LED incandescent lamp substitutes likewise falls as a result, it will become less urgent for the industry to continue to optimise the quality of these substitutes. But this is coupled with a hidden risk. There always is a niche market, such as the historic environment. In that segment there will always be demand for light sources which emulate the character and characteristics of the original incandescent lamp as closely as possible, and fit in the fittings used. This applies to use in historic light fittings as well as to use in 'design classics.' The demand will not be extensive but it will continue to exist.

For that reason it is important for the industry to continue to supply these products at acceptable prices, even if demand is relatively minimal. The moment manufacturers no longer show any interest in supplying a full-fledged substitute for the incandescent lamp, or do not have the technical capability to do so this should be reason enough to permit the incandescent lamp once again. Perhaps not as a standard light source, but as a limited-scale luxury product for occasional use. The LED industry has a strong focus on offering alternatives for various types of incandescent lamps, including the candle lamp, which is common in chandeliers. Yet a question that remains unasked is whether the candle lamp that was originally intended as a substitute for the candle was actually a good alternative for the candle. It would seem more appropriate to take a step back and develop a good substitute for the candle.

In practice 6: The candle lamp

Among all incandescent lamps in historic interiors, the candle lamp is the most common. They are frequently found in historic luminaires that at one point in time were electrified, but candle lamps were also widely used in classic light fittings dating from a later period. The year 1920 marked the advent of the candle lamp. The glass of the lamp is shaped as a flame but its dimensions are much larger than that of an actual flame. Until recently these lamps were only available as incandescent lamps with an output of 15 to 60 watts, in both matt and clear versions. This is changing as a consequence of the future ban on such versions. Energy-efficient alternatives have meanwhile become available; a wide array of both LED and energy saving lamp versions are on offer. There also are halogen alternatives but they only form an interim solution since they too will no longer be available within a few years. Where the incandescent lamp version offered a choice of matt and clear versions in different wattages, the range has now grown more extensive. The choice of LED versions in particular is substantial. Many of these LED lamps have completely different design principles, and their level of illumination varies widely. Every light source manufacturer seems to have developed their own individual LED alternative for the candle lamp, among them good but also poor versions. In the quest for a suitable replacement for the incandescent candle lamp, it thus is important to take a good look around and not to choose from the range offered by a one single supplier. The light fittings designed for these light sources vary widely, just as the rooms where the light fittings are located. It is not possible to qualify a LED or energy saving candle lamp as the most suitable. It remains a matter of experiment. The extinction of the incandescent lamp in itself

- Clear incandescent lamp
- Matt incandescent lamp
- Clear halogen lamp
- Energy saving lamp
- Clear LED lamp, Megaman
- ‘Golden’ LED lamp, Megaman
- Matt LED lamp, Megaman
- Clear LED lamp, Philips
- Clear LED lamp, Rayleich

represents degradation of the light quality, particularly in terms of colour rendering. Yet there may be models among the newly developed LED lamps that add something to the experience aspect of the light fitting, something that the incandescent lamp, particularly the matt versions were unable to achieve. In assessing the various light sources, the visual aspect is vital. The light sources will not differ that much from each other in terms of energy efficiency. The way light is experienced is pivotal.

The fact that myriad essentially different LED versions are available likewise increases the risk that a number of these will cease to exist in the long term, and at the same speed at which they appeared. If a product does not take off the manufacturer will cease to produce it. A particular standard may perhaps be set in a number of years.

7. The visual quality aspects of lighting systems

7.1 The visual quality aspects of lighting systems

Recommendations and standards for lighting specify the lighting quality for most of the aspects described above, and for a wide array of interiors and activities. Tables A and B feature the lighting aspects as applied in the European Standard for the lighting of workplaces (EN 12 464). Note: The colour appearance of light itself is not specified in the European standard. This is because colour appearance is currently viewed as a psychological and aesthetical matter and thus depends on taste.

7.2 The phasing out of incandescent lamps

At the end of 2008 the European Union passed a resolution to a phased ban on incandescent lamps. The first group of lamps were no longer available from autumn 2009. The table on page 72 shows what this means for the various types of incandescent lamps.

7.3 Glossary

7.3.1. Terms denoting light sources

Argand lamp
An Argand lamp refers to the method used to construct an oil lamp introduced around 1783 by the Swiss chemist and mechanical engineer Aimé Argand. The lamp offers virtually smokeless, soot-free combustion because oxygen has been added to the flame.

