TCXDVN

VIETNAM CONSTRUCTION STANDARDS

TCXDVN 333 : 2005

Artificial outdoor lighting for public buildings and urban infrastructure – Design standard

(This English version is for reference only)

CONSTRUCTION PUBLISHING HOUSE

Foreword

The standard TCXDVN 333: 2005 "Artificial outdoor lighting for public buildings and urban infrastructure - Design standard" was published by the Minister of Construction in accordance with Decision No 08/ 2005/ QD – BXD on April 4, 2005.

This standard replaces TCXD 95: 1983 "Standard design for artificial outdoor lightning for civil construction".

Artificial outdoor lighting for public buildings and urban infrastructure - Design standard

1. The scope:

This standard is applied to calculate designation, supervision and inspection to evaluate the quality of artificial lightning system outside public construction and urban infrastructure. This standard also replaces the construction standard TCXD 95: 1983 - Standard design for artificial outdoor lightning for civil construction.

Public constructions and urban infrastructures consist the following:

- Public constructions: outdoor parking; roads, bridges and passenger tunnel; the outside of schools, hospitals, trade centers, exhibition centers and headquarters.

- Parks and gardens.

- Architecture constructions – Fountains – Monuments.

- Outdoor sport constructions.

Note:

- In addition to abide this standard, designing lightning system must abide current related standards and regulations.
- This standard is not applied in designing artificial lightning inside urban infrastructures (railway stations, bus stations…) and indoor/ roof sport constructions.
- All lightning technical terminologies used in this standard are explained in appendix 1, besides; the standard TCVN 4400: 1987 – Lightning technology – Terminologies and definitions can be used as reference.

2. Normative reference:

2.1. TCVN 4400: 1987 – Lighting technics. Terms and definitions.

2.2. TCXDVN 259: 2001 – Designing artificial lightning standard for urban roads, streets, squares.

2.3. 11 TCN 18: 1984 – Electric equipment regulations – Part 1: General regulations.

2.4. 11 TCN 19: 1984 - Electric equipment regulations – Part 2: Line of conduct system.

2.5. TCVN 5828: 1994 – Street electric luminairs. General technical requirements.

2.6. TCVN 4086: 1985 – Electrical safety in construction. Specifications.

2.7. TCVN 4756: 1989 – Code of practice of ground connection and 'O' connection of electrical equipments.

2.8. Related Vietnamese standards on environment and landscape protection.

3. General regulations:

3.1. This standard is applied to design artificial lightning which uses discharge lamps (fluorescence; high voltage mercury; Metal halide; high voltage sodium, low voltage sodium) and incandescent lamps (including haloids incandescent lamp). For cases using different typical lightning (high voltage LED, induction lamp), we can use equivalent research method based on technical functions of lamps.

3.2. Artificial lightning system outside public constructions and urban infrastructures (except outdoor sport constructions) may be a part of public lightning system. It is funded and controlled by a general control network of urban public lightning system. On the other hand, it can be manage and operate independently. Lightning system for training and competition at sport construction is needed managing and operating independently.

3.3. Defining the standard illumination (in lux) must follow illumination scale stipulated in table 1.

Table 1: Standard illumination scale

Scale	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Illumination (lx)	0,5	1	2	3	5	7	10	20	30	50	75	100

XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XXI	XXII	XXIII	XXIV	XXV
150	200	300	400	500	600	750	1000	1250	1500	2000	2500	3000

3.4. When calculating the design, maintaining coefficient of lamps which is stipulated in table 2 must be considered.

Table 2: Maintaining coefficient of lamps

Lamp Maintenance Cycle (Months)	Protection level of lamps								
	IP 2X			IP 5X			IP 6X		
	Environment Selection			Environment Selection			Environment Selection		
	Big cities, heavy industrial zones	Small and medium cities, light industrial zones	Rural Area	Big cities, heavy industrial zones	Small and medium cities, light industrial zones	Rural Area	Big cities, heavy industrial zones	Small and medium cities, light industrial zones	Rural Area
12	0,53	0,62	0,82	0,89	0,90	0,92	0,91	0,92	0,93
18	0,48	0,58	0,80	0,87	0,88	0,91	0,90	0,91	0,92
24	0,45	0,56	0,79	0,84	0,86	0,90	0,88	0,89	0,91
36	0,42	0,53	0,78	0,76	0,82	0,88	0,83	0,87	0,90

3.5. All lightning equipments used must have high electric using efficiency, durability and optical maintenance ability in the conditions of outdoor working. Also, they have to have minimum IP protection level as regulations in table 3.

Table 3: Minimum IP protection level of lightning equipments

No.	Characteristic – working environment selection	Minimum IP protection level
1	Lamps in rural area	IP 23
2	Lamps in small and medium cities, light industrial zones and dwelling buildings	IP 44
3	Lamps in big cities and heavy industrial zones	Optical part: IP 54 Other parts: IP 44
4	Lamps hanging under 3m height	IP 44
5	Lamps in tunnels, on bridges	IP 55
6	The position of lamps can be flooded	IP 67
7	Lamps usually operate under water	IP 68

3.6. Designing electric supply for lightning system must abide the following standards:

- 11 TCN 18: 1984 – Regulations on electric equipment – Part 1: General regulations
- 11 TCN 19: 1984 - Regulations on electric equipment – Part 2: Line of conduct system.

3.7. Lightning system (lamps, lamp poles and electric boxes) must be designed to satisfy the requirements on anti-thunderbolt safety and protection and ground connection following standards:

TCVN 4086: 1985 – Regulations on electric network safety in constructions.

TCVN 4756: 1989 – Regulations on ground and air connection of electric equipments.

3.8. Lightning equipments and accompany equipments (lamps, lamp poles and lamp rods) must have taste and be appropriate to landscape and environment. They have to meet the standards stipulated in environment protection. Designing lightning for a typical subject or area must pay attention to lightning characteristics and requirements of neighboring areas in order to avoid “lightning pollution” to these areas.

3.9. Lightning level stipulated in this standard is shown in medium horizontal illumination degree – En(tb), medium vertical illumination degree – Ed(tb), medium dazzling degree – L(tb), lightning intensity – I. These targets are minimum limens which lightning system needs to meet the lightning requirements for standardized subjects. To ensure economic efficiency of outdoor construction and save electric consumption, the maximum allowed lightning level of outdoor sport construction is not more than twice the minimum margin and to other construction, the maximum level is not more than 1.5 times the minimum margin regulated in the standard.

4. Technical requirements:

4.1. Lightning for urban infrastructures:

4.1.1. Lightning for outdoor public parking space.

4.1.1.1 The medium and minimum horizontal illumination degree on foundation surface of outdoor public parking is not smaller than the number stipulated in table 4.

Table 4: Lightning standard for outdoor public parking space

No.	Lightning subject	En (tb) (lx)	En (min) (lx)
1	Bus – interprovincial bus stop	50	20
2	Outdoor parking space at city center	30	10
3	Outdoor parking space in outskirt and rural area	10	3
4	Parking – public parking on streets (occupying parts of streets, pavements)	According to designation of artificial streets, roads, city square TCXDVN 259: 2001 applied for that street.	

Note:

- En(tb): The medium horizontal illumination degree, En(min): the minimum horizontal illumination degree.

- The above indices conclude the decline factor of lightning system.

4.1.1.2. The uniform coefficient of illumination degree En(min)/ En(tb) must be ensured not be smaller than 0,2.

4.1.1.3. Lamps must be installed appropriately to avoid dazzling for drivers.

4.1.1.4. Net for examining and horizontal illumination calculation method of outdoor parking is stipulated in Index 4.

4.1.2. Lightning for streets, bridges and passenger tunnels.

4.1.2.1. The medium and minimum horizontal illumination degree on street and areas for passengers is not smaller than the number stipulated in table 5.

Table 5: Lightning standard for passenger area

No.	Lightning subject	**En (tb) (lx)**	**En (min) (lx)**
1	Streets and walking areas at city center, near entertainment clubs, shopping malls with high traffic density and complicated security order	10	5
2	Streets and walking areas on the outskirts with medium traffic density	7	3
3	Streets and walking areas in rural, town, inside dwelling buildings with low traffic density and good security order	3	1

4.1.2.2. The medium and minimum horizontal illumination degree on bridges and inside passenger tunnels is not smaller than the number stipulated in table 6.

Table 6: Lightning standard for bridges and passenger tunnels

Lightning subject		Day		Night	
		En (tb) (lx)	En (min) (lx)	En (tb) (lx)	En (min) (lx)
Passenger tunnels L <= 60m		75	30	75	30
Passenger tunnels L>60m					
The first 20m at the beginning and in the end of tunnel		300	100	75	30
Mid-tunnel area		75	30	75	30
Stair for passengers	Uncover	K/a	K/a	30	10
	Cover	75	30	75	30
Stairs and Up/ Down path	Uncover	K/a	K/a	30	10
	Cover	75	30	75	30

Note:

- En(tb): The medium horizontal illumination degree, En(min): the minimum horizontal illumination degree.
- The above indices conclude the decline factor of lightning system.
- K/a: not apply.

4.1.2.3. In passenger tunnels, lamps must be installed to light all tunnel surfaces, especially vertical surfaces.

4.1.2.4. Lamps used to light passenger tunnels need having protection angle which is not smaller than 15º, lamp capacity in use and maximum optical flux are stipulated in table 7.

Table 7: The total lamp capacity and maximum optical flux for tunnel lightning

No.	Lamp in use	The maximum total capacity of lamps (W)	The maximum total optical flux from lamps (Lm)
1	Fluorescent lamp, HQ compact	80	7000
2	High voltage mercury lamp	125	6500
3	High voltage sodium lamp	70	6000
4	Metal halide lamp	70	5500

4.1.2.5. Lightning control system using time or photoelectric relay needs designing to change lightning level in order to meet the standards stipulated diurnal and at night.

4.1.2.6. To long complex or crowded tunnels (inside railway station, mall or exhibition center…), beside general lightning system, lightning for break-down is needed in order to maintain the minimum lightning (En)tb = 5 lx within 1 hour when break-out happens.

4.1.2.7. Lightning system for stairs must reflect the differences between horizontal and vertical surfaces of stairs even when stairs use materials with different colors. The average ratio of horizontal surface to vertical surface of stairs is not smaller than 3:1.

4.1.2.8. The arrangement of lights in tunnel and on bridge must consider anti-rupture ability and convenience in light maintenance operation.

4.1.3. Outside lightning for schools, hospitals, malls, exhibition centers and headquarters.

4.1.3.1. The average horizontal illumination for outside areas of schools, hospitals, malls, exhibition centers and headquarters can not be smaller than the number stipulated in table 8.

Table 8: Outside lightning standards for schools, hospitals, malls, exhibition centers and headquarters.

No.	Lightning Subject	En (tb) (lx)	Note
1	Schools		
	- Gate	10	
	- Internal path	5	
	- Playground and sport area	5	
2	Hospitals		
	- Gate, reception	20	
	- Paths inside treaty areas	5	
	- Relax area	3	
	- Parking	10	
3	Malls – Exhibition centers		
	- Gate	20	
	- Paths inside exhibition and sale areas	10	
	- Exhibition yards, outdoor sale areas	50	
	- Parking	10	
4	Headquarters		
	- Gate	20	
	- Internal path	5	
	- Parking	10	

4.1.3.2. The ratio of the maximum horizontal illumination value to the average horizontal illumination of lightning subjects can not be larger than:

- 3:1 – In case the standard average illumination above 6 lx.
- 5:1 - In case the standard average illumination from 4 lx to 6 lx.
- 10: 1 - In case the standard average illumination below 4 lx.

4.2. Lightning for parks and gardens:

4.2.1. General regulations:

4.2.1.1.Beside guarantee the standard lightning, designing lightning for parks and gardens must consider embellishing factor.

4.2.1.2. The style of lightning equipments (lights, lightning poles and lightning rods) must be consistent and suit architectural landscape of the area.

4.2.1.3. Depending on appearance and size of each parks, gardens, lightning system may consist of all or parts of the following:

a) Public lightning for entrance: guarantee the stipulated lightning level.

b) Lightning for outdoor ground: guarantee the stipulated lightning level.

c) Lightning for parkway: Beside guarantee the stipulated lightning level, designing and arrangement of lights must direct the way in order to make passengers see clearly the shape and direction of path.

d) Lightning for lawn, parterre, and water surface.

e) Lightning to create embellishing background: Using head lights to lighten trees.

f) Lightning to create stressing architectural points such as fountains, rock-works and trees.

4.2.2. Technical requirements:

4.2.2.1.The average horizontal illumination level in parks and gardens can not be smaller than the number stipulated in table 9.

Table 9: Lightning standard for parks and gardens

No.	Lightning subject	En(tb) (lx)	
		Parks	**Gardens**
1	Parks and gardens in big cities with crowded passenger density and high criminal possibilities		
	- Main entrance	20	K/a
	- Additional entrance	10	K/a
	- Main pathway	10	7
	- Access road, parkways with lots of trees	5	3
	- Outdoor yards	10	10
2	Parks and gardens on the outskirts of big cities with medium passenger density and medium criminal possibilities		
	- Main entrance	10	K/a
	- Additional entrance	7	K/a
	- Main pathway	5	3
	- Access road, parkways with lots of trees	3	2
	- Outdoor yards	7	7
3	Parks and gardens in small cities with low passenger density and low criminal possibilities		
	- Main entrance	7	K/a
	- Additional entrance	5	K/a
	- Main pathway	5	3
	- Access road, parkways with lots of trees	2	1
	- Outdoor yards	5	5

4.2.2.2.The ration of maximum horizontal illumination value to medium horizontal illumination value of lightning subject can not be larger than:

- 3:1 – In case the standard average illumination above 6 lx.
- 5:1 - In case the standard average illumination from 4 lx to 6 lx.
- 10: 1 - In case the standard average illumination below 4 lx.

4.2.2.3.Lightning equipments used must have ability to limit dazzling. The position, height and irradiate angle must be considered in order to avoid dazzling for users. Types of lights for parks and gardens are stipulated in table 10.

Table 10: Types of lights for parks and gardens

No.	Lightning subjects and purposes	Types of lights					
		Head light	Luster	Bulb light	Street lightning	Spot light	Head light for water
1	Lightning for entrance	Yes	Yes	Yes	Yes	K/a	K/a
2	Lightning for outdoor yard	Yes	Yes	Yes	Yes	K/a	K/a
3	Lightning for parkway	K/a	Yes	Yes	Yes	K/a	K/a
4	Lightning for landscapes: lawn, fountain, parterre	K/a	Yes	Yes	K/a	K/a	K/a
5	Lightning to create embellish background	Yes	K/a	K/a	K/a	K/a	K/a
6	Lightning to create stressing architectural point	Yes	K/a	K/a	K/a	Yes	Yes

4.2.2.4.The selected source of light should have the appropriate optical spectrum to the environment with lots of trees and have cold white light to create cool and relaxing feeling. Types and capacities of used lights for parks and gardens are stipulated in table 11.

Table 11: Types and capacities of lights for parks and gardens

No.	**Lightning subjects and purposes**	**Lights capacity (W)**				
		Metalhalide	**Ca Mercury**	**HQ Compact**	**Halogen**	**Ca Natrium**
1	Lightning for entrance	70 - 400	80 - 250	K/a	K/a	70 - 250
2	Lightning for outdoor yard	70 - 400	80 - 250	K/a	K/a	70 - 400
3	Lightning for parkway	70 - 150	80 - 125	15 - 40	K/a	K/a
4	Lightning for landscapes: lawn, fountain, parterre	70 - 250	80 - 125	15 - 40	K/a	K/a
5	Lightning to create embellish background	70 - 400	K/a	K/a	K/a	K/a
6	Lightning to create stressing architectural point	70 - 400	80 - 125	15 - 40	80 - 300	70 - 250

4.3. Lightning for architectural constructions – Fountains – Monuments

4.3.1. Lightning for architectural constructions

4.3.1.1. Lightning system for buildings, architectural constructions (which will be called lightning for architecture) must join harmoniously with other parts of urban lightning system.

