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GUIDE FOR FLOODLIGHTING

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This Technical Report has been prepared by CIE Technical Committee 5-06 of Division 5 'Exterior and other Lighting Applications' and has been approved by the Board of Administration of the Commission Internationale de l'Eclairage for study and application. The document reports on current knowledge and experience within the specific field of light and lighting described, and is intended to be used by the CIE membership and other interested parties. It should be noted, however, that the status of this document is advisory and not mandatory. The latest CIE proceedings or CIE NEWS should be consulted regarding possible subsequent amendments.

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PREFACE

At the XXth congress of the CIE at Amsterdam in 1983, the Technical Committee TC 5-06 was formed to study floodlighting, later extended to include exterior decorative lighting.

During the early meetings it became apparent that many of the elements contained in CIE Publication 37 (1976) were of value and should be brought up to date and incorporated in the new publication. This has been done and the present Guide now replaces Publication 37.

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SUMMARY

The purpose of this Guide from CIE Technical Committee TC 5-06 is to provide information on how to use exterior lighting for the decoration of the night time urban landscape. Of the many possible applications of lighting in an urban environment, this Guide deals with those having a purely aesthetic and decorative purpose. Such lighting can be used every night, as is often the case in the lighting of monuments, public art, commercial buildings, or used only periodically on the occasion of a festival or public gathering. The lighting of natural sites, parks, and gardens is also dealt with in this Guide. Permanent lighting for traffic or public safety, although affecting the quality of a city's night time ambience, is not dealt with in the Guide. The Guide provides tools for the exterior lighting designer and ideas for the town architect. For those who have to make the decisions on expenditure, this Guide explains the possibilities of combining outdoor urban beautification with economical and energy friendly decorative lighting.

ZUSAMMENFASSUNG

Diese Veröffentlichung des Technischen Komitees der CIE TC 5-06 hat zum Zweck, Informationen darüber zu geben, wie die Außenbeleuchtung dekorativ in der nächtlichen Stadtlandschaft eingesetzt werden kann. Von den vielen möglichen Lichtapplikationen in der Stadt behandelt diese Veröffentlichung solche, die einen ästhetischen und dekorativen Zweck erfüllen. Diese Beleuchtung kann jede Nacht eingesetzt werden, wie z. B. bei Denkmälern, Kunstwerken, öffentlichen Gebäuden, oder nur periodisch bei Festen oder Versammlungen. Ferner wird in dieser Veröffentlichung auch auf die Beleuchtung von Naturlandschaften, Parks, Gärten und Blumenbeeten eingegangen. Die ständige Beleuchtung zum Zwecke der Verkehrssicherheit oder der öffentlichen Sicherheit wird in dieser Publikation nicht behandelt, obwohl sie sich auf das nächtliche Wohlbefinden in den Städten auswirkt. Diese Veröffentlichung bietet auch Hilfsmittel für den Designer von Außenbeleuchtungen und Ideen für den Stadtplaner. Für Entscheidungsträger wird die Möglichkeit der Verschönerung des Stadtbildes durch energiesparende dekorative Beleuchtung beschrieben.

RESUME

L'objectif de ce guide, préparé par le Comité Technique TC 5-06 de la CIE, est de donner des informations sur les différentes manières d'utiliser l'éclairage extérieur pour la mise en valeur du paysage urbain nocturne. Parmi toutes les applications possibles de la lumière dans l'environnement urbain, il traite plus spécialement de celles ayant un objectif esthétique et décoratif. De tels éclairages peuvent être utilisés, soit chaque soir, c'est en général le cas pour les illuminations des monuments, des oeuvres d'art et l'éclairage des immeubles à l'usage commercial, soit périodiquement lors des festivités et réunions publiques. Ce guide traite aussi de l'éclairage des sites naturels, jardins et massifs floraux. Par contre, il n'aborde pas l'éclairage pour la circulation automobile ou la sécurité publique, bien que ces équipements aient une influence sur l'ambiance urbaine nocturne. Ce guide donne les informations de base nécessaires aux concepteurs en éclairage extérieur et aux architectes urbanistes. Il décrit également, à l'intention des décideurs, les possibilités d'améliorer l'esthétique urbaine par un éclairage qui soit décoratif tout en ne gaspillant pas l'énergie.