Ballast device
A device connected to the power supply and one or more discharge lamps that maintains the current through the lamp(s) at the required value. A ballast device can also contain a transformer for the supply voltage, correct the work factor and cause the lamp(s) to ignite. Modern ballast devices are electronically operated.

Carbon filament lamp
Incandescent lamp, the luminous component of which comprises a non-spiral carbon filament.

Quality aspect	Quality parameter
Lighting level	Average level of lighting intensity, E_{gem} . workplace
Spatial distribution	Uniformity: E_{min} /E_{gem} Reduction of glare (Unified Glare Rating, UGR)
Colour rendering	Ra

Table A Visual quality aspects of lighting systems

No.	Type of interior, function or activity	Egem	UGR	Ra
1	Filing, photocopying, etc.	300	19	80
2	Writing, typing, reading	500	19	80
3	Technical drawing	750	19	80
4	CAD work station	500	19	80
5	Conference and meeting area	500	19	80
6	Reception desk	300	22	80
7	Archives	200	25	80
Emin/Egem uniformity for all categories exceeding 0.7 on the work surface area.				

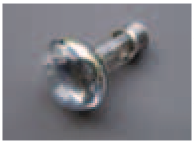
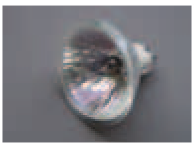
Table B Lighting requirements for offices in accordance with the European standard for indoor work (EN 12 464).

Compact fluorescent lamp (CFL).
A compact version produced by folding or bending the discharge tube of a fluorescent lamp during the manufacturing process. Versions are available with an in-built (integrated) starter and a ballast device containing an Edison lamp cap which can directly replace incandescent lamps. In other versions the ballast device, and sometimes the starter too, are not in-built (non-integrated). The ballast device and possibly the starter need to be housed in the light fitting. The low-energy lamp is often used as the generic name for all these types of lamps. The output of low-energy lamps is approximately a factor of 5 higher than that of incandescent lamps and their average life is ten times longer.

Fluorescent lamp
Low-pressure mercury vapour lamp, most of the light in which is emitted by one or more fluorescent layers attached to the interior of the gas discharge tube, which are excited by the ultraviolet radiation of the discharge causing them to emit visible light. The light and colour characteristics are mainly determined by the composition of the fluorescent layers. The most well- known version is the tubular fluorescent lamp which is often referred to as the fluorescent tube.

Fluorescent tube
See: Fluorescent lamp.

Gas discharge lamp
A lamp in which the light or radiation is generated by an electric discharge in a gas, metal vapour or a mixture of different gases and vapours. If the gas or the vapour has a relatively high pressure in the gas discharge tube, the lamp is referred to as a high-pressure gas discharge lamp; if the pressure is relatively low the lamp is referred to as a low-pressure gas discharge lamp. The pressure and composition of the gas and the vapour determine the light and colour characteristics of the light emitted by the gas discharge lamp.

<table>
<tr><th></th><th>Sept. 2009</th><th>Sept. 2010</th><th>Sept. 2011</th><th>Sept. 2012</th><th>Sept. 2013</th><th>Sept. 2014</th><th>Sept. 2015</th><th>Sept. 2016</th></tr>
<tr><td rowspan="6"></td><td>15 W</td><td>15 W</td><td>15 W</td><td colspan="5" rowspan="3">Total ban on clear incandescent light bulbs</td></tr>
<tr><td>25 W</td><td>25 W</td><td>25 W</td></tr>
<tr><td>40 W</td><td>40 W</td><td>40 W</td></tr>
<tr><td>60 W</td><td>60 W</td><td colspan="6"></td></tr>
<tr><td>75 w</td><td colspan="7"></td></tr>
<tr><td>100 W</td><td colspan="7"></td></tr>
<tr><td></td><td colspan="8">Matt incandescent light bulbs, incl. soft and flame</td></tr>
<tr><td rowspan="5"></td><td>25 W</td><td colspan="7" rowspan="5">Guidelines are expected for reflector lamps</td></tr>
<tr><td>40 W</td></tr>
<tr><td>60 W</td></tr>
<tr><td>75 W</td></tr>
<tr><td>100 W</td></tr>
<tr><td rowspan="5"></td><td>< 60 lm</td><td>< 60 lm</td><td>< 60 lm</td><td>< 60 lm</td><td colspan="3"></td><td rowspan="5">Ban on label C</td></tr>
<tr><td>60 lm</td><td>60 lm</td><td>60 lm</td><td colspan="4"></td></tr>
<tr><td>450 lm</td><td>450 lm</td><td colspan="5">Ban on clear halogen lamps with energy label D & E</td></tr>
<tr><td>725 lm</td><td colspan="6"></td></tr>
<tr><td>950 lm</td><td colspan="6"></td></tr>
<tr><td></td><td colspan="8">Ban on matt halogen lamps: 230V and 12V</td></tr>
<tr><td></td><td colspan="8">Guidelines are expected for reflector lamps</td></tr>
</table>