4.3.1.2. Depending on dimension, property and characteristic of architectural constructions, lightning for buildings and architectural constructions must satisfy some or all of the following:

a. Lightning to create the ability to observe of main constructional surfaces.

b. Make clear all limited points of construction (roof, top of tower…)

c. Describe typical architectural details and characteristics of construction

d. Create bright – dark reflection and reflection of color light.

The method to arrange architectural lightning can be referred in Index 5 of this standard.

4.3.1.3.Designing to select types of lights (types – lightning arrangement – capacity), light position and angle must satisfy the following requirements:

a. Maximum limit dazzling for users.

b. Maximum limit optical spectrum waste of lights (meaning the optical spectrum from lights which is not distributed on the surface of lightning subject).

c. Maximum limit the ability to observe directly on the light (except from the case using embellish lights).

4.3.1.4.Arrangement of architectural lights can use the following methods:

a. Arrange lights above the lightning constructions.

b. Arrange lights above nearby constructions.

c. Arrange lights on separated lightning poles.

d. Arrange lights on street lights or other lightning poles (electric or post poles).

e. Arrange lights on the ground.

4.3.1.5.Using head lights on the ground must have apron to prevent lightning go directly to people eyes. If head lights are large, they must be designed inside bin under the ground with good drainage system to guarantee the lights not flood with water. Besides, measures to prevent stealing and destroy must be considered.

4.3.1.6. To increase sense for architectural lightning construction and create the harmony with the whole architectural space of the area, beside lightning for the construction, lightning for nearby space must be considered. (Refer index 5)

4.3.1.7. Selecting the source of light (bulb) used for lightning buildings – architectural construction must consider colors of lightning subject and follow the rules:

a. To lighten space with lots of trees and surfaces of subjects having “cold” colors (such as green, blue, grey…), we have to use source of light having high color such as Metal Halide bulbs, high voltage mercury, day light fluorescence bulb – cold white…

b. To lighten surfaces of subjects having “hot” colors (such as red, orange…), we have to use source of light having low color such as incandescent bulb, incandescent halogen, warm white light fluorescence bulb…

4.3.1.8.The average illumination level on building – architectural construction surfaces (or the average dazzling level of construction surfaces) is lightened by the general equal lightning method on construction surfaces and it can not be smaller than the number stipulated in table 12.

Table 12: Lightning standard for buildings and architectural constructions

No.	Surface material of construction	Reflected number of material	The average illumination level (lx) / The average dazzling level (cd/m2) on the dazzling of ground: Low <1cd/m2	Medium 1-5cd/m2	High > 5 cd/m2	The adjustable illumination number K to construction surface situation: A little dirty	Dirty	Very Dirty
1	Marble, mortar, white enameled brick	p > 0,6	20 / 3	30 / 5	75 / 15	3,0	5,0	10,0
2	Brick, yellowish paint	0,6 ≥ p > 0,45	30 / 5	50 / 8	100 / 15	2,5	5,0	8,0
3	Grey rock, cement wall	0,45 ≥ p > 0,3	50 / 5	75 / 8	150 / 15	2,5	5,0	8,0
4	Brick, brownish paint	0,45 ≥ p > 0,3	50 / 5	75 / 8	150 / 15	2,0	4,0	7,0
5	Pink granite rock	0,45 ≥ p > 0,3	50 / 5	75 / 8	150 / 15	2,0	4,0	6,0
6	Constructional cement	0,45 ≥ p > 0,3	75 / 10	100 / 12	200 / 25	1,5	2,0	3,0
7	Red brick	0,3 ≥ p > 0,15	100 / 8	150 / 10	300 / 20	2,0	3,0	5,0
8	Black rock, grey granite, grey paint	0,3 ≥ p > 0,15	150 / 8	200 / 10	400 / 20	2,0	3,0	5,0
9	Brick, dark paint	0,15 ≥ p	150 / 8	200 / 10	400 / 20	1,5	2,0	3,0

Note:

- Depending on specific condition, we select to apply either illumination or dazzling standard.
- The average illumination on construction surface and the average dazzling have considered the reduction factor.

- If the lightning subject is on the outskirt of city with green or sky not being lightened background, the number of dazzling level of ground is smaller than 1 cd/m2.

- If the lightning subject is near the construction with large lightning surface (building with large glass surfaces with lightning system inside), the number of dazzling level of ground is larger than 5 cd/m2.

4.3.1.9.To construction using partial lightning system, the standard stipulated in table 12 can be use as reference. The detailed lightning is decided by the designer basing on analyzing the following factors: dimension, constructional property, architectural characteristic, requirements on style and observation, electric supply ability and financial ability.

4.3.1.10. The method to calculate the number of head lights used to lighten architectural construction can refer index 6 of this standard.

4.3.2. Lightning for monuments:

4.3.2.1Monuments and memorials which have independent architecture meaning with nearby construction and can be observed from different directions must be lightened in important directions including the main direction. To other monuments and memorials, they can be lightened in the main observation direction.

4.3.2.2. Selecting source of light (lights) used for monuments and memorials must follow the regulations stipulated in 4.3.1.7 of this standard.

4.3.2.3. The average illumination level on the main net surface of monuments, memorials (or the average dazzling level on the main surface of construction) can not be smaller than the number stipulated in table 13. The average illumination level (or the average dazzling level) on other surfaces depend on the art requirements.

Table 13: Lightning standard for monuments – memorials

No.	Surface materials of monuments, memorials	Reflected number of material	The average illumination level (lx) / The average dazzling level (cd/m2) on the dazzling of ground		
			Low < 1 cd/m2	Medium 1-5 cd/m2	High > 5 cd/m2
1	Gypsum, light enameled tile	$p > 0.6$	30 / 5	50 / 10	75 / 15
2	Light and grey-ish cement	$0.6 \geq p > 0.45$	50 / 8	75 / 12	100 / 15
3	Granite and grey cement, grey marble	$0.45 \geq p > 0.3$	75 / 10	100 / 12	150 / 20
4	Dark carved stone and marble	$0.3 \geq p > 0.15$	100 / 8	150 / 10	200 / 15
5	Black copper, cast iron, dark tabrado	$0.15 \geq p$	150 / 8	200 / 10	300 / 15

Note:

- Depending on specific condition, selecting only one of the two standards: the illumination or dazzling level.
- If monument or memorial needs being observed from the distance of 300m, the values in table 13 can be multiplied with the adjustable coefficient K = 1.5.

- If monument or memorial is in park, garden or on the outskirts of city, the values in table 12 can be multiplied with the adjustable coefficient K = 0.5.

4.3.2.4.The method to calculate the number of head lights used to lighten monument can be referred the direction in index 6 of this standard.

4.3.3. Lightning for fountains:

4.3.3.1. Lightning for fountains include all the following parts (see figure 1):

a. Lightning for streams, flows and fillets.

b. Lightning for monuments (if have).

c. Lightning for other specific architectural details of fountain.

4.3.3.2.Designing lightning for fountain need to consider the factors: shape, size of fillets, limitations of position of light equipments, the main observation and protection against stealing and break-up.

4.3.3.3. The lightning system must use high quality equipments having good water resistance. Lights on water surface must have the minimum protection IP X5, the lights under water must have the minimum protection IP X7.

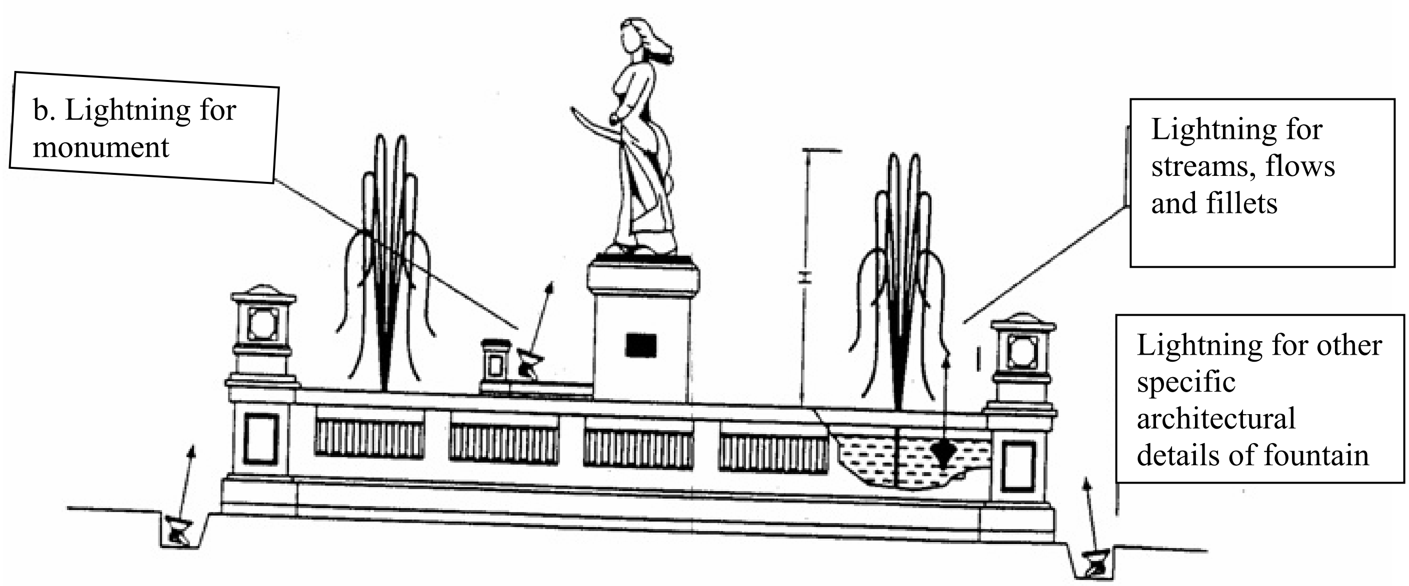
4.3.3.4. Lightning system must use lights with electric protection class III with low electric power source (from 12V to 36V).

4.3.3.5. The total light intensity (I) of sources of light at the bottom of each water column in fountain in the direction which is perpendicular with the horizontal surface can not be smaller than the value in table 14.

Table 14: Lightning standard for fountains

Height of the water column H (m)	The total light intensity of sources of light at the bottom of each water column I (cd)
1,5	4.000
3,0	11.000
6,0	34.000
9,0	69.000
12,0	115.000
15,0	170.000

Figure 1: Lightning for fountain



4.4. Lightning for outdoor sport constructions:

4.4.1. General regulations:

4.4.1.1. Before designing lightning system for outdoor sport constructions, we must research and investigate the following points:

a. Shape, architectural structure, constructional size, size of lightened area, material, color, reflected property of ground, stand, places which can install lights.

b. Using purpose: We must distinguish area used for competition and area used for training, normal competition ground and competition ground for color televised broadcasting.

c. Nearby construction space characteristics: Construction in residential area, next to highway, railway, airport…

d. Weather characteristics: maximum wind speed, air humidity, fog, sea climate…

e. Electric power source for lightning system: using the current electrical substation or building a new electrical substation for lightning, supply capacity, 3 phases or 1 phase power source, electric tension, frequency…

4.4.1.2. Designing lightning system for outdoor ground must guarantee the following requirements:

a. The average illumination level and the equivalent grade of illumination level on ground must satisfy requirements of the standard.

b. Limit maximum the dazzling caused by lightning equipments to avoid affecting athletes and viewers' observation.

c. Solutions to "flash effect" if using electric discharge lights with power supply with frequency 50 Hz.

d. Selecting appropriate source of light (lights) depending on reviewing technical properties:

- Photogenic difference of lights calculating on lm/W (in case using electric discharge light must calculate capacity loss on ballast).

- The average duration of lights and luminous flux decrease coefficient.

- Light color (color temperature T) and color transmitting index (CRI).

(Refer index 9 for more detail).

e. Other requirements:

- Selecting constructional materials, equipments and methods to suit realistic constructional characteristics.

- Guarantee operation and maintenance ability.

- Designing with consideration of extension in the future.

- Safety requirements of lightning system.

- Constructional style.

- Economic effect of lightning system.

4.4.1.3. According to required using, lightning control system of outdoor ground must be arranged in one place and has the ability to control lightning for a group of grounds and separated ground. Depending on constructional size and required using, lightning control system for one ground can satisfy the maximum 4 states: 1. Training – Entertainment

2. Friendship competition

3. Official competition

4. Competition being televised

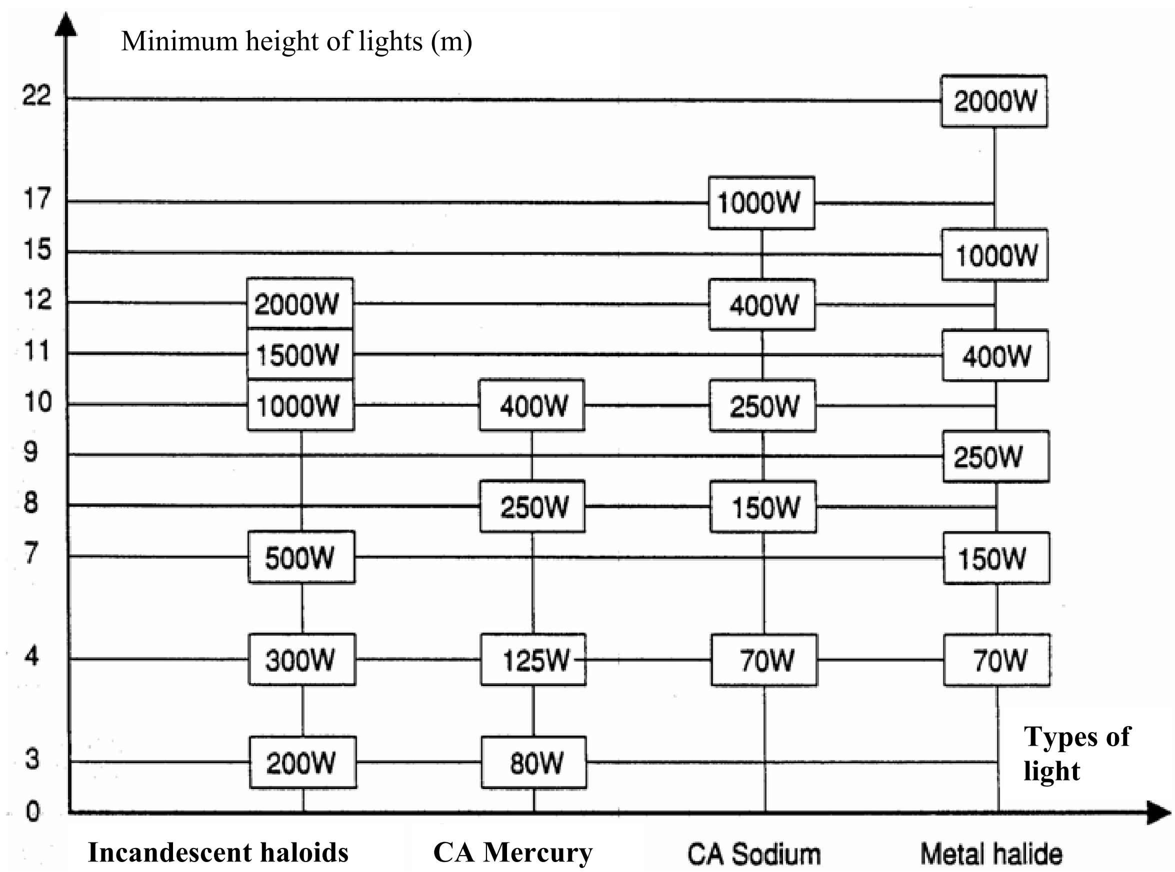
4.4.1.4. Lightning for official competition field with crowded viewers such as football or multi-function field must have independent backup electric source for emergency lightning in case the main electric power has black-out.

4.4.1.5. Lightning equipments for emergency lightning must use incandescent bulbs or electric discharge bulbs with quick restart. In emergency, the average horizontal illumination on field surface and stand can be smaller than 5 lx.

4.4.1.6. Sport construction with large size and important meaning must have the protection lightning system with the average horizontal illumination near the construction can not be smaller than 2 lx.

4.4.1.7. To depend on height of calculated lights and guarantee requirements on dazzling limitations and using effect, types and capacity of lights used in lightning equipments must follow regulations in figure 2.

Figure 2: High level for light installment and types – capacities of used lights



Note:

In case using bulbs with special design to limit the maximum dazzling, the high level to install lights can be decrease by 1.5 times in comparison with regulation in figure 2.