1. INTRODUCTION

1.1 SURVEY OF SUBJECTS

With the evolution of lighting techniques, the relative cost of lighting has steadily diminished; it is now reasonable to use exterior lighting for purposes such as animation and decoration of the night-time urban landscape. Investment in urban decorative lighting has both social and economic benefits.

A well-lit city is a welcoming, reassuring and agreeable place in which to live. It attracts the tourist and holds his interest. It improves the quality of life for the residents by favouring and prolonging the time available for personal contact. At the urban level, lighting integrates the building into the context of the site. No longer made up simply of façades with geometric proportions, buildings become the elements of a subtle composition, where masses alternate with spaces according to the creativity of the planner. Architecture becomes a journey, and light is present everywhere to highlight the itinerary. The spatial impressions offered to the viewer are continually renewed, whether he is at close or long range from the object. Light becomes a working tool for the architect and the city planner to a degree never before possible, on a scale from the very small to the very large.

To a greater and greater extent, and this is where the renewed interest in decorative lighting lies, the marriage between the illuminated object and the light source becomes intimate. A few years ago, a decorative lighting project was regarded as a success if, by projecting an intelligently planned light on it, it permitted the observer to recognize the object. The situation is different now; the modern architect uses light as a supplementary tool and the lighting project is no longer required to be neutral or objective. It allows buildings and other subjects to be shown at night from a point of view that is original and can be planned in advance.

Whether the lighting is classical or modern, uniform or selective, constant or flashing, slow or fast, it can penetrate urban spaces and buildings, and objects will glow as they are bathed in its rays.

The qualities apparent in these constructions during the day are not always evident at night. Light now brings additional effects, thanks in part to the fact that light sources in a good decorative lighting scheme are no longer found only on the outside, but are intimately mixed with the masses and the spaces. New and previously unknown effects emerge from each fold and corner. The purpose is to reinforce the three-dimensional image of the architecture.

It is important to realize that:

- a) light, thanks to technical and electronic advances, can be varied according to the desires of the user to an unprecedented degree,
- b) there is an increasing tendency to mix the qualities of daylight and artificial light, giving "exterior" decorative lighting a new dimension,
- c) many new artists are using light to contribute to the dynamism of constructed objects, whether functional or purely decorative,
- d) the play of light, integrated with the architecture, is increasingly linked to the other tools of the architect, such as acoustics, movement, water and advanced technology.

In conclusion, we note the title of a book by the architects Venturi and Rauch, on *"Complexity and contradiction in architecture"*; if these two key words are valid for urbanism and architecture, could not one also speak of *"Complexity and contradiction in decorative lighting"* in order to describe the immense richness of possibility and lighting in our environment ?

1.2 SCOPE

Of the many possible applications of lighting in the city, this document only deals with those having a purely aesthetic and decorative purpose. This lighting may be used every night, or used only occasionally for a festival or public gathering. For the latter, the equipment requires to be installed only for the duration of the festivities.

This document does not cover lighting for traffic or pedestrian movement, nor for the security of property, which are covered by the CIE Publications 12.2, 23, 32/AB, 33/AB, 47, 61, 68, 88 and 92.

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2. DEFINITIONS

2.1 TYPES OF SUBJECT

When the objective of a lighting project is principally or solely decorative, many subjects justify the use of light in bringing out their outstanding features. These subjects may be natural or landscaped spaces, as well as buildings both ancient and contemporary.

2.1.1 *Classic buildings*

These are any buildings meriting interest by their architectural, aesthetic, or plastic qualities; cathedrals, castles, churches, theatres, certain public or private buildings, etc.

2.1.2 *Commercial and industrial buildings*

Buildings used as offices or factories may be lit if the aesthetics, the balance of the volumes and the quality of the façade of the building justify the lighting installation. This kind of lighting is nevertheless controversial from a decorative point of view, as its principal purpose is usually to ensure safety, and to offer a commercial or public relations advantage.