The phasing out of incandescent lamps in accordance with European guidelines

Halogen lamp
Gas-filled tungsten incandescent lamp containing halogens or halogen compounds. A halogen lamp has a higher output (around factor 1.5) and a longer average life (factor 2 ∑ 4) than a standard incandescent lamp. Halogen lamps are available in 12V and 230V versions.

High pressure sodium lamp
High pressure gas discharge lamp in which light is mainly generated by the radiation emitted by the sodium vapour. High pressure gas discharge lamps have been used in street lighting since the 1960s. These versions emit yellow-white light and render moderate colour. A more recent supra high-pressure version emits warm white light with a good colour rendering and can be used as accent lighting in interior spaces.

Incandescent lamp
Lamps in which light is generated by means of an incandescent filament mounted inside a glass balloon heated by an electric current passing through it causing it to glow. The balloon has low oxygen content and contains an inert gas. The incandescent filament is usually made of tungsten and comprises dual or triple spirals. The glass balloon is available in a wide range of designs, from round and pear-shaped to candle-shaped.

Ignition device
See starter.

LED (Light emitting diode)
See solid state p-n junction device.

LED lamp
Lamp, in which LEDs generate light. LED lamps are intended to replace the incandescent lamp or low-energy lamp and can be used in existing light fittings without the need to adapt the fittings. (known as 'retrofitting'). The pattern of light emitted (light distribution) may differ from that of an incandescent lamp.

LED light fitting
Lighting device developed with the LED light source as the starting point.

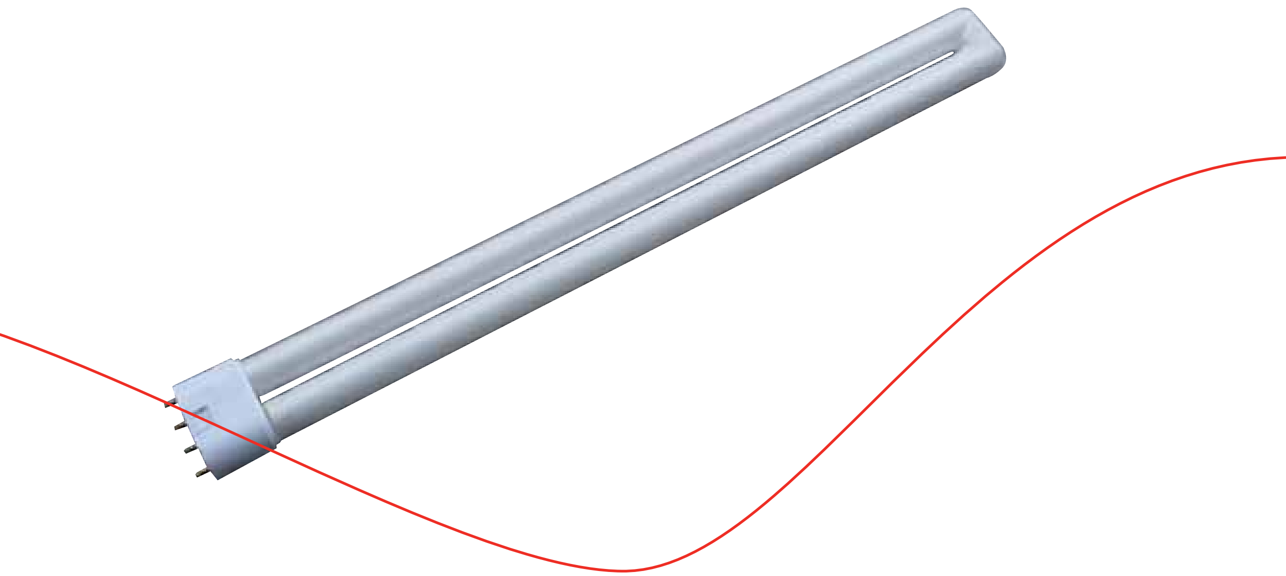
Light fitting
A device which serves to distribute, filter or transform (the colour) of light emitted through one or multiple lamps comprising all components required to attach and protect the lamps, and electrical connection devices to the extent necessary.