4.4.2. Lightning for football and multi-function fields:

4.4.2.1. Lightning area:

Lightning area of football field consist of the field limited by horizontal and vertical touch-lines.

Lightning area of multi-function field consist of the field limited by outside boundary of tracks around the field. In case there are some sport categories placed outside track border, lightning area must consist of those areas.

4.4.2.2.The average horizontal illumination level on field and the homogene of illumination coefficient can not be smaller than the value stipulated in table 15.

Table 15: Lightning standard for football – multi-function fields

No.	Using purpose	The horizontal illumination on the field	
		Average value En(tb) (lx)	Homogeneous horizontal coefficient Un
1	Training – Entertainment	100	0,40
2	Friendship competition	200	0,50
3	Official competition	500	0,60
4	Competition being televised	Following the standard stipulated in article 4.4.6	

Note:

- Official competition: competitions which the results are recorded in official record.
- Normal competition: competitions which the results are not recorded in official record.
- Un: The homogeneous coefficient on the horizontal of illumination level.
- En(tb): The average horizontal illumination value on the field (lx).

4.4.2.3.The arrangement of lights:

Depending on many factors: size, constructional structure and requirements on light quality, the arrangement of lights for football and multi-function fields can follow 2 forms:

a. Installing lights on lightning poles.

b. Installing lights on stand roofs.

4.4.2.4.High level of lights installation:

The height of lightning poles and designation of lights must calculate so that the lowest high-level of lights can not be smaller than the value stipulated in table 16.

Table 16: Height of lights installation for football and multi-function fields

No.	Light installation plan	Lightning poles quantity	Height of the lowest light H(m)	
			Calculated formula	Note
1	Light installation on the two sides of field	08	0,35 L1≤ H ≤ 0,6 L1 and 1 L2 ≤ H ≤ 4 L2	H, L1, L2 defined as figure 3
2	Light installation at 4 corners of field	04	0,35 L1≤ H ≤ 0,6 L1 and H ≤ 3 L2	H, L1, L2 defined as figure 4

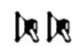
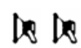
Note:

- H: Height of the lowest light.

4.4.2.5.Light equipments:

Light equipments for football and multi-function fields must be head lights with the type selected from the standard stipulated in table 17.

Table 17: Types of light equipments for football and multi-function fields

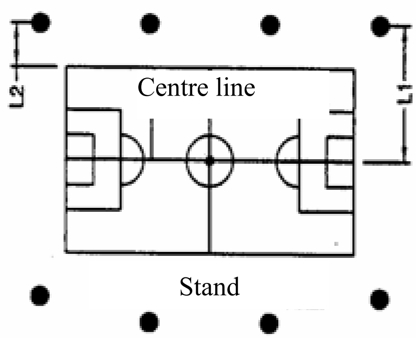
No.	Using purpose	Light installation plan	Light distribution of head lights		
			Narrow	Medium	Large
1	Training - Entertainment	4 corners or 2 sides of the field			
2	Normal and official competition	4 corners of the field			
		2 sides of the field			

Note:

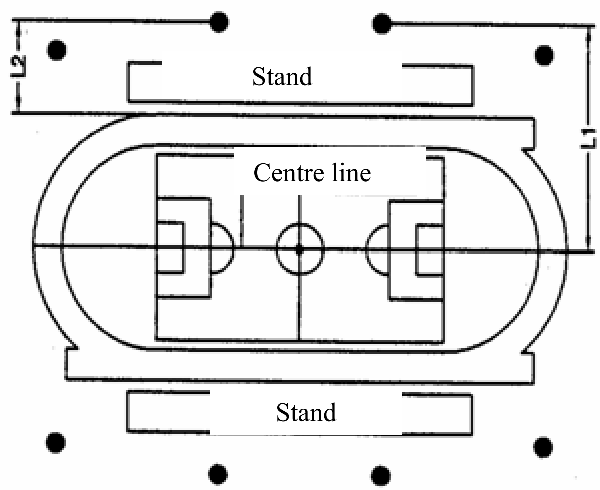
- Selection of light distribution of head lights defined in index 1.
- Lights can be used for additional lightning; Priority lights used for main lightning.

Figure 3: High-level of light installation for stadium – in case of lightning on 2 sides of the field

a. Football field



b. Multi-function field



c. Horizontal section

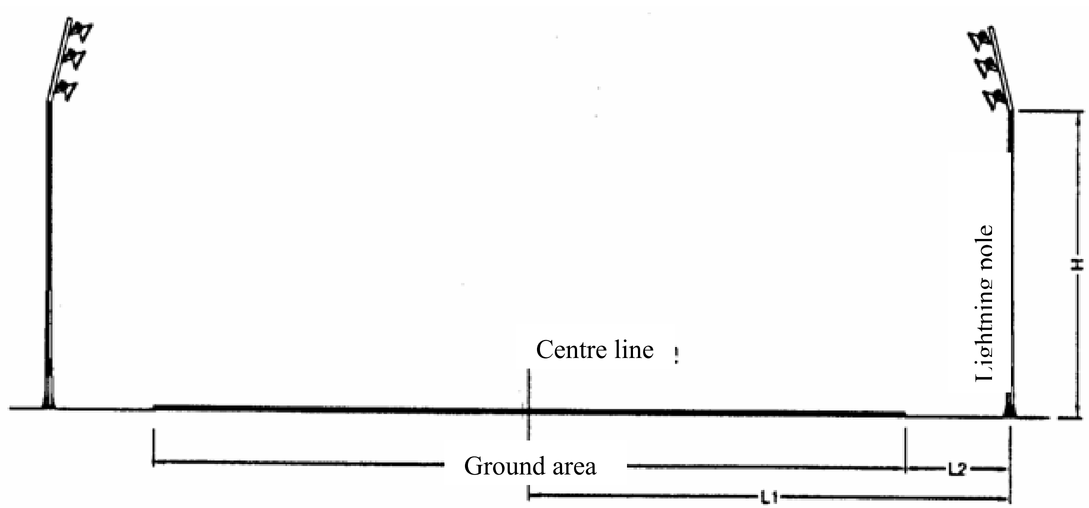
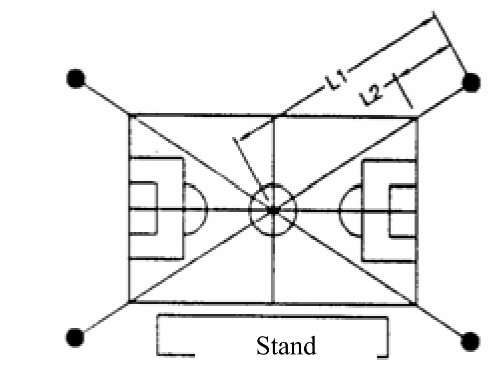
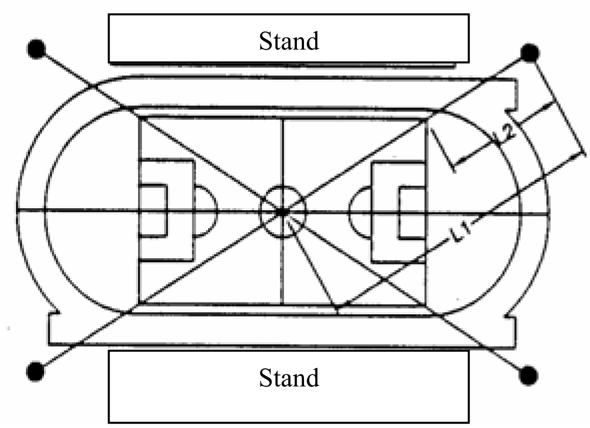


Figure 4: High-level of light installation for stadium – in case of lightning at 4 corners of the field

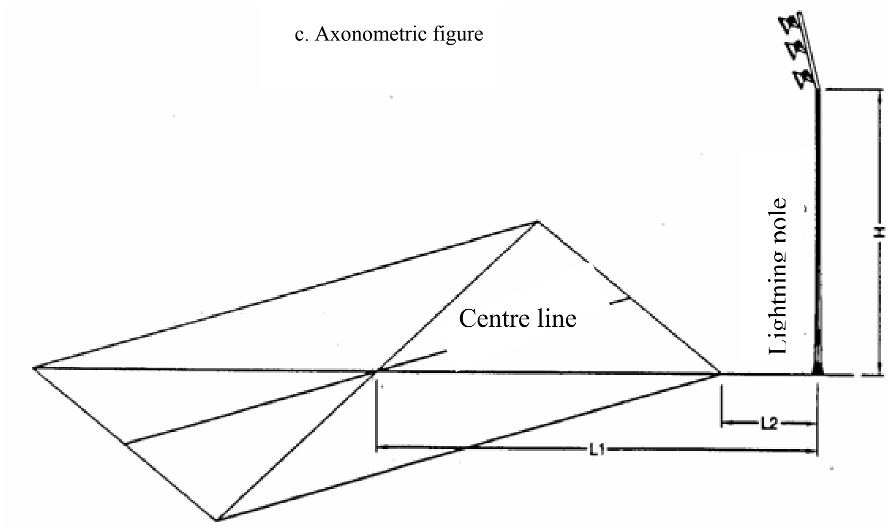
a. Football field



b. Multi-function field



c. Axonometric figure



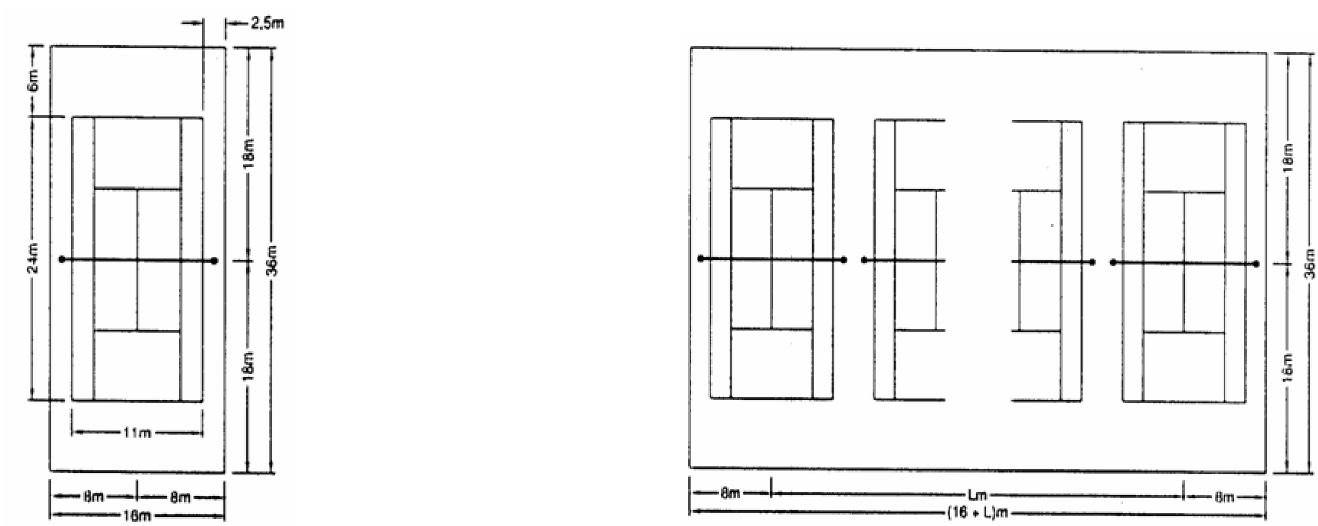
4.4.3. Lightning for tennis court:

4.4.3.1. Lightning area:

The lightning area of tennis court consists of all the court used for competition which is limited by fence or stand. In the process of calculation, measure and assessment of illumination level and homogeneous coefficient of illumination level on the field, the lightning area is stipulated in figure 5.

Figure 5: Measure and assessment lightning area of tennis court

a. Single court   b. Double courts or many courts



4.4.3.2.The average horizontal illumination level on the field and the homogeneous coefficient of illumination level can not be smaller than the value stipulated in table 18.

Table 18: Lightning standard for tennis court

No.	Using purpose	The horizontal illumination level on the field	
		Average value En(tb) (lx)	Horizontal homogeneous coefficient Un
1	Training – Entertainment	300	0,40
2	Common competition	500	0,50
3	Official competition	750	0,60
4	Televised competition	Following the standard stipulated in article 4.4.6	

Note:

- Un : The homogeneous coefficient on the horizontal of illumination level.

- En(tb): The average horizontal illumination value on the field (lx).
- See article 4.4.2.2. for the selection of competition forms.

4.4.3.3. Installation of lightning poles:

See index 7 as reference for the installation of lightning poles for single court, double or many courts without fence separated each courts.

4.4.3.4.High-level for light installation:

The height of lightning poles and designation of lights must be calculated so that the height of the lowest lights can be smaller than the value stipulated in table 19.

Table 19: High-level to install lights for tennis court

No.	Using purpose	High-level of the lowest light H(m)	
		The calculated formula	The minimum value
1	Training - Entertainment	$H2 \geq 3 + 0,4L$	8,0
2	Normal and official competition	$H1 \geq 5 + 0,4L$	10,0

Note:

- H1: High-level of the lowest light in case of competition court
- H2: High-level of the lowest light in case of training court.
- L : Distance of lightning
- H1, H2, L are defined as in figure 6.

4.4.3.5.Lightning equipments:

Equipment used for lightning tennis court must be head lights with the selected type from the standard stipulated in table 20.

Table 20: Types of lightning equipments for tennis court

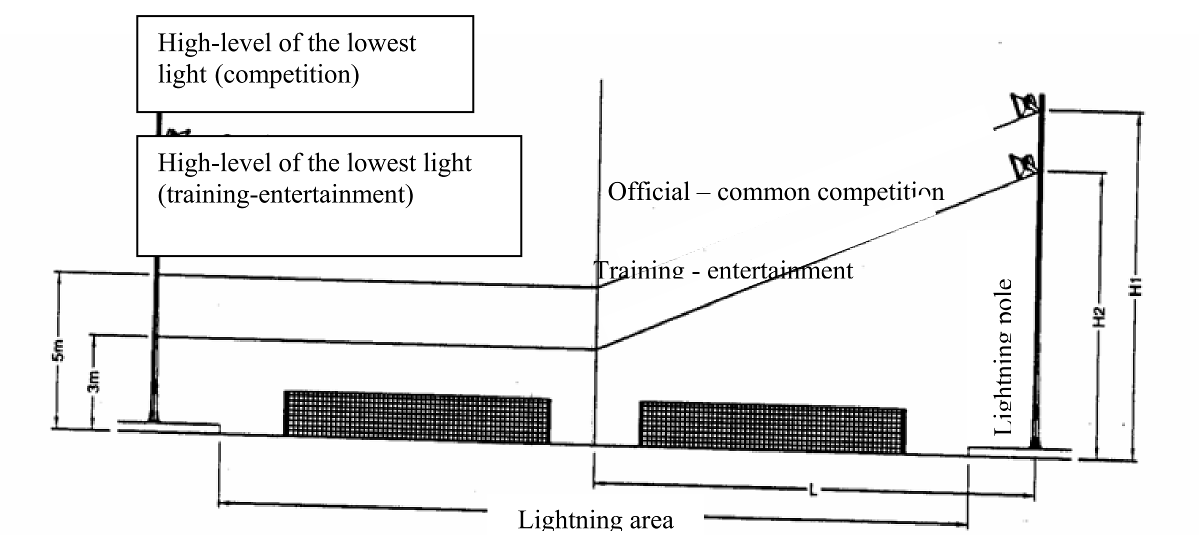
No.	Using purpose	Court size	Light distribution of head lights		
			Narrow	Medium	Large
1	Training – Entertainment	Single court			
		Double court or more			
2	Normal competition	Single court			
		Double court or more			
3	Official competition	Single court			
		Double court or more			

Note:

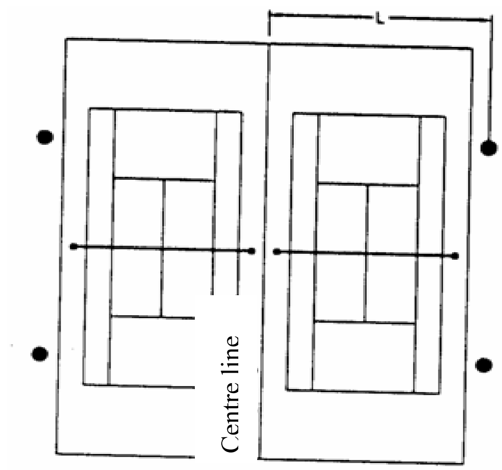
- Selection of light distribution of head lights defined in index 1.
-  Lights can be used for additional lightning;  Priority lights used for main lightning.