2.1.3 *Natural sites*

Nature is a great architect. Cliffs, gorges and waterfalls may contribute to the animation of the city by night, or constitute a point of interest in themselves if they are located outside metropolitan area.

2.1.4 *Constructions*

Constructions are technical or utilitarian structures, not intended for human habitation, which by their aesthetic import and their audacious or novel conception, constitute a benchmark in the evolution of technical knowledge and skill. Examples are bridges, viaducts, towers, railway stations, water-towers, walls, dams, etc.

2.1.5 *Artworks and pavilions*

Artworks are all creations in any material or medium having a purely decorative function, such as statues, sculptures, bas-reliefs, mobiles

Pavilions are small constructions intended for decoration or space arrangement, usually without a functional purpose and not inhabited; examples are shelters, gazebos, follies, etc.

2.1.6 *Parks, gardens, and flowerbeds*

These include all landscaped areas, especially those intended for enjoyment and relaxation, such as woodlands, shrubberies, and flowerbeds, according to fixed or seasonal plans; also all plantations in beds and boxes arranged in pedestrian zones.

2.2 LIGHTING EFFECTS

To create a night-time urban decor, light can be used in many ways to reveal the presence of a natural site or a constructed object. The user has a choice of the most diverse kinds of sources of light used bare or, more generally, in luminaires.

Modern technology is sufficiently flexible to produce the decorative luminous effect desired or to provide the luminous emphasis required on any edifice or artwork. The architect,

the artist and the decorator, working in collaboration with the lighting engineer, will have a complete panoply of means at their disposal to create the desired effect.

2.2.1 Static floodlighting

Floodlighting is the lighting of a flat or a three-dimensional subject, such as a building façade, a monument, or an artwork, in order to make it visible at night and to reveal its plastic or historical aspects.

The subject stands out from its background and its environment because of its relatively greater luminance. The effect is permanent and static. It is generally achieved by floodlights carefully positioned around the subject.

2.2.2 Floodlighting with variable luminous effects - Dynamic floodlighting

This is the same basic notion as floodlighting (2.2.1), but the effect is enhanced by varying the level of lighting on different parts of the subject, creating animation.

2.2.3 Outline lighting

This effect is achieved by creating strong contrast between the surfaces and the spaces of a building or between the shaped edges of a feature and its background.

Silhouette, or backlighting, is obtained either by projecting light on the back of an element or by creating a luminous background against which the outline of the structure of the subject appears dark or black. This is particularly appropriate for non-massive constructions such as colonnades, crenellations or metal skeleton structures; the object remains in darkness and the light spaces become important.

Reverse silhouette emphasises the principal characteristics of a construction by making the edges and contours in the foreground bright against a darker background, revealing the whole volume and general appearance of the subject.

2.2.4 Self-luminous effects

Self-luminous decorative effects can be created by the form, the colour and the arrangement of light sources themselves, not attempting to illuminate particular objects. One example is the use of decorative strings or festoons of lamps; another is the display of illuminated motifs (butterflies, birds, flowers, etc.).

There are new techniques in self-luminous effects which are still being developed. These include lasers, holograms and slide projections which can be used to create animated or fixed displays. These installations are generally localized and temporary.

2.2.5 "Son et Lumière"

This is a programme of limited duration in the form of a dramatic presentation, based on the floodlighting of a subject by a succession of white and coloured light, in a rhythm tied to the speaking of a historical or other type of narrative and completed by an accompaniment of music and sound effects. This particular technique is only mentioned in passing, and is not developed in detail in the document because it has more of the characteristics of a show than of a decorative lighting project.

3. DECORATIVE LIGHTING: ITS CONCEPT AND ACHIEVEMENT

The technical and artistic conception of a decorative lighting project is only a part of the entire task to be undertaken between the initial decision and the inauguration of the installation. Amongst the many necessary considerations, certain historical and administrative problems must be closely studied to avoid errors and disappointments.

The following paragraphs take up the important points as they occur chronologically.