Metal halogenide lamp
High-pressure mercury gas discharge lamp in which the light is largely generated by the radiation emitted by of a metal vapour mixture. Initially developed for stadium floodlights, nowadays low-voltage (ceramic) metal halogenide lamps are available to provide accent lighting in interior spaces. CDM and PB are the brand names of these lamps.

Reflector lamp
Incandescent lamp or discharge lamp, of which a section of the balloon contains a reflective layer to beam and direct the light.

Solid state p-n junction device
Semi-conductor element with a p-n junction that emits light when an electric current is applied to it. The most common term for light sources based on the above is LED (light-emitting diode).

Starter
Ignition device, which together with the impedance of the ballast device provides an impulse to the lamp causing the gas discharge lamp to ignite. In most fluorescent lamps the starter also preheats the lamp cathodes, which is required in order to start the cold lamp.



7.3.2 Terms denoting light, radiation and colour

Blackbody radiation
A black body is an idealised physical body that completely absorbs all incoming radiation independent of the wavelength, the direction of incident light and polarisation. It is the best possible emitter of thermal radiation. Blackbody radiation serves as the basis for some light quantities (for instance, colour temperature). Its effects can be simulated using computer software.

Brightness
Subjective impression of the quantity of light emitted by a luminous surface. The objective measure is called luminance.

Colour rendering
The effect of a type of light on the colour appearance of objects illuminated by that type of light.

Colour Rendering Index (Ra or CRI)
A measure used to express the ability of a light source to reproduce the colours of an object faithfully in comparison with a reference light type. The Colour Rendering Index can be calculated based on the spectrum of the light source. The result is a number between 0 and 100.

Colour temperature
The temperature (in Kelvin, K) of a black body radiator, which renders the same colour appearance as the relevant light source. Used as a measure to express the hue of whiteness of the light emitted by a light source (ranging from red white to denote low colour temperature, to blue white, which denotes high colour temperature).

Contrast
Measure for the difference in brightness between two or more parts of the field of vision perceived simultaneously or consecutively.

Electromagnetic radiation
The emission or transfer of energy in the form of waves comprising cohesive electric and magnetic fields.

Glare
Visual condition experienced as uncomfortable, or which reduces the ability to see details or objects as a result of an unfavourable distribution of luminance or excessive contrasts.

Infrared (IR) radiation
Electromagnetic radiation with a higher wavelength than that of visible radiation. Heat radiation is a key characteristic of IR radiation.

Lighting intensity
Measure used to express the quantity of light (lighting intensity) that reaches a surface, per surface unit (lm/m2 called lux).

Luminance
Measure used to express the lighting intensity emitted per unit on the surface of a luminous surface in a specific direction (cd/m2)

Luminous flux
Measure used to express the total quantity of light emitted per second by a light source (in lumens, lm).

Luminous intensity
Measure used to express the concentration of light emitted in a specific direction per second (in candela, cd).

Specific luminous flux
Measure used to express the energy efficiency of a light source (lumens per watt, lm/W).

Spectrum
Reproduction of the wavelength components containing the visible radiation.

UV load
The intensity of radiation in the UV area of the spectrum per surface unit (W/m2).

UV radiation
Electromagnetic radiation with a smaller wavelength than that of visible radiation. UV radiation causes materials to discolour and age.

Visible radiation
Electromagnetic radiation that may evoke visual perception. There are no exact limits for the spectral reach of visible radiation as this may vary per observer. The lower limit lies between wavelengths of 360 and 400 nm, the upper limit between 760 and 830 nm.

Wavelength
The distance between successive points in the same phase of a wave. The energy transmitted in electromagnetic radiation is much higher than in smaller wavelengths. In the visible field, the wavelength also determines the colour of the radiation emitted.

8. About the authors

Prof. W.J.M. van Bommel worked for Philips Lighting for over 35 years in various lighting application positions. He was President of the Commission Internationale de l'Eclairage (the international Lighting Commission, CIE) and represented the Netherlands in the European Standard Commission CEN TC 169 for Lighting Application for 20 years. He is a Board Member of the Netherlands Light and Health Research Foundation (SOLG). In 2004 he was appointed professor at Fudan University in Shanghai. Following his recent retirement from Philips, he advises lighting designers, researchers, companies, municipalities and public bodies in the Netherlands and abroad in his capacity as an independent lighting consultant.