Figure 6: High-level of light installation and light distance of tennis court

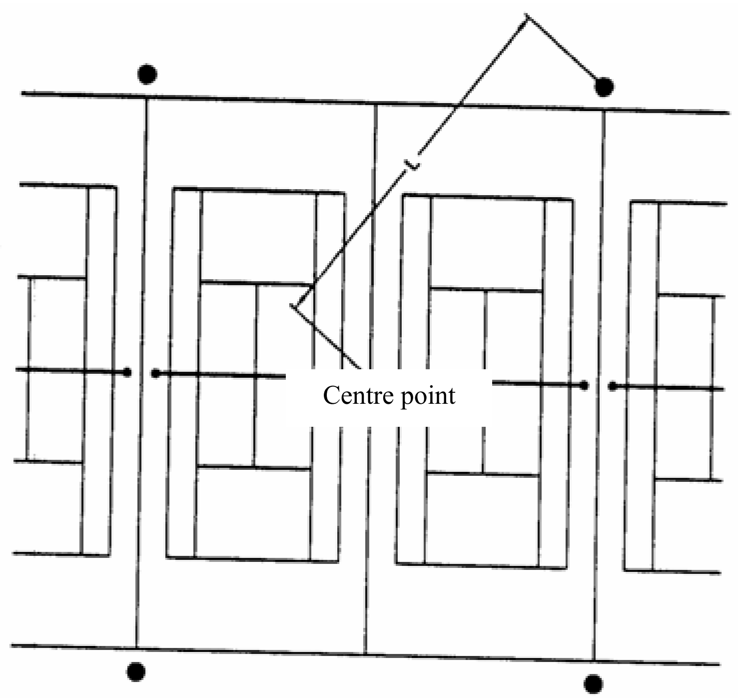
a. Horizontal section (double court)



b. Lightning poles on the 2 sides of court



c. Lightning poles in the back of court



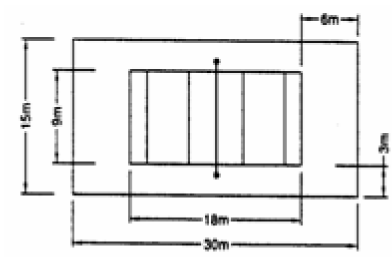
4.4.4. Lightning for baseball – basketball – badminton fields:

4.4.4.1. Lightning area:

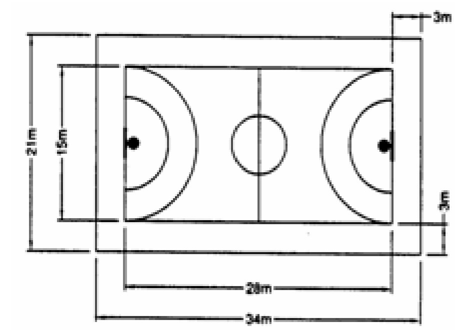
The lightning area of baseball – basketball – badminton field consists of the entire field used for competition. In the process of calculation, measure and assessment of illumination level and homogeneous coefficient of illumination level on the field, the lightning area is stipulated in figure 7.

Figure 7: Measure and assessment lightning area of baseball – badminton court

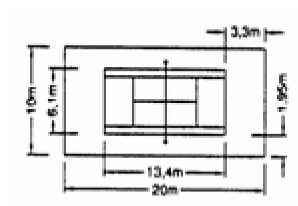
a. Baseball field



b. Basketball field



c. Badminton field



4.4.4.2. The average horizontal illumination level on the field and the homogeneous coefficient of illumination level can not be smaller than the value stipulated in table 21.

Table 21: Lightning standard for baseball – basketball – badminton field

No.	Using purpose	Horizontal illumination level on the field			
		Average value En(tb) (lx)			Horizontal homogeneous coefficient Un
		Baseball	Basketball	Badminton	
1	Training – Entertainment	100	100	200	0,40
2	Normal competition	200	200	300	0,50
3	Official competition	300	300	400	0,60
4	Televised competition	Following the standard stipulated in article 4.4.6			

Note:

- Un : Homogeneous coefficient on the horizontal of illumination level.

- En(tb): Average horizontal illumination value on the field (lx).
- See article 4.4.2.2. for the selection of competition forms.

4.4.4.3. Installation of lightning poles:

See index 7 as reference for the installation of lightning poles for baseball – basketball – badminton field.

4.4.4.4. High-level for light installation:

The height of lightning poles and designation of lights must be calculated so that the height of the lowest lights can be smaller than the value stipulated in table 22.

Table 22: High-level to install lights for baseball – basketball – badminton field

No.	Using purpose	High-level of the lowest light H(m)	
		Calculated formula	Minimum value
1	Training - Entertainment	$H2 \geq 3 + 0,4L$	6,0
2	Normal and official competition	$H1 \geq 5 + 0,4L$	8,0

Note:

- H1: High-level of the lowest light in case of competition court
- H2: High-level of the lowest light in case of training court.
- L : Distance of lightning
- H1, H2, L are defined in figure 8.

4.4.4.5. Light equipments:

Equipment used for lightning baseball – basketball – badminton ground must be head lights with the selected type from the standard stipulated in table 23.

Table 23: Types of lightning equipments for baseball – basketball – badminton ground

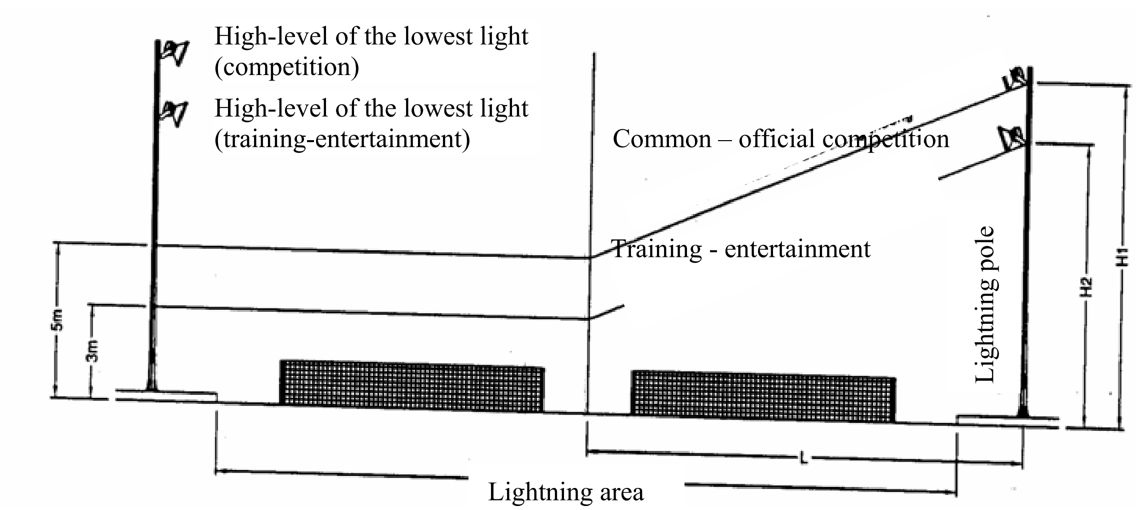
No.	Using purpose	Court size	Light distribution of head lights		
			Narrow	Medium	Large
1	Training – Entertainment	Baseball - Basketball			
		Badminton			
2	Normal competition	Baseball - Basketball			
		Badminton			
3	Official competition	Baseball - Basketball			
		Badminton			

Note:

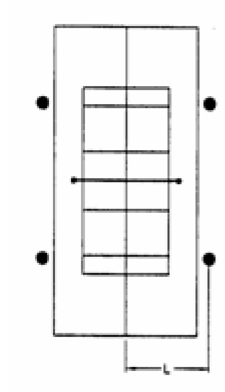
- Selection of light distribution of head lights defined in index 1.
-  Light can be used for additional lightning;  Priority lights used for main lightning.

Figure 8: High-level of light installation and light distance of baseball – basketball – badminton field

a. Horizontal section



b. Field plan



4.4.5. Lightning for outdoor swimming pool:

4.4.5.1.Lightning area:

Lightning area of swimming pool consists of the swimming pool and nearby area limited by fence or stand.

4.4.5.2.The average horizontal illumination level in the pool and the homogeneous coefficient of illumination level can not be smaller than the value stipulated in table 24.

Table 24: Lightning standard for outdoor swimming pool

No.	Using purpose	Horizontal illumination level		Vertical illumination level
		Average value En(tb) (lx)	Horizontal homogeneous coefficient Un	Average value Ed(tb) (lx)
1	Training – Entertainment	200	0,40	-
2	Normal competition	500	0,50	200
3	Official competition	750	0,50	200
4	Televised competition	Following the standard stipulated in article 4.4.6		

Note:

- Un : The homogeneous coefficient on the horizontal of illumination level.
- En(tb): The average horizontal illumination value on the water surface or floor around the swimming pool (lx). In case there are differences in high-level of water surface and floor around the swimming pool, the horizontal illumination level is checked and calculated at the high-level of floor near water surface.
- The vertical illumination level standard is applied for swimming pool with diving stage used for competition and performance.

Ed(tb): the average vertical illumination level at the high-level which air performance of athletes take place and direct to 2 sides of swimming pool.

- See article 4.4.2.2. for the selection of competition forms.

4.4.5.3.Installation of lightning poles:

Depending on shape, size of swimming pool, we can select different plans of installation lightning poles to ensure that there is no dark spot in lightning area.

See index 7 for the installation of lightning poles for outdoor swimming pool.

4.4.5.4. High-level for light installation:

The height of lightning poles and designation of lights must be calculated so that the height of the lowest lights can be smaller than the value stipulated in table 25.

Table 25: High-level for light installation of outdoor swimming pool

No.	Type of swimming pool	High-level of the lowest light H(m)	
		The calculated formula	The minimum value
1	Swimming pool with stand	H1 $\geq$ 0,8W - h	0,25d
2	Swimming pool without stand	H2 $\geq$ 0,6W - h	0,25d

Note:

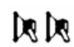
- H1: The high-level of the lowest light in case swimming pool having stands.
- H2: The high-level of the lowest light in case swimming pool not having stands.

- W: The distance on horizontal direction between the centre of lightning pole and opposite pool side.
- h: The different height between water surface and floor around swimming pool.
- d: The distance among lightning poles.
- H1, H2, W, h, d are defined in figure 9.

4.4.5.5.Lightning equipments:

Equipment used for lightning swimming pool must be head lights with the selected type from the standard stipulated in table 26.

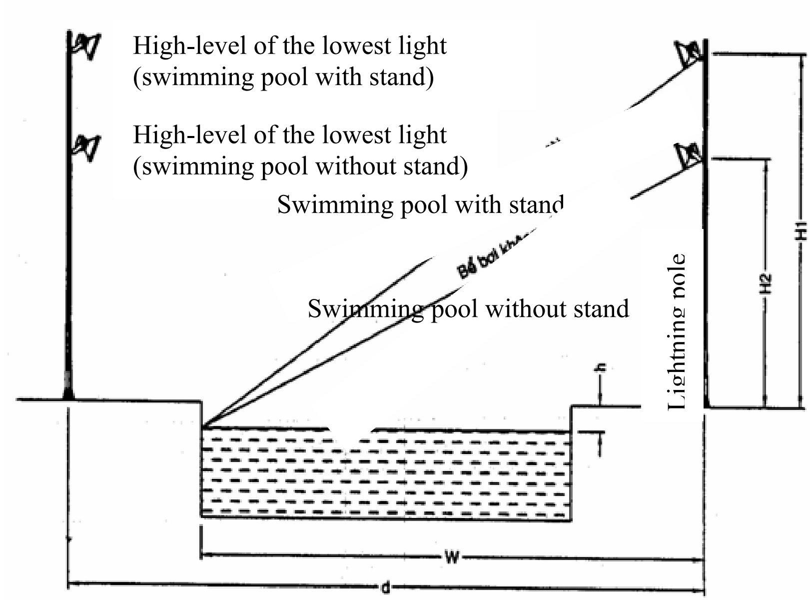
Table 26: Types of lightning equipments for swimming pool

No.	Using purpose	Light distribution of head lights		
		Narrow	Medium	Large
1	Training – Entertainment			
2	Common competition			
3	Official competition			

Note:

- Selection of light distribution of head lights defined in index 1.
- Lights can be used for additional lightning; Priority lights used for main lightning.

Figure 9: High-level to install lights for outdoor swimming pool



4.4.6. Lightning for color televised broadcasting:

4.4.6.1. Lightning for competition field:

The average horizontal illumination level and the homogeneous coefficient of illumination level on the field must satisfy regulation in table 27.

Table 27: Lightning standard for color televised broadcasting

No.	Illumination level selection	Average value (lx)	Homogeneous coefficient
1	The illumination level on vertical section Ed(tb)	Ed(tb) ≥ 1000	Ud ≥ 0,3
2	The illumination level on horizontal section En(tb)	En(tb) ≥ 1000	Un' ≥ 0,5

Note:

- Ed(tb): the average vertical illumination level at 1,5m height on the main field with main camera.
- En(tb): the average horizontal illumination level on the field.
- The homogeneous coefficient of vertical illumination level Ud is calculated by the formula: Ud = Ed(min)/ Ed(max), in which:

Ud: the homogeneous coefficient of illumination level on vertical section

Ed(min): The minimum vertical illumination value at 1,5m height on the field (lx).

Ed(max): The maximum vertical illumination value at 1,5m height on the field (lx).

- The homogeneous coefficient of horizontal illumination level Un' is calculated by the formula: Un' = En(min)/ En(max), in which:

Un': The homogeneous coefficient on horizontal direction of the illumination level (use in case the construction used for color televised broadcasting).

En(min): The minimum horizontal illumination value on the field (lx).

En(max): The maximum horizontal illumination value on the field (lx).

4.4.6.2. Lightning for stands:

The average illumination level on vertical section of stand at the contiguous place with the field directing toward the main camera can not be smaller than 250 lx.

4.4.6.3. Power supply:

If lightning system use source of light which is electric discharge bulb, power supply of the lightning system must be 3 phases electric source and lights must be connected and distributed evenly for 3 phases.

4.4.6.4. Source of light:

The source of light (bulb) used for lightning color televised broadcasting must have color temperature and transmitting index satisfying the conditions stipulated in table 28:

Table 28: Technical properties of bulbs used for color televised broadcasting

No.	Technical properties of source of light	Standard
1	Color temperature T (K)	6000 K ≥ T ≥ 3000 K
2	Color transmitting index CRI (%)	CRI ≥ 65%

APPENDIX 1

RELATED TERMS AND CONCEPTS

1. Color Temperature (T)

The color temperature of light source (bulb) is the temperature of total radiator (or ideal radiator) that has the same color temperature as the examined light source. The color temperature is measured by the unit ^{0}K.

2. Color Rendering Index (CRI)

The color rendering index of a light source (bulb) expresses the equivalence level between eye recognition of colored thing illuminated by standard light source and that by tested light source in certain conditions of observation.

The color rendering index (CRI) is measured by the unit %.

3. Emergency Lighting

The emergency lighting guarantees the people's easy escape in case of the break-down of the lighting mains for work.

4. Standby Lighting

The standby lighting is for keeping on working in case of the break-down of the lighting mains.

5. Protection Lighting

The protection lighting is for limiting the area (or project) that must be protected in the night time.