3.1 PRELIMINARY RESEARCH

In any project to highlight a building or an artistic construction by static floodlighting, dynamic floodlighting, outline lighting or "son et lumière", it is essential to collect the historical, architectural and local information concerning the subject. This permits the designer to appreciate the importance of the different parts of the edifice, their symbolism and their interest, and allows him to recreate this hierarchy in the lighting.

For old structures, the architects, historians, and curators involved with the monuments are generally the best qualified to furnish this kind of information. The municipal, regional or national services and departments of architecture and archives, can also be called upon to furnish pertinent information. For contemporary structures, the architects and engineers involved in the conception and realization must contribute to any decisions on the lighting.

3.2 PRIVATE AND ADMINISTRATIVE AUTHORIZATION

3.2.1 *Owner authorization*

The organization promoting a decorative lighting project is not always the owner of the subject to be lit. Even where the lighting equipment is not mounted on the subject itself, it is essential to obtain the authorization of the owner whether a private party or a local, regional or national authority.

3.2.2 *Administrative authorization*

At historical sites, permission must be obtained from the administrative or architectural authority responsible for conservation and coordination of the work.

Depending on the position of the monument to be lighted, it may be necessary to consult the Aviation and Maritime navigation services concerning any interference that this lighting might cause to air traffic or to shipping.

3.2.3 *Community and third-party interests*

In cities, the luminaires (floodlights and decorative string lighting) are often attached to neighbouring buildings. It is necessary to obtain the permission of the owners before attaching fixtures to their building.

3.3 DOCUMENTATION

A decorative lighting project requires knowledge of the surfaces and volumes to be lit, the emplacements for lighting, and the anchor-points for the supports. Researching the following documents is desirable.

3.3.1 *Maps and plans*

The floorplans and façade drawings of the monument, surveyor's plans, street and area maps, as well as any sketches or surveys, must be studied.

These documents are generally available from architects and curators and at the municipal, regional or national archives. Detailed road maps and maps of other public rights-of-way are generally available from the city's technical services departments.

3.3.2 *Photographs*

Photographs of the subject, the surroundings, or the public ways complement the maps and plans. Views of the surrounding area help in finding, at the time of the preliminary study, possible locations for the lights to suit the height and arrangement of the neighbouring buildings.

Photomontages and aerial views are also useful in developing the project.

3.4 PRELIMINARY SITE STUDY

Contrary to highway, office, or factory lighting which can be designed from plans alone, a decorative lighting project demands a preliminary visit to the site, so that the designer can fully appreciate the characteristics of the surroundings and how they will influence the project. The designer must take the following elements into account:

3.4.1 *Surrounding night-time lighting*

An examination of the surrounding lighting, whether public or commercial, is necessary in determining the illuminance level necessary to achieve the desired effect on the subject. The more the surrounding area is lit, the greater the illuminance necessary to make the decorative effect perceptible.

3.4.2 *Seasonal influences*

The presence of deciduous trees and bushes must be taken into account for permanent installations. Foliage constitutes a kind of mask which, according to the situation, either blocks light from the luminaires or serves to hide them, rendering the total installation more pleasing and less dazzling.

Fountains are stopped and ponds may be emptied during the winter months, which may significantly change the character of an urban site.

Account should also be taken of the seasons in the choice of light sources. A "warm" light such as high pressure sodium may be used in the winter on leafless trees; in summer, a cold light is preferable for use on foliage. Two parallel installations may be required, one for each season.

3.4.3 Access

The installation and subsequent maintenance of floodlighting and other lighting effects, may necessitate the use of a tower wagon or other equipment to gain access. The route for moving this equipment to the site must be confirmed well in advance, particularly if it is via pedestrian zones or narrow streets.

3.4.4 Viewing points

For floodlighting projects, the viewing positions or observation points strongly influence the preferred direction of the lighting (see chapter 5). To minimize the risk of glare, the light sources should ideally be hidden from direct view both by day and night.

Other kinds of lighting effect such as decorative festoon lights should be set up when the direction of view is known.

3.4.5 Power supply

All lighting locations must have easy access to the electrical power supply; the cost of providing the supply may be related to the importance of the project.