Rob van Beek is a restoration architect, who graduated from the Restoration Department of the Royal Academy of fine arts in Copenhagen. He has been working for the Government Buildings Agency since 2000 and for the Monument Cluster from 2009. As an architect he is involved in various lighting projects in monuments owned by the Government Buildings Agency. He also is a member of the Netherlands Lighting Foundation (Nederlandse Stichting Voor Verlichtingskunde, NSVV) Light and Health Committee. In addition to his work at the Government Buildings Agency, he has been involved in the development of light fittings for the Swedish Fagerhult Company since 2006. This has resulted in a number of his own designs, which now form part of the Fagerhult collection.

Henk van der Geest is a lighting designer for architecture and theatre, a role he has fulfilled since 1982. In this position he was responsible for the lighting of hundreds of theatre, dance and opera company productions. Based on his background in theatre, he incorporates the dramatics of light in architecture. Museum and exhibition illumination has meanwhile become his area of expertise. He founded the Institute for Lighting Design (Instituut Lichtontwerp, iLO) in 2006 to support talented young lighting designers in their early career. The institute contributes to the overall professionalisation of the lighting design profession in the Netherlands. He holds domestic and international workshops for prospective lighting designers as well as for people that work with lighting designers, with a primary focus on teaching them to communicate about light.

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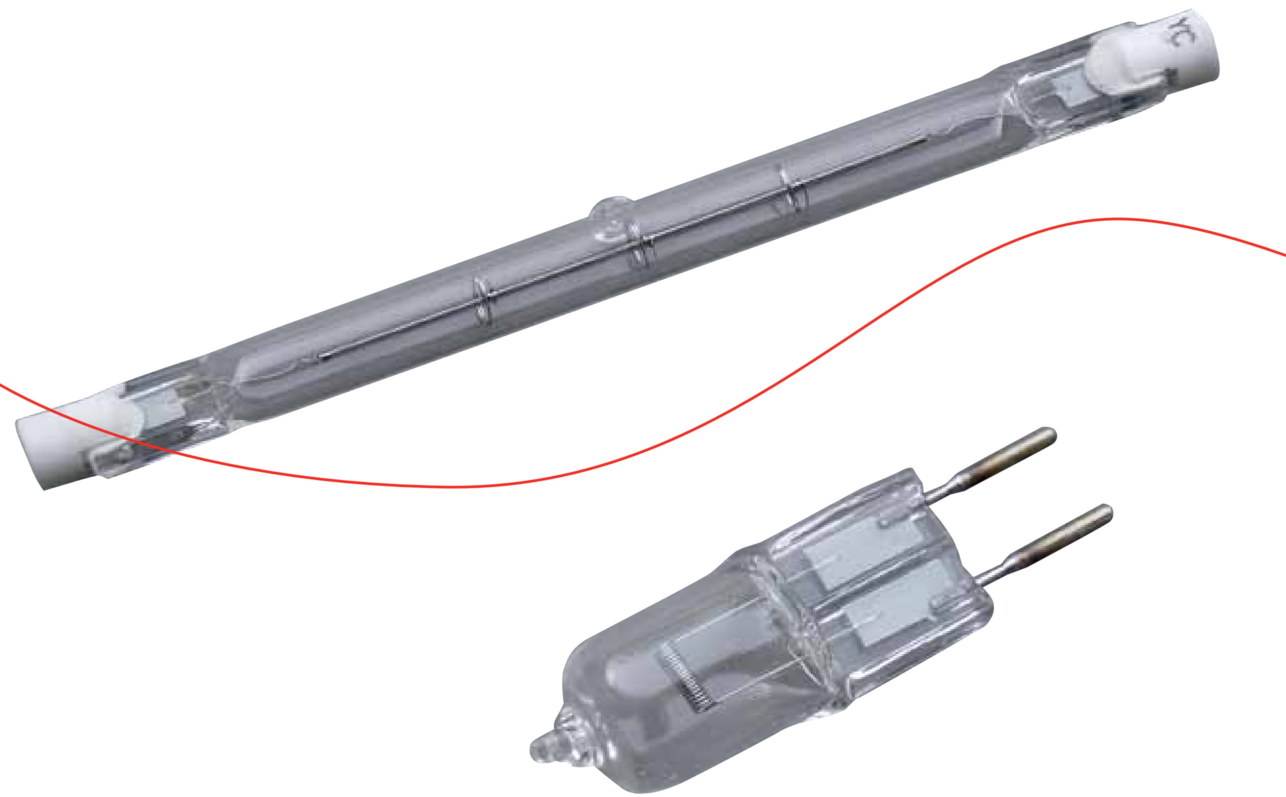

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