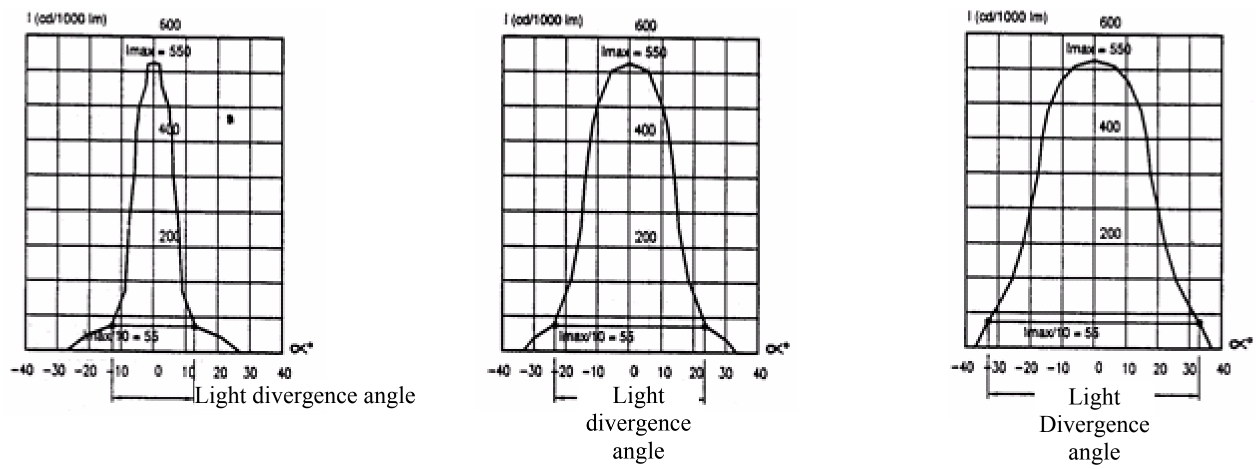
6. Classifying headlights according to light's distribution

6.1. Angle of light divergence

The angle of light divergence is among directions whose luminous intensity is equal to 1/10 lmax shown on the distribution curve of the luminous intensity of the luminaire that is drawn in the surface passing the bulb's central axis and the direction containing lmax.

Picture 10: The distribution curve of the luminous intensity

a. Narrow light's distribution   a. Average light's distribution   a. Wide light's distribution



6.2. The headlight with narrow distribution of light has the angle of light divergence $\alpha < 30^0$

6.3. The headlight with average distribution of light has the angle of light divergence $30^0 \leq \alpha \leq 60^0$

6.4. The headlight with wide distribution of light has the angle of light divergence $\alpha > 60^0$

7. Maintenance Factor

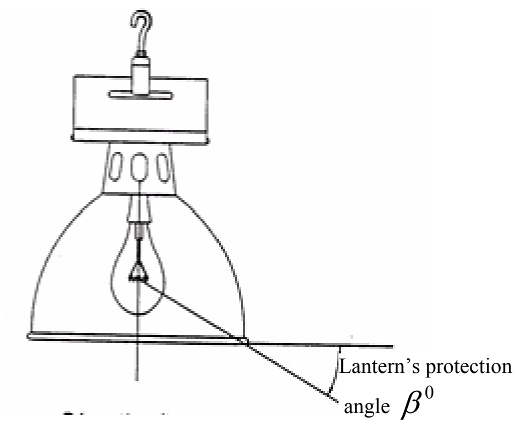
The maintenance factor M_F is the standby factor used in illumination analysis in order to ensure that the designed and built lighting system will satisfy the requirements of defined standard not only right after completion but also when the quality of lighting system decreases after a period of operation.

The maintenance factor is chosen in calculation depending on the elements:

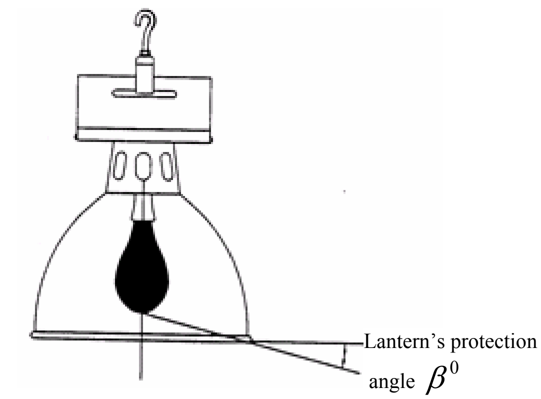
- The decline of the light source's luminous flux during the period of operation.
- The level of protection from dust and water of the luminaire.
- The level of the surrounding environment pollution.
- The cycle of cleaning and maintaining the lantern.

8. Protection angle of lantern

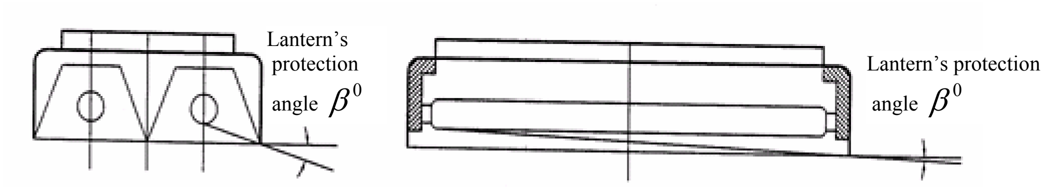
Picture 11: The protection angle of lantern



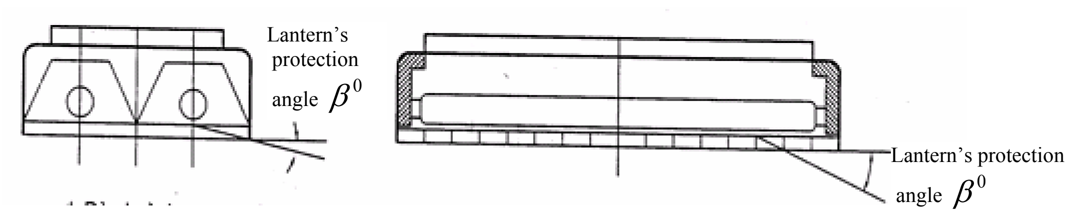
a. Transparent plump bulb



b. Oval bulb



c. Fluorescent lamp without dispersity part



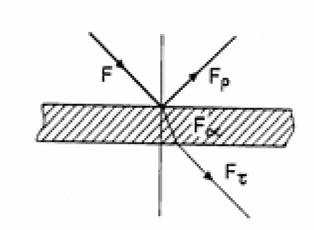
d. Fluorescent lamp with dispersity part (net of reflected light)

9. Coefficient of Reflectance – Coefficient of Absorbance – Coefficient of Transmittance

When a beam lights on the surface of one material, the total volume of luminous flux F of the beam will be divided into 3 parts:

- The part of luminous flux F_ρ reflects out of the material's surface.
- The part of luminous flux F_α is absorbed into the material.
- The part of luminous flux F_τ transmits through the material.

Picture 12: Optical coefficients of the material



9.1. Coefficient of Reflectance

The coefficient of reflectance ρ of one material is the rate between the volume of luminous flux F_ρ reflecting out of the material and the total volume of the beam's luminous flux F towards that material's surface.

$$\rho = \frac{F_\rho}{F}$$

9.2. Coefficient of Absorbance

The coefficient of absorbance α of one material is the rate between the volume of luminous flux F_α absorbed in the material and the total volume of the beam's luminous flux F towards that material's surface.

$$\alpha = \frac{F_\alpha}{F}$$

9.3. Coefficient of Transmittance

The coefficient of transmittance τ of one material is the rate between the volume of luminous flux F_α transmitting through the material and the total volume of the beam's luminous flux F towards that material's surface.

$$\tau = \frac{F_\tau}{F}$$

Note: $\rho + \alpha + \tau = 1$

10. Uniformity Ratio of Illuminance

10.1. Uniformity Ratio of Horizontal Illuminance

The uniformity ratio of horizontal illuminance Un is calculated according to the formula: $Un = \frac{En(\min)}{En(tb)}$

With:

- Un: The uniformity ratio of horizontal illuminance
- En(min): The minimum value of horizontal illuminance on the surface (lx)
- En(tb): The average value of horizontal illuminance on the surface (lx)

10.2. Uniformity Ratio of Vertical Illuminance

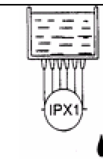
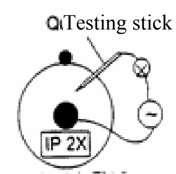
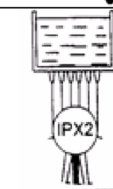
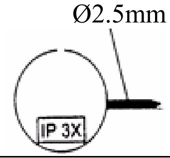
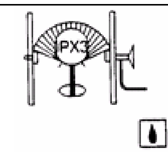
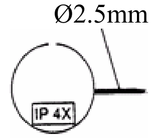
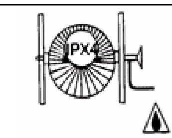
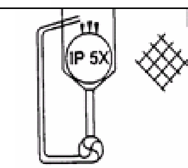
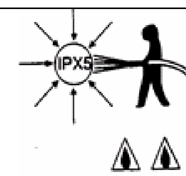
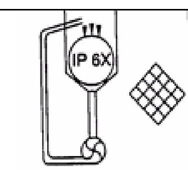
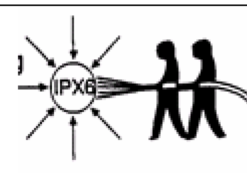
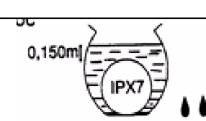
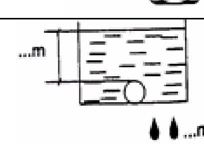
The uniformity ratio of vertical illuminance Ud is calculated according to the formula: $Ud = \frac{Ed(\min)}{Ed(\max)}$

With:

- Ud: The Uniformity ratio of illuminance on the vertical surface
- Ed(min): The minimum value of vertical illuminance at the pitch 1.5m on the surface (lx)
- Ed(max): The maximum value of vertical illuminance at the pitch 1.5m on the surface (lx)

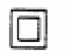
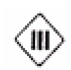
APPENDIX 2

Table 29: SIGNS OF DUST – WATER PROTECTIVE CLASS (IP XX)

The first index	Description	Sign	The second index	Description	Sign
1	Solid protection with diameter of Ball over 50mm	Ball Ø50mm 	1	Protection against water drops that fall vertically	
2	Solid protection with diameter of over 12mm	 Ball Ø2.5mm	2	Protection against water drops that fall cantingly 15^0 compared with the vertical	
3	Solid protection with diameter of Steel roll over 2.5mm	Steel wire Ø2.5mm 	3	Protection against rain-water canting 60^0 compared with the vertical	
4	Solid protection with diameter of Steel roll over 1.0mm	Steel wire Ø2.5mm 	4	Protection against spray from all directions	
5	The dust load that fits in doesn't affect the equipment		5	Protection against spray from all directions with the pressure of 0.3bar from the distance of 3m	
6	Absolute dust protection		6	Protection against spray of seawater from all directions with the pressure of 0.3bar from the distance of 3m	
			7	Soaking protection (<1m)	
			8	The material can be submerged Protection from long soaking under pressure	

APPENDIX 3

Table 30: SIGNS OF ELECTRIC PROTECTIVE CLASS

Protective class	Sign	Description
Class 0		Without the protection by earth connection
Class I		Protection by earth connection method
Class II		The contact surface of the equipment doesn’t include the ability of conducting electricity Without the protection by earth connection method
Class III		The luminaire operates safely at low electric pressure

APPENDIX 4

METHOD OF TESING THE LIGHTING OF OUTDOOR PARKING LOT

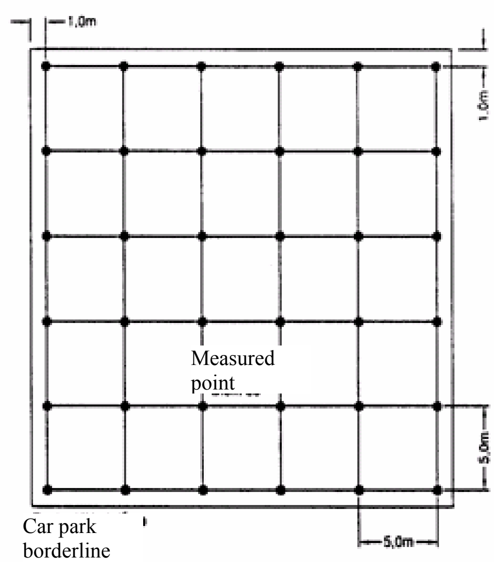
1. Testing area

The area of testing the lighting of outdoor parking lot includes the whole area of the site plan used for parking.

2. Testing net of the lighting

The testing net of the lighting of outdoor parking lot is stimulated in picture 13:

Picture 13: The testing net of the lighting of outdoor parking lot



3. Calculating method

The average horizontal illuminance in the limit of parking area is calculated according to the formula:

$$En(tb) = \frac{1}{n}\sum_{i=1}^{n} Ei$$

Note:

- En(tb): The average horizontal illuminance in the limit of parking area (lx)
- Ei: The horizontal illuminance at measuring points at the pitch of yard’s surface (lx)
- n: The number of measuring points

APPENDIX 5

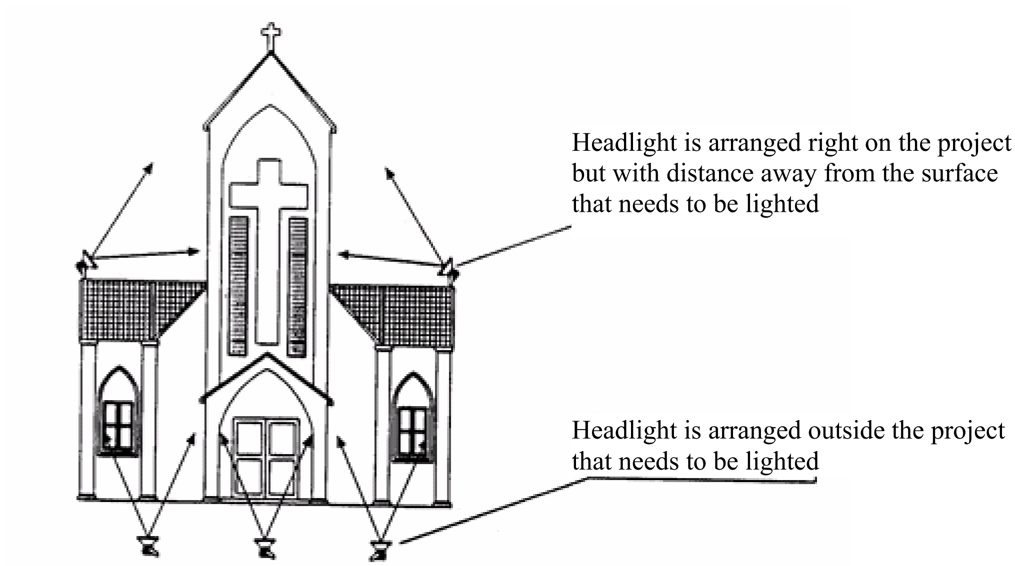
METHOD OF ARCHITECTURAL LIGHTING ARRANGEMENT

1. Method of architectural lighting arrangement

Depending on elements such as: the scale, property, architectural characteristic of the project and requirement of illumination efficiency; in arranging the architectural lighting, it is possible to apply one or combination of some following solutions:

1.1. General uniform lighting on the project's surface

Picture 14: Method of general lighting arrangement



- Solution's content:

Using sets of headlights to illuminate generally and uniformly the whole main surface and other surfaces of the project (on observing demand). Lights are often arranged at a relatively far distance from the point needed to be illuminated, normally outside the project.

- Advantage:

Easy to execute, not big required amount of device and expenditure investment, possible to combine with lighting purpose of protecting the project.

- Disadvantage:

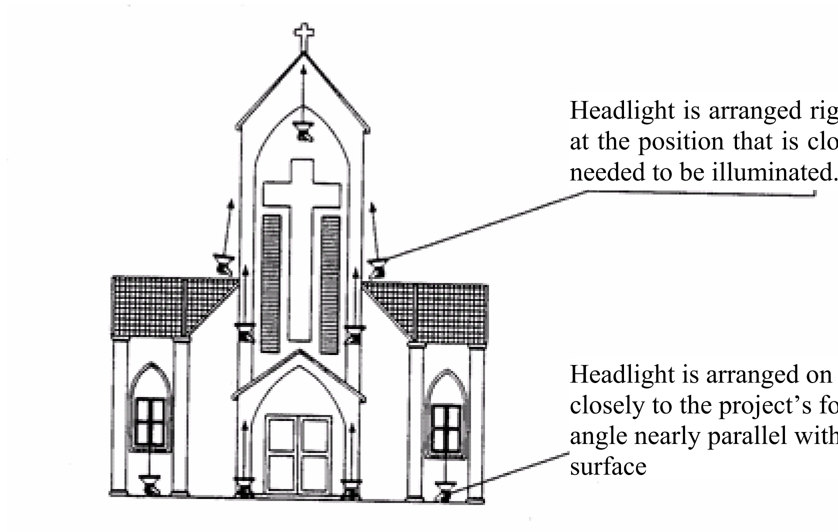
Not high aestheticism, only suitable for projects with simple and modern architecture

- Field of application:

Lighting modern high buildings, projects with relatively simple structure and large size, projects with requirement of protection lighting.