Areas that are difficult of access by electric cables should be avoided as far as possible; in order to ensure access, the routes for electrical conduits should be determined at the same time as the luminaire positions are chosen.

3.4.6 Financial considerations

Estimation of the costs involved in a decorative lighting or a floodlighting project is a complicated procedure: criteria relevant to one scheme may not be applicable to an apparently similar scheme, because the specific characteristics of each subject have to be assessed in relation to its particular geographical situation.

Several schemes to achieve the original lighting concept may be explored in the early planning stages to provide a range of costs and construction programmes from which the most advantageous can be chosen.

3.5 PRELIMINARY PLAN

3.5.1 Procedures and criteria

Once the preceding information and the documents have been assembled, the designer can begin preliminary studies.

Most important at this stage is to determine the lighting effects which are appropriate for the particular subject or site, and whether their achievement is feasible and in accordance with the objectives of the project. In general, the overall lighting concept requires a greater degree of expertise when the subject is of large dimensions, complex structure, or of great historical importance.

In complex schemes, a small-scale lighting test can provide valuable information in planning the definitive project. In addition, such a test demonstrates to the non-professionals involved in planning the project, how the equipment achieves the end result. It is easier to visualize what one gets for one's money. The cost of lighting tests is such that they are often only practicable for large and complex installations, although they can be valuable for projects of any size.

The choice of light sources, the evaluation of their power and the selection of the luminaires depend on the objectives of the project and on the proposed frequency of use (daily, weekly, seasonal, periodic or temporary) as well as on the characteristics of the subject, its dimensions, its colour, etc.

The preliminary plan should include:

- determination of the numbers, rating and type of luminaire to be used at each source point,
- an estimation of the electrical power necessary,
- an evaluation of the installation and operating costs and the duration of the work,
- preliminary approval by the project supervisor as well as by the competent authorities,
- preliminary tests of lighting in the most sensitive areas,
- negotiation of authorizations for location of the equipment and for access over private property (way-leaves).

3.5.2 Energy conservation

Whilst the primary objective of any project is to achieve a high quality of lighting, it is important to find the most efficient solution, with respect to both the cost of the installation and its energy consumption.

3.6 FINAL PLAN FOR THE PROJECT

The information collected during the preliminary investigation should be sufficient for a definitive plan for the final project to be drawn up. This plan should include the data for the number and types of lighting units and their auxiliary equipment, the power and make of the lamps and instructions for mounting and supporting each proposed component. Details of the electrical supply (routeing and cable sections, power and location of the sub-station and circuit protection) are not an integral part of the lighting concept because they require a different technical expertise. These details could nevertheless be determined by the same person if he is technically proficient.

The final project plan enables the determination of an exact budget for financing purposes. It is also useful for requesting final authorizations (attachments, use of public and private property, way-leaves, etc.).

3.7 INSTALLATION AND ADJUSTMENT

The installation work must be done by a contractor competent in decorative lighting who will ensure correct installation of the selected equipment.

Adjustment is the final phase before the lighting is put into service. At this time, checks are made of floodlight orientation, sound and lighting effects and any other necessary final corrections are made to the project. Two-way radios are recommended for use in large-scale installations. This adjustment phase is essential to the success of a decorative lighting project, and must be completed with the greatest care in conjunction with the designer of the installation.

4. LIGHT SOURCES

This chapter gives an overview, summarized in Table 1, of the principal characteristics of light sources used in exterior decorative lighting. Most of these types of lamp are under constant development; this chapter describes the situation in 1992.

4.1 INCANDESCENT LAMPS (*Tungsten filament lamps*)

Although incandescent lamps are no longer suited to urban or highway lighting, they remain useful in many kinds of exterior decorative lighting. Since these applications are generally for a short period of time, the short service life and poor efficacy are not problems.

These lamps offer the following advantages:

- colour temperature appropriate to a wide range of lighting effects,
- good colour rendering,
- large range of types and ratings,
- extra-low-voltage power supplies can be used,
- possibility of repeated switching for dynamic effects,
- can be dimmed.

4.1.1 *General lighting service lamps*

These lamps have a luminous efficacy of 5 to 25 lm/W, according to their ratings, and a rated life of approximately 1000 hours. For decorative lighting use, notably in festoon lighting, they are available in low ratings in a variety of colours.

Applications: decorative string lighting, luminous motifs, low lighting for flowerbeds.

4.1.2 *Soft-glass reflector lamps*

The bulb contains a reflector, usually of aluminum or silicates, which gives a directed luminous beam. They are available in white and in colour, in ratings from 40 to 300 watts, and often in a variety of beam angles. Special lamps with bulbs of neodymium glass can increase relative output in the blue and green ranges.

Applications: localized lighting

4.1.3 *Crown-silvered lamps*

The aluminized surface on the inside of the bulb directs the light from the filament in such a way that, when placed in a suitable external reflector, a narrow beam is obtained. These lamps exist in ratings of 25, 40, 60 and 100 watts.

Application: localized lighting with special luminaires.

4.1.4 *Extra-low-voltage lamps*

The principal advantage of incandescent extra-low-voltage lamps is an improved luminous efficacy. The compact filament facilitates control of luminous output and enables the use of floodlights with a narrow beam and an increased luminous intensity along the beam axis. These lamps are limited to low-power use. Use of extra-low-voltage lamps reduces the risk to passers-by in the event of a fault or accident. Both standard and halogen extra-low-voltage lamps are available.

Applications: punctual spot lighting, installations requiring protection of the public.

4.1.5 Halogen lamps

These lamps take advantage of the tungsten-halogen cycle, which gives them a higher luminous efficacy, a higher colour temperature, and a longer rated life than standard incandescent lamps. Certain precautions are necessary in handling these lamps to avoid damaging the quartz bulb.

Halogen lamps rated between 100 and 2000 watts having a tubular form and a socket contact at each end, must be used in a horizontal position. The linear form of their filament allows precise control of luminous flux in a parabolic trough reflector.

In the version known as the "double envelope" lamp, the quartz bulb is fixed inside a glass bulb with a single lamp cap. This type may be operated in any position, and presents no handling problems.

The technology involved in these lamps is developing rapidly. The choice is expanding, particularly in the low-rating range of mains voltage and extra-low-voltage lamps.

Applications: floodlighting.

4.1.6 Sealed-beam (PAR) lamps

The bulb is made of a robust thick pressed glass with a silvered or aluminised interior surface and a plain or prismatic front. This optical system provides a simple control of the luminous flux and forms a beam without the need for an external reflector. The beam spreads available range from 6 to 120 degrees, according to the power and the type.

The ratings for incandescent versions range from 25 to 500 watts with a rated life averaging 2000 hours. Halogen versions are available up to 1000 watts and some ratings have lives averaging up to 4000 hours. As the reflecting surface is renewed each time a lamp is changed, a steady output is assured. PAR lamps are available in low voltage (120 and 240 volts) as well as in extra-low-voltage (6 volts, 12 volts, etc.).

Coloured light may be obtained from PAR lamps by using a coloured glass filter, a dichroic coating or a coloured lacquer (blue, green, yellow or red in 80 watts). An internal dichroic reflecting surface, instead of metallic, can give coloured light in the beam without using coloured glass or lacquer, or can give the so-called "cool beam" output; such lamps may heat the luminaire more than with metallic reflection.

PAR lamps are very well suited to the lighting of buildings and artworks.

Applications: floodlighting, localized illumination.

4.2 DISCHARGE LAMPS

All discharge lamps require auxiliary electrical equipment (ballast, ignitor, capacitor) to limit the current and to ensure proper igniting and re-igniting of the discharge. In most lamps, there are time delays in ignition and re-ignition.

These lamps have greater luminous output and longer lives than incandescent lamps, which makes them economical in use. The technology involved in these lamps is developing rapidly.

4.2.1 Fluorescent lamps

4.2.1.1 Standard fluorescent tubular lamps

These lamps are available in many different ratings, lengths, diameters, and nuances of colour. Their linear form makes them suitable for use in the luminous outlining of constructions, in lighting balustrades, and other similar applications.

Decorative effects can be obtained by using coloured fluorescent lamps as well as differently tinted "bright white" or "daylight" lamps.