1.2. Partial Lighting

Picture 15: Method of partial lighting arrangement



- Solution's content:

Using sets of headlights arranged on the ground or right above the project to describe details of specific architecture (column, balcony, window, ridge roof …). The purpose of this solution is not to create a level of regular uniform lighting on the project's surface but to create disparity and contrast of the lighting level among different areas. Lights are arranged on the ground or on the project's surface at the position close to the surface that needs to be lighted with almost parallel direction compared to that surface.

- Advantage:

High aestheticism, suitable for projects with complicated architecture.

- Disadvantage:

Difficult to execute, big required amount of device and expenditure investment, low illumination efficiency.

- Field of application:

Lighting projects with ancient architecture, gothic-styled architecture, complicated architectural outline; large-structural projects with complicated design; buildings with low pitch.

1.3. General lighting in combination with partial lighting

- Solution's content: Combining two aforementioned lighting methods

Using sets of headlights to illuminate generally and uniformly the whole main surface and other surfaces of the project (on observing demand). Lights are often arranged at a relatively far distance from the point needed to be illuminated, normally outside the project.

Using sets of headlight arranged on the ground or right above the project to describe details of specific architecture (column, balcony, window, ridge roof,…). Lights are arranged on the ground or on the project's surface at the position close to the surface that needs to be lighted with almost parallel direction compared to that surface.

Note: In order to make necessary aesthetic efficiency, it is needed to pay attention to creating contrast between areas that are lighted generally and uniformly and areas that are emphasized by partial lighting:

- To level of illumination: The difference rate of vertical illuminance on the project's surface between the area lighted partially and the area lighted generally and uniformly is not smaller than 3/1.
- To color of light: Using kinds of bulb with different colors of light to create the contrast.

In order to illuminate generally, it is better to use kinds of bulb with white-cold color of light such as high-pressure mercury lamp, Metal halide. To illuminate partially, it is better to use light source with yellow-warm color such as Halogen filament, Natri high pressure.

- Advantage:

High aestheticism, suitable for projects with complicated architecture.

- Disadvantage:

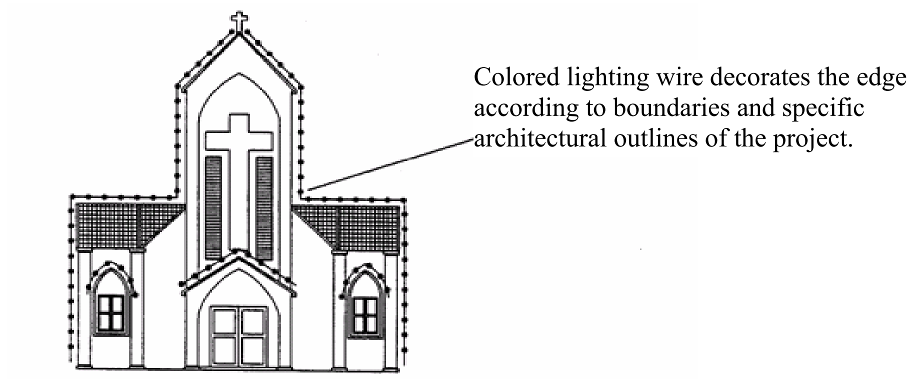
Difficult to execute, big required amount of device and expenditure investment, low illumination efficiency.

- Field of application:

Illuminating projects with ancient architecture, gothic-styled architecture, complicated architectural outline; projects with large structure; buildings with high requirement of lighting, including protection lighting.

1.4. Lighting according to boundaries of the project

Picture 16: Method of lighting arrangement according to boundaries of the project



- Solution's content:

Using colored lighting wires to decorate the edge according to boundaries and specific architectural outlines of the project. The lighting equipment can be colored lighting wires (snaked-wire light) or incandescent bulb with low capacity (25W – 40W).

- Advantage:

Creating resplendent beauty for the building, easy to execute, low installment expenses

- Disadvantage:

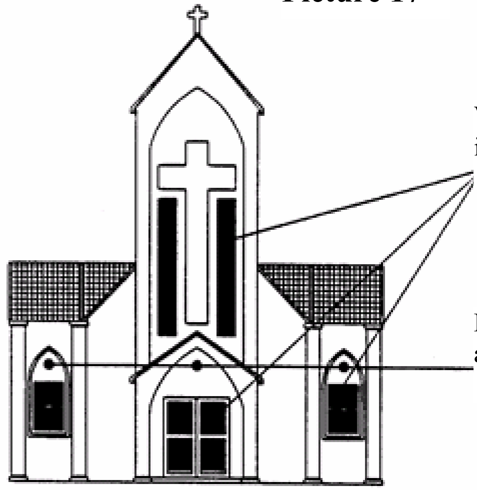
The lighting system is only temporary decoration, without the ability of long-term operation, the arrangement of lighting wires on the project's surface can make bad influence on the architecture of the project in the daytime.

- Field of application:

Decoration lighting for architectural projects (except Mausoleum-monument-statue) during festivals.

1.5. Description lighting the project's appearance through window-panes with turned-on lights inside and partial lights arranged on balcony-eaves of rooms

Picture 17



- Solution's content:

Using equipment to illuminate furniture arranged inside window-panes and decorative lights arranged on balcony, eaves of rooms and on the project's surface to light and describe the project's appearance.

- Advantage:

Being uniformly designed, executed when building the project so the lighting system doesn't influence the aestheticism of the project in the daytime.

- Disadvantage:

Limited ability of application, only suitable for projects with large area of grass door. The control of switching on and off must be performed with concentration.

- Field of application:

Lighting buildings with large area of grass door, windows and balconies homogeneously distributed on the project's surface.

Collection for choosing solution of architectural lighting, referring table 31:

Table 31: Solutions of architectural lighting

Order	Method of lighting arrangement	Types of project					
		Royal Tomb - Monument	Statue	Project with ancient architecture	Structure with large size	Building with nice architecture	Modern high building
1	General and uniform lighting				●		●
2	Partial lighting	●	●	●	●	●	
3	Lighting with the combination of (1) and (2)	●		●	●	●	●
4	Lighting boundaries CT					●	
5	Lighting panes of balconies - eaves					●	

2. Lighting space around the project

In order to increase the aestheticism efficiency for the project of architectural lighting, create the harmony with the whole architectural space within the area, besides lighting the project, it is necessary to pay attention to lighting the space around the project by following solutions:

a. Lighting the green space around the project to create background.

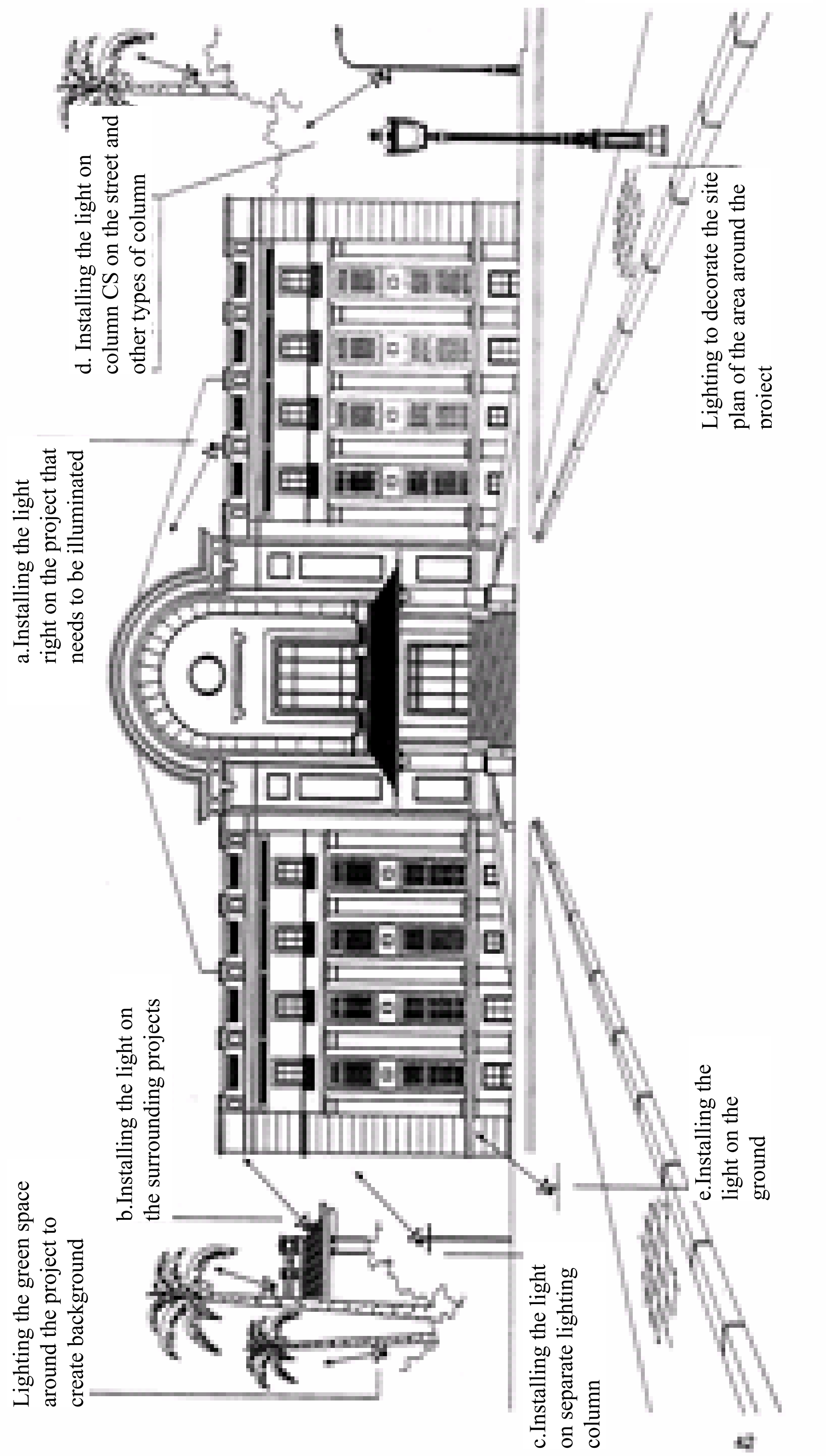
b. Lighting to decorate the area's site plan around the project.

(View picture 18)

3. Arrangement of architectural lighting.

(View picture 18)

Picture 18: Methods of architectural lighting installment



APPENDIX 6

METHOD OF CALCULATING THE NUMBER OF ARCHITECTURAL LIGHTS

1. General principle

To calculate preliminarily the number of architectural lights needed to be installed, it is possible to use the calculating method according to the norm of luminous flux presented on article 2 of this appendix.

To calculate more accurately the number of architectural lights needed to be installed, it is possible to use the calculating method according to the norm of luminous intensity presented on article 3 of this appendix.

2. Method of calculation according to luminous flux

The necessary luminous flux that emits from luminaires distributed on the surface of the project to achieve the required average illuminance level on the surface of that project is calculated according to the formula:

$$F_t = \frac{AE}{U_F M_F} \quad \text{(View picture 19)}$$

The necessary number of lights is calculated according to the formula:

$$N = \frac{F_t}{F_{bd}}$$

Note:

- F_t: The total necessary luminous flux of bulbs (lm)
- F_{bd} : The luminous flux of one bulb (in case of one-bulb light) or the total luminous flux of bulbs in luminaire (in case of multi-bulb light) (lm).
- A: The area of the project's surface that needs to be illuminated (m2)
- E: Necessary average illuminance level on the project's surface with the consideration of the decreasing factor (lx).
- U_F: Coefficient of utilization of luminous flux with the consideration of the loss of luminous flux inside the luminaire and the waste of luminous flux outside the luminaire (the luminous flux emits from the luminaire but isn't distributed on the necessary object CS). The value of this parameter depends on the

capacity of the light (supplied by the manufacturer) and solution of lighting arrangement. Normally U_F = 0.35 to 0.50

- $M_F = M_{bd} M_đ$ With

  M_F: General maintenance factor.

  M_{bd} : The factor accounts for the decrease of luminous flux of the bulb because of aging phenomenon.

  $M_đ$: Maintenance factor of the luminaire with the consideration of the decrease of the bulb's luminous ability because of dust and aging material.

- N: The necessary number of luminaire (round-off)

3. Method of calculation according to luminous intensity

The luminous intensity that emits from the luminaire to one certain direction to achieve the illuminance level Ei on the surface of the object at the lighting point i is calculated according to the formula:

$$I = \frac{Eih^2}{Sin^2\alpha Cos\alpha} \text{ (View picture 19)}$$

The illuminance level Ei achieved at the lighting point is calculated according to the formula:

$$Ei = \frac{ISin^2\alpha Cos\alpha}{h^2} \text{ (View picture 19)}$$

The average illuminance level achieved on the surface needed to be illuminated is calculated according to the formula:

$$E(tb) = \frac{1}{n}\sum_{i=1}^{n} Ei$$

The number of necessary luminaire is calculated according to the formula:

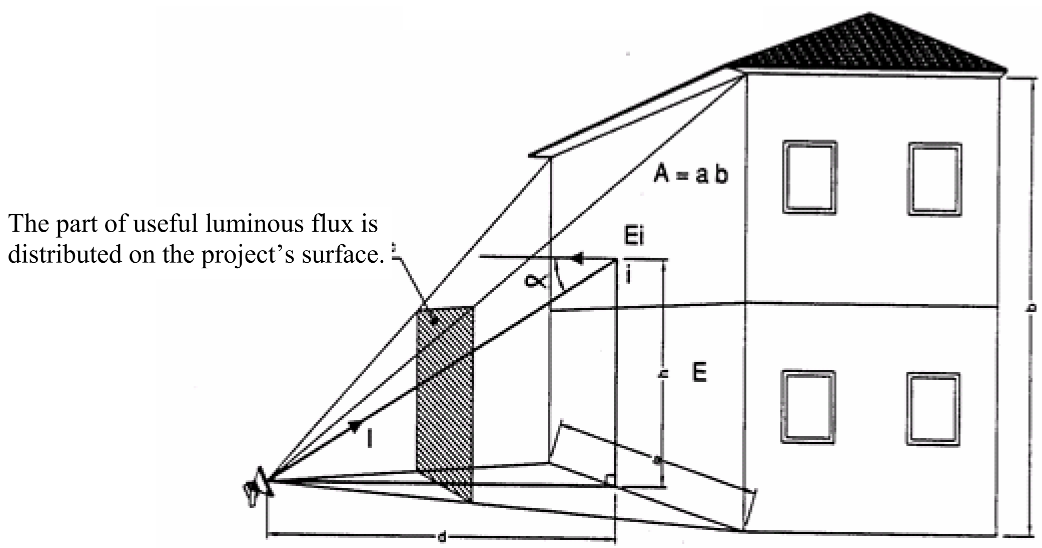
$$N = \frac{E}{E(tb)M_F}$$

Note:

- The luminous intensity emits from the luminaire to the point needed to be illuminated (cd). I can be looked up from the distribution curve of luminous intensity in the catalogue of luminaires supplied by the manufacturer.

- Ei: The illuminance level achieved on the project's surface at the lighting point i (lx).
- E(tb): The average illuminance level achieved on the project's surface because of the illumination efficiency of one luminaire (lx).
- E: The average illuminance level needed to be achieved on the project's surface with the consideration of decreasing factor (lx).
- n: The number of points to calculate the illuminance level.
- h: The height difference between the light's position and the lighting point of the beam's centre on the project's surface (m).
- α: The illumination angle (degree).
- M_F: The general maintenance factor.
- N: The number of necessary luminaire (round-off).