Their outdoor use is limited by their sensitivity to low temperatures.

4.2.1.2 Compact fluorescent lamps

These lamps are miniaturized fluorescent lamps and there are many types available. Generally of small diameter, compact lamps have a wide variety of shapes: U, double U and double D. Some can directly replace ordinary incandescent lamps and incorporate a traditional or electronic ballast and ignitor, and e. g. an E27 or B22 base. Other varieties, intended for use with special sockets, contain only the ignitor, and require an external ballast.

These compact fluorescent lamps have definite economic advantages over traditional incandescent lamps; the rated life is at least five times longer and luminous efficacy is four to five times higher.

In exterior decorative lighting, they can be used in very diverse applications, such as floodlighting in decorative strings or festoons, and so on. It is still important, however, to take into account the influence of ambient temperature on the operating characteristics of the lamps. Built on the same principles as the fluorescent lamp, they function best with long periods of continuous operation; frequent switching is prejudicial to their service life.

Applications: luminous silhouettes, signboards, traffic applications.

4.2.2 Cold cathode lamps

These long, fine tubes can be shaped to accomplish many purposes, such as following the lines of a construction or establishing separate decorative motifs.

They have a low luminous efficacy, but a long rated life. The large range of colours available allows for numerous special effects. They light instantly and are not affected by repeated switching which makes them suitable for long-term animation effects.

As these lamps require a power source of several thousand volts, their use imposes certain precautions and the strict observance of electrical safety regulations for the protection of the public.

Applications: luminous silhouettes of buildings, luminous decorative motifs.

4.2.3 High-pressure mercury lamps

Based on the principle of electrical discharge in high pressure mercury vapour, these lamps are available in ratings from 50 to 1000 watts. The discharge tube is placed inside a glass bulb, usually coated on the inside with a fluorescent powder to correct the colour of the light emitted by the discharge.

For decorative lighting of pools and foliage, lamps with clear tubular or ellipsoidal outer bulbs are sometimes used, as their blue-green light is particularly suitable. Some ratings are available with an internal phosphor reflecting reflector.

There are also lamps based on this same principle, but stabilised by an internal filament. The light emitted is much warmer, but the luminous efficacy is significantly reduced.

High pressure mercury vapour lamps have a long rated life and a luminous efficacy of the order of 30 to 60 lm/W. Their shape and size preclude their use in narrow-beam projectors for lighting from long distances, but they are well suited for lighting large areas. Lighting is not instantaneous and re-striking requires either an interval for cooling or a special high-voltage restarting system. These lamps are thus very difficult to use in dynamic effects.

Applications: floodlighting for trees and vegetation (dominant blue-green).

4.2.4 Metal-halide lamps

These lamps are made up of a quartz discharge tube containing mercury vapour and different metal halide additives. They are available in various forms. The discharge tube is either bare with a contact at each end, or enclosed in a clear tubular or ovoid bulb covered with fluorescent powder, with or without an internal reflector, with a standard base.

They are available in a range of ratings from 30 W to 3500 W with a luminous efficacy ranging from 50 to 125 lm/W, colour temperatures from 3500 to 6500 K and colour rendering indices from 50 to 85.

The small dimensions of the discharge tube, enclosed in a clear glass envelope, allow for focusing in projectors to give a precise beam. It is nevertheless necessary to take into account the limitations on the operating angle, which may be different for each type of lamp. The recommendations of the manufacturer should be followed.

A PAR type of metal-halide lamp with an internal reflecting surface is available, rated at 1000 watts. The narrow beam spread (about 6 degrees) and the high axial intensity make it suitable for lighting from long distances. Exterior prismatic lenses may be used to modify the beam spread and intensity.

In addition to the ballasts and capacitors needed to stabilize them, these lamps require a separate ignitor. As with high-pressure mercury vapour lamps, striking and re-striking takes several minutes. There are special "instant" re-striking types also available.

Applications: floodlighting projectors with very precise colour rendering.

4.2.5 High-pressure sodium lamps

The golden-white colour of the light ($T = 2000$ K), the luminous efficacy of 90 to 170 lm/W, the acceptable colour rendering index (from 20 to 85) and the long rated life, give these sources a wide range of application in exterior decorative lighting. The small discharge tube is enclosed, according to the manufacturing specifications, in either a clear tubular glass bulb, or an ovoid opaline bulb. With the clear glass version, the lamp may be focused by a precise beam projector.

In addition to the ballasts and capacitors needed to stabilize them, many of these lamps require a separate ignitor.

There are also low power versions (35 and 50 watts) with a colour temperature approaching 2500 K, a colour rendering index of 80 and a luminous efficacy of 45 lm/W. Their colour gives the same impression as that of incandescent, but they last five times longer and give four times as much light. With their very reduced size, they can be focused by precise reflectors, making them potentially very suitable for achieving certain luminous effects.

High-pressure sodium lamps are also available with characteristics which allow their use in standard high-pressure mercury lamp luminaires; with a slightly lower wattage, these lamps provide approximately 50 % more light. Thus a lighting installation can be upgraded at little cost. In addition, the lamps may be changed to adapt the colour of the light to seasonal requirements, although lighting vegetation with high-pressure sodium sources can sometimes give disappointing results.

Applications: floodlighting for buildings, primarily in brown, red or yellow materials.

4.2.6 Low-pressure sodium lamps

These lamps have a high luminous efficacy (up to 200 lm/W) and a fairly long rated life. The inner discharge tube is enclosed in a tubular outer bulb; the power range is 15 to 200 watts. Their light is a pure monochromatic yellow, with no colour rendering, which limits their use to special luminous effects; examples are the lighting of yellow or orange surfaces, silhouette lighting and the accentuation of architectural elements such as vaulting or the arches of bridges.

Applications: special (yellow) floodlighting effects, security lighting.

Table 1

Table 1: Principal characteristics of light sources. Exact values may be obtained from the manufacturers. Light source technology is in constant development; these values are intended for non-specialist users. Exact values may be obtained from the manufacturers. Light source technology is in constant development; this table describes the situation in 1992.

Lamp type and reference number in text	Initial luminous flux (lumens)	Rating ranges (watts)	Auxiliary equipment necessary	Luminous efficacy (lm.W ⁻¹)		Approximate colour temperature (K)	Colour rendering index (Ra)	Rated life (hours)	Striking time		Restriking time
				lamp alone	including ballast loss				min = minutes s = seconds		
TUNGSTEN FILAMENT LAMPS											
4.1.1 General lighting service	50 - 35000	10 - 1500	NO	5 - 25	-	2500 - 3000	100	100 - 2000	instantaneous		instantaneous
4.1.5 Halogen lamps	150 - 120000	10 - 5000	NO	15 - 30	-	2800 - 3300	100	50 - 2000	instantaneous		instantaneous
4.2 LOW-PRESSURE DISCHARGE LAMPS											
4.2.1 Fluorescent lamps (tubular, compact)	150 - 15000	4 - 200	YES	40 - 100	30 - 80	2500 - 6500	60 - 95	5000 - 20000	< 3 s		< 1 s
4.2.6 Low-pressure sodium vapour	1500 - 35000	15 - 200	YES	100 - 200	72 - 160	1700	---	10000-15000	7 - 12 min		0 - 10 s
4.2 HIGH-PRESSURE DISCHARGE LAMPS											
4.2.3 Mercury high-pressure lamps	up to 60000	50 - 1000	YES	30 - 60	26 - 57	3000 - 6000	25 - 60	10000-20000	4 min		10 min
4.2.4 Metal halide lamps	1500 - 30000	30 - 3500	YES	50 - 125	43 - 120	3500 - 6500	50 - 85	2000 - 10000	5 min		10 min
4.2.5 Sodium high-pressure lamps: normal	up to 150000	35 - 1000	YES	70 - 150	90 - 170	2000	20	10000-25000	5-10 min		1 - 5 min
colour improved and "white" versions	up to 40000	30 - 400	YES	45 - 100	36 - 94	2100 - 2800	60 - 85	5000 - 15000	5-10 min		1 - 5 min