Picture 19: The relationship of the luminous intensity, the lighting distance and the illuminance level on the lighted surface.



APPENDIX 7

METHOD OF LIGHTING ARRANGEMENT FOR SOME OUTDOOR PROJECT OF SPORT AND PHYSICAL EDUCATION

1. Lighting football field and multifunction stadium

Arranging illuminators for football fields and multifunction stadiums can follow 2 forms:

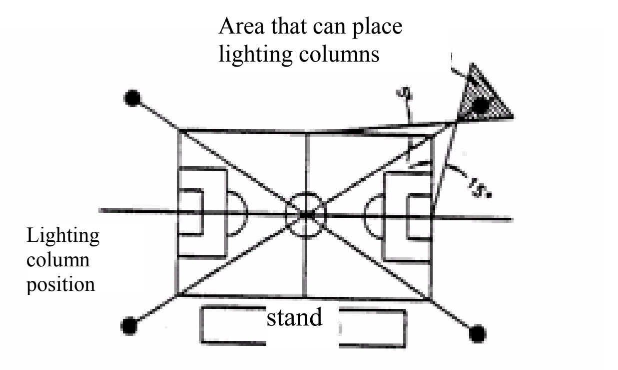
a. Installing illuminators on lighting columns.

b. Installing illuminators on stand's canopy.

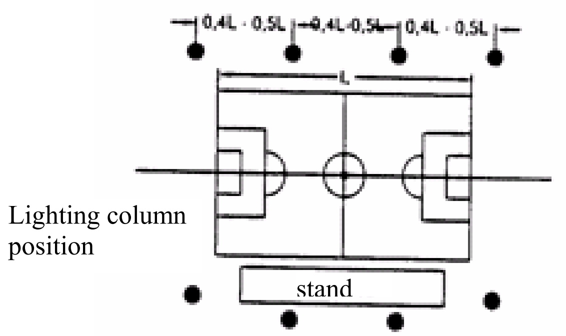
1.1. In case that the design doesn't allow lighting arrangement on the stand's canopy, solution of lighting column arrangement can be performed according to picture 20:

Picture 20: Arrangement of illuminators on lighting column

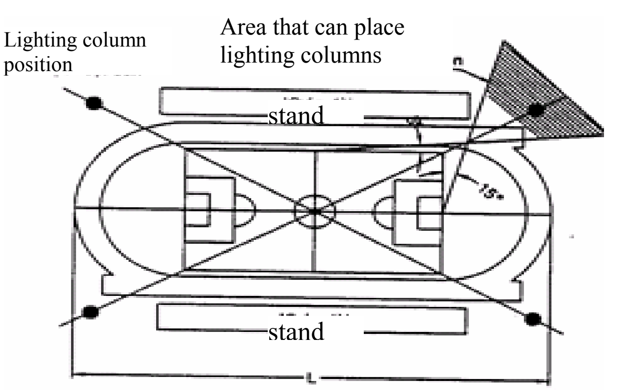
a. Football field – Solution of using 4 lighting columns



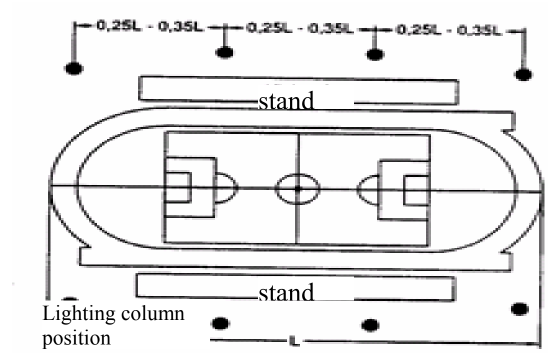
b. Football field – Solution of using 8 lighting columns



c. Multifunction stadium – Solution of using 4 lighting columns



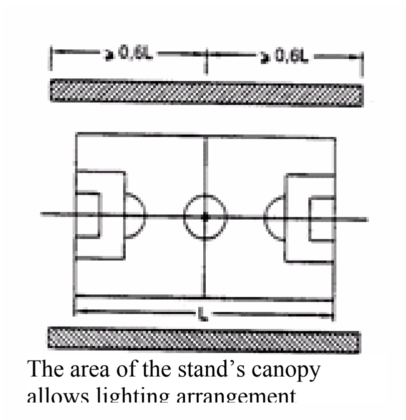
d. Multifunction stadium – Solution of using 8 lighting columns



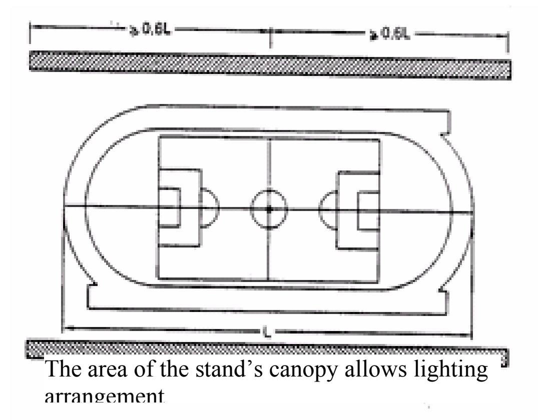
1.2. In case that the canopy structure of the stand allows lighting arrangement and the pitch of installing illuminators satisfies conditions regulated in article 4.4.2.4, the solution of lighting arrangement on the canopy can follow picture 21:
10m to 15m

Picture 21: Lighting arrangement on the stand's canopy

a. Football field



b. Multifunction stadium

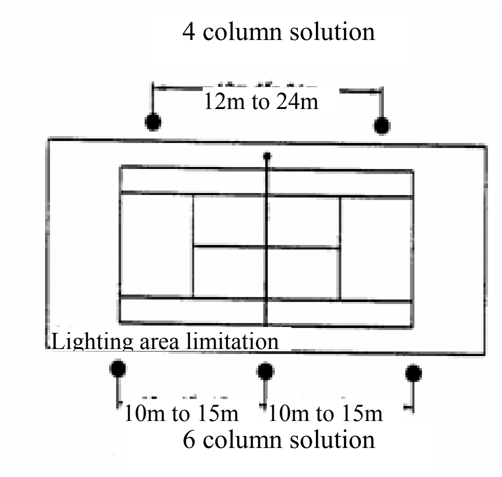


2. Lighting tennis-court

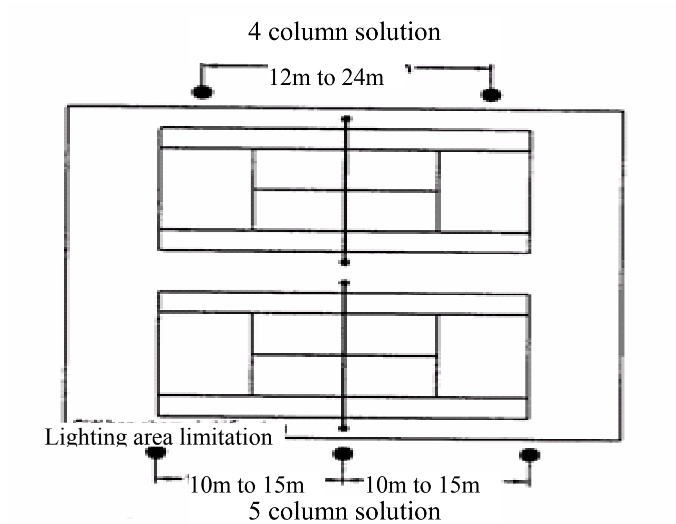
2.1. Solution to arrange lighting columns to illuminate single tennis-courts, double tennis-courts or multi tennis-courts without barriers among courts can follow picture 22:

Picture 22: Arrangement of lighting columns to illuminate tennis-court without barriers

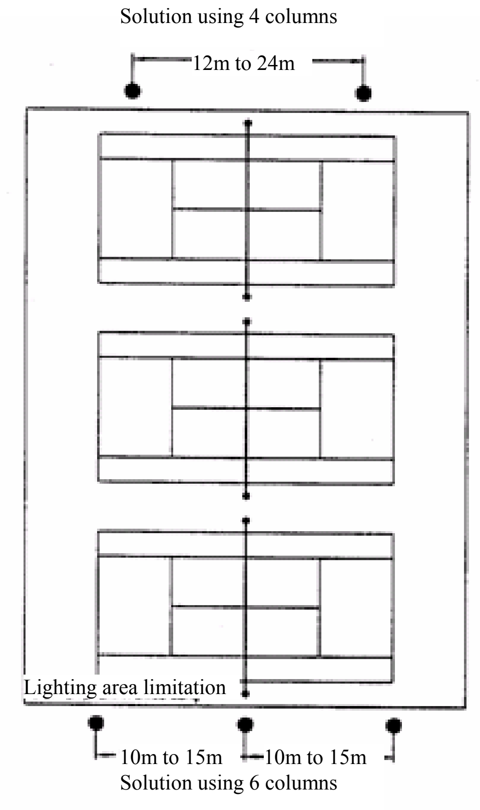
a. Single tennis-court



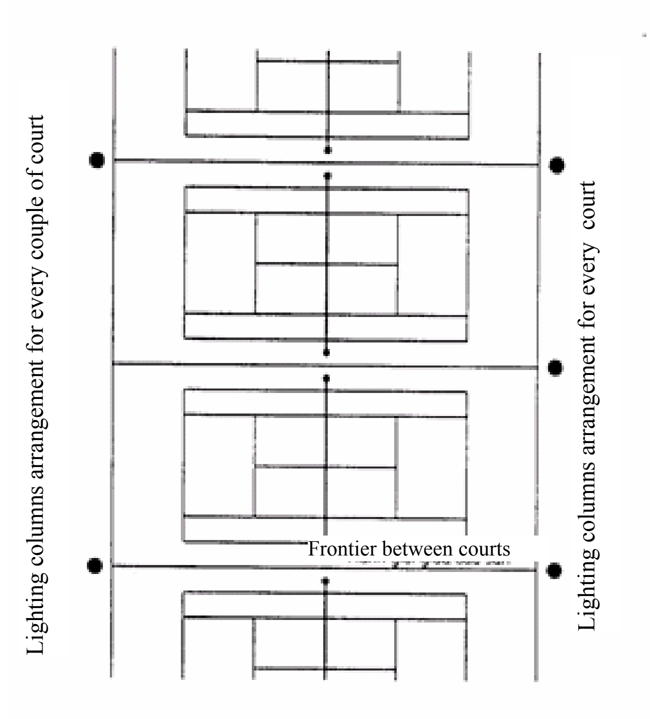
b. Double tennis-court



c. Triple tennis-court



d. Tetra tennis-court or multi tennis-court



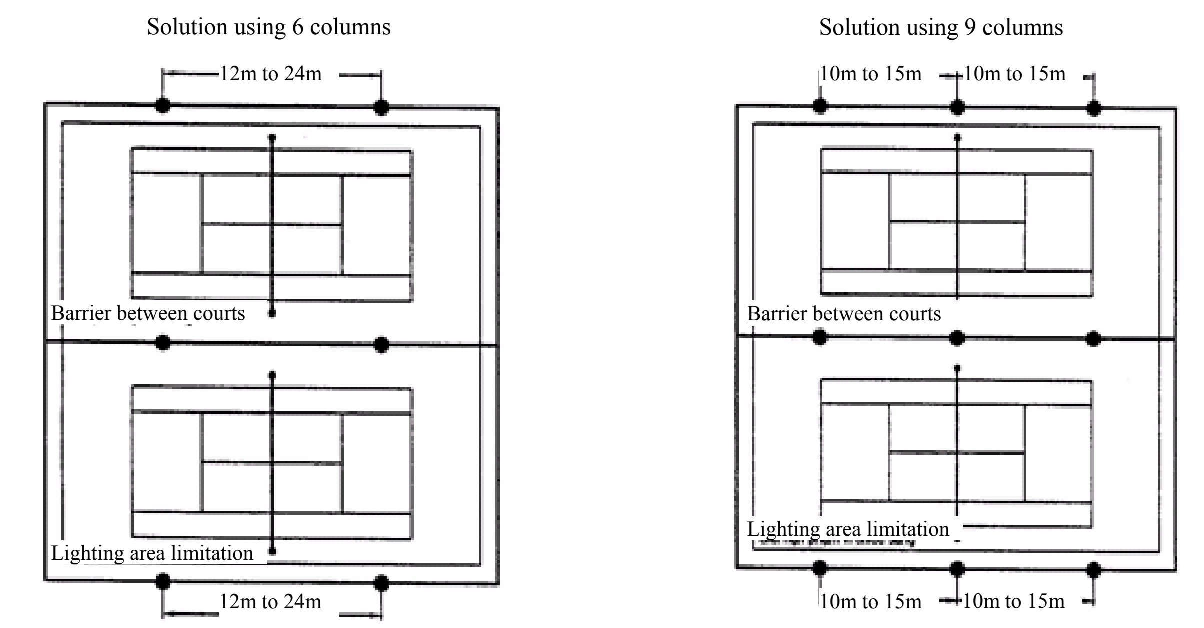
Note:

- In case that the court includes surrounding fence, the lighting columns can be arranged outside the fence, between fences or inside and close to the fence.
- If arranging lighting following picture 10(d), it is needed to base on the using demand to design the system of controlling lighting according to groups of courts for the purpose of saving electric consumption.

2.2. Solution to arrange lighting columns to illuminate single tennis-courts, double tennis-courts or multi tennis-courts with barriers among courts can follow picture 23:

2.3.

Picture 23: Arrangement of lighting columns to illuminate tennis court with barriers



Note:

- Triple tennis-court or multi tennis-court is arranged lighting following the similar method.
- System of controlling lighting needs to be designed to be able to turn on and off lights for each separate court.

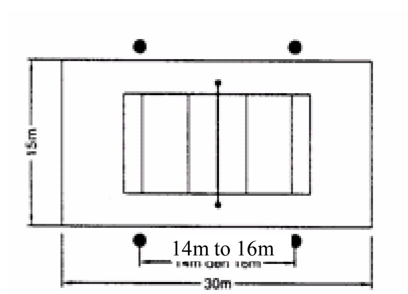
3. Lighting volleyball-basketball-badminton field

3.1. Volleyball field

Picture 24: Arrangement of lighting columns to illuminate volleyball field

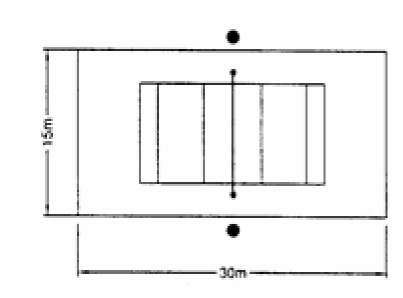
a. Solution of using 4 lighting columns:

Competition-training field



b. Solution of using 2 lighting columns:

For training field only

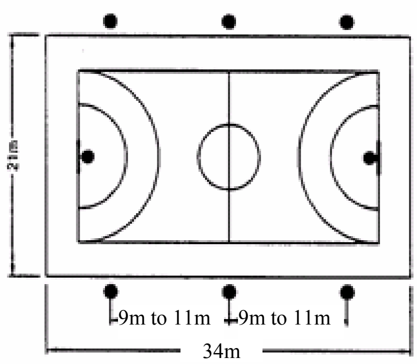


3.2. Basket-ball field

Picture 25: Arrangement of lighting columns to illuminate basket-ball field

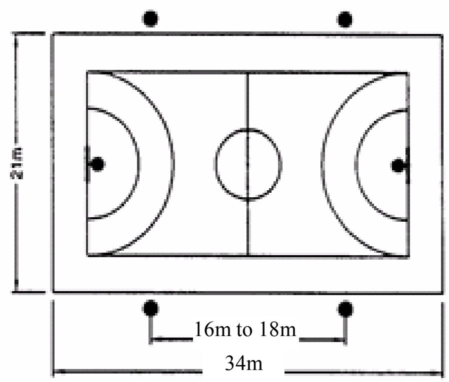
a. Solution of using 6 lighting columns:

Competition-training field



b. Solution of using 4 lighting columns:

For training field only

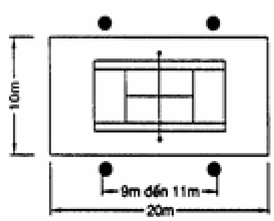


3.3. Badminton field

Picture 26: Arrangement of lighting columns to illuminate badminton field

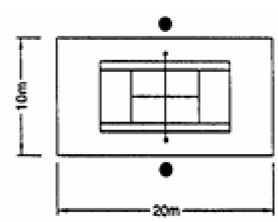
a. Solution of using 4 lighting columns:

Competition-training field



b. Solution of using 2 lighting columns:

For training field only



4. Lighting outdoor swimming pool

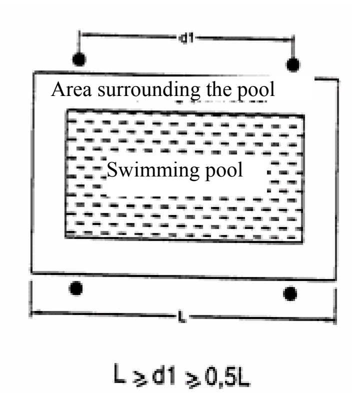
Solution of lighting arrangement for outdoor swimming pools can be chosen according to elements: the swimming pool's form and size and the purpose of using. Referring table 32 and picture 27:

Table 32: Solution of lighting arrangement for outdoor swimming pool

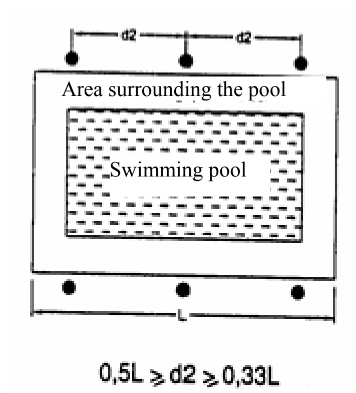
Order	Purpose of using	Solution of lighting arrangement	
		Swimming pool of 25m	Swimming pool of 50m
1	Training-entertainment	Using 4 lighting columns	Using 6 lighting columns
2	Normal competition	Using 6 lighting columns	Using 8 lighting columns
3	Official competition		

Picture 27: Arrangement of lighting columns to illuminate outdoor swimming pool

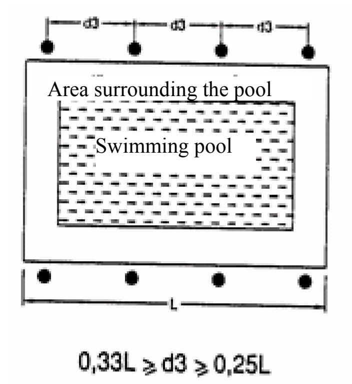
a. Solution of using 4 lighting columns:



b. Solution of using 6 lighting columns:



c. Solution of using 8 lighting columns:



Note:

- L: Length of lighting area (m)
- d1, d2, d3: distance between lighting columns (m)

APPENDIX 8

Method to measure lightning for outdoor sport constructions

1. Football field and multi-function field:

1.1. Measuring area:

Lightning measuring area of football field consists of the whole field which is limited by horizontal and vertical touch-line.

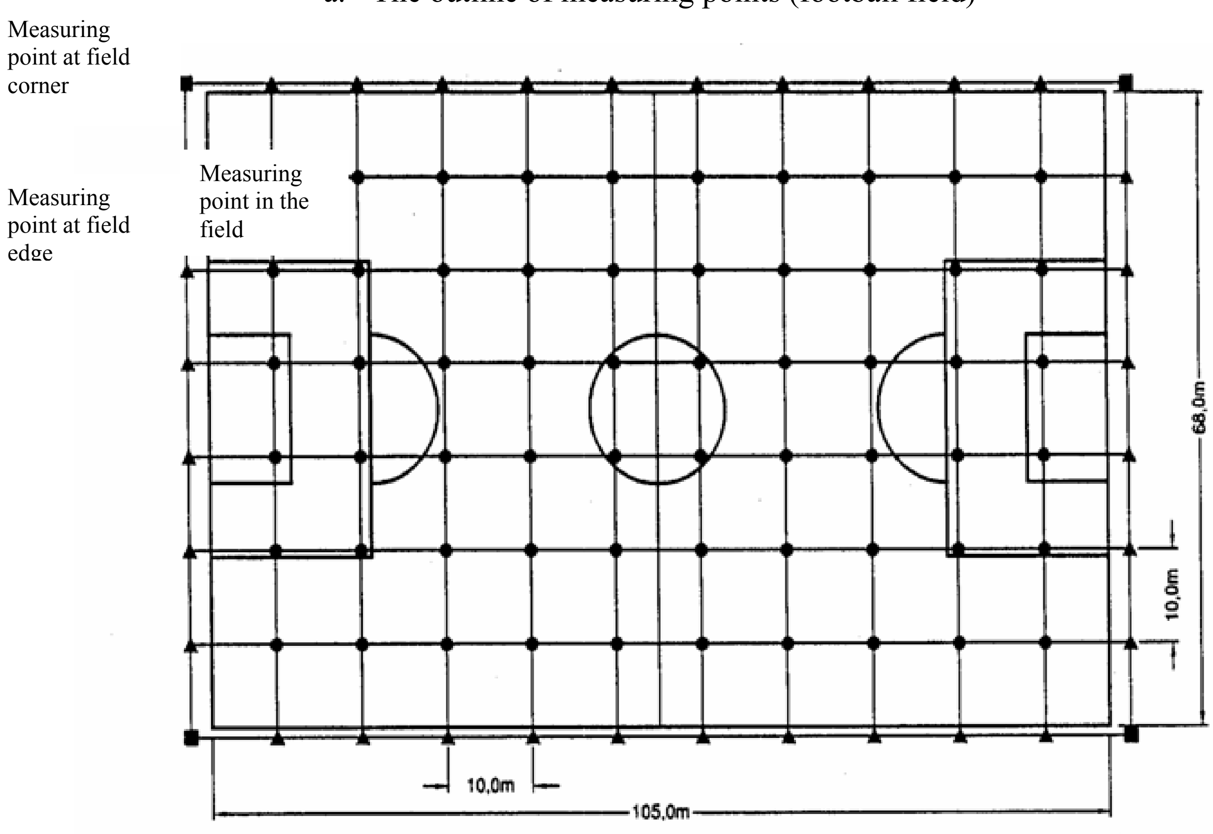
Lightning measuring area of multi-function field consists of the whole field which is limited by outer boundary of tracks around the field.

1.2. Lightning measuring net:

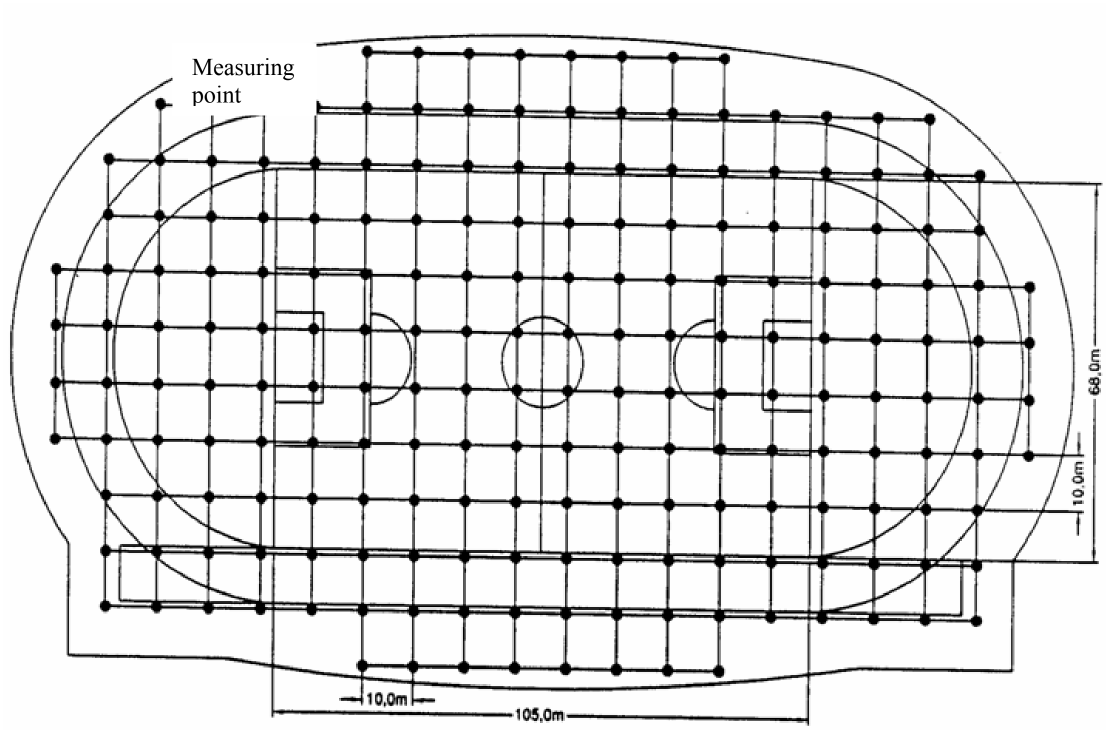
1.2.1.Lightning measuring net of football field and multi-function field is stipulated in figure 28:

Figure 28: Lightning measuring net of football field and multi-function field

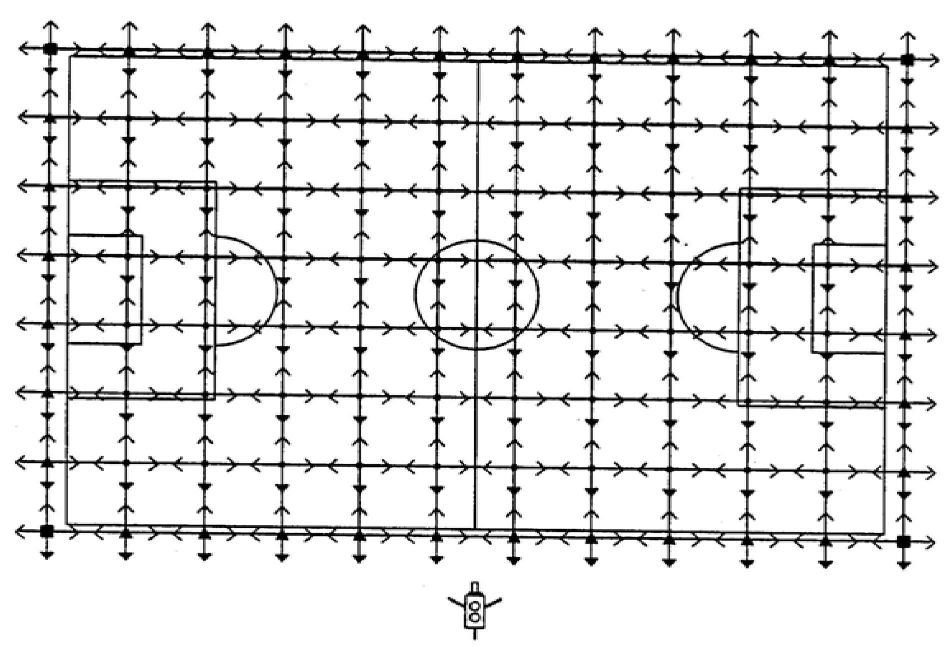
a. The outline of measuring points (football field)



b. The outline of measuring points (multi-function field)



c. Measuring illumination level in vertical direction (football field)



Note:

→ Vertical direction toward the main camera of measuring illumination level

→ Other direction of measuring illumination level.

1.2.2. If field structure and lightning system have symmetric design through the glide path of the field, we need to measure all measuring points on ½ of the field and then deriving the measuring result for the other half.

1.2.3. To maintain and manage lightning system, we should select some model measuring points to measure. On that establishment, we can monitor changes of lightning level of field when used.

1.3. Measuring method:

1.3.1. The average horizontal illumination level of football and multi-function field:

1.3.1.1.The average horizontal illumination level of football field follows the formula:

$$En(tb) = \frac{1}{4N}\left(\sum_{i=1}^{4} E_{\blacksquare}i + 2\sum_{i=1}^{m} E_{\blacktriangle}i + 4\sum_{i=1}^{t} E_{\bullet}i\right)$$

Note:

- En(tb): The average horizontal illumination level of football field (lx).
- $E_{\blacksquare}i$: The horizontal illumination level at measuring points at field corner at field height (lx).
- $E_{\blacktriangle}i$: The horizontal illumination level at measuring points at field edge at field height (lx).
- $E_{\bullet}i$: The horizontal illumination level at measuring points at field center at field height (lx).
- N: The number of square of illumination net.
- m: The number of measuring points at field edge.
- t: The number of measuring points in the field.

1.3.1.2. The average horizontal illumination level of multi-function field follows the formula:

$$En(tb) = \frac{1}{n}\sum_{i=1}^{n} Ei$$

Note:

- En(tb): The average horizontal illumination level of multi-function field (lx).
- Ei: The horizontal illumination level at measuring points at field height (lx).
- n: The number of measuring points.

1.3.2. The average vertical illumination level of football field follows the formula:

$$Ed(tb) = \frac{1}{n} \sum_{i=1}^{n} Ed\ i$$

Note:

- Ed(tb): The average vertical illumination level of football field (lx).

- Ed i: The vertical illumination level at measuring points at 1,5m height in the direction toward the main camera (lx).

2. Tennis court:

2.1. Measuring area:

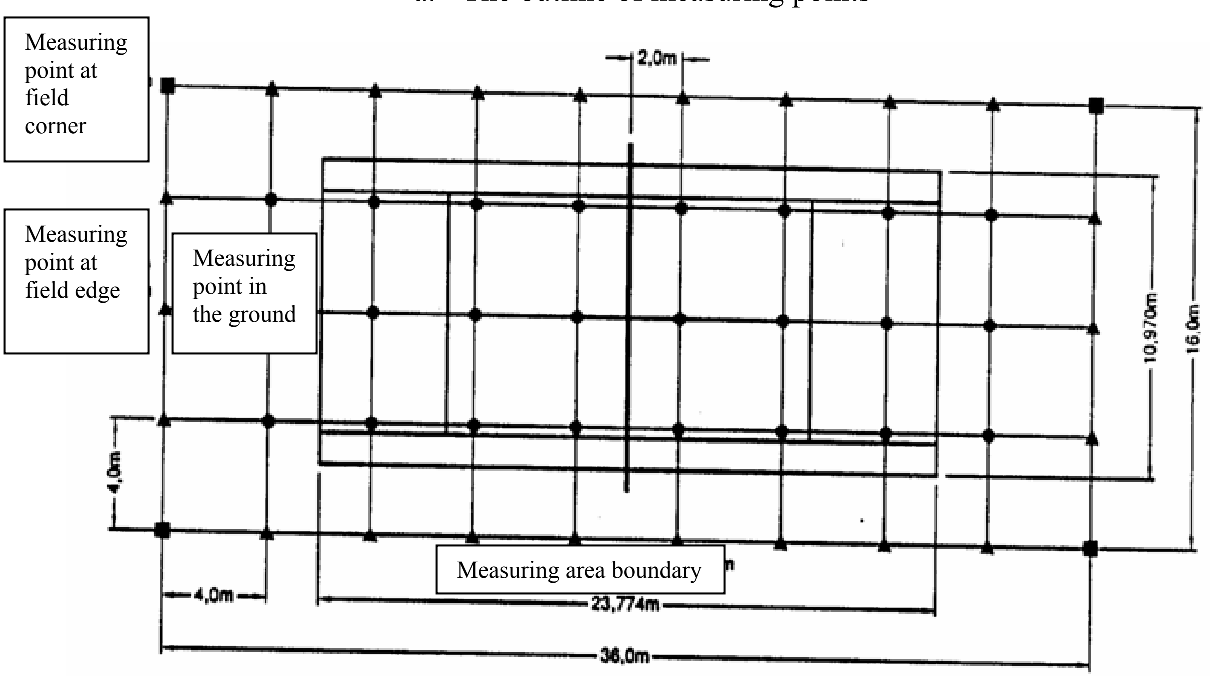
Lightning measuring area of tennis court consists of the whole area (16m x 36m) covering the court at the center of the area. If there are two continuous or more than two continuous courts, we measure the same area for each court.

2.2. Lightning measuring net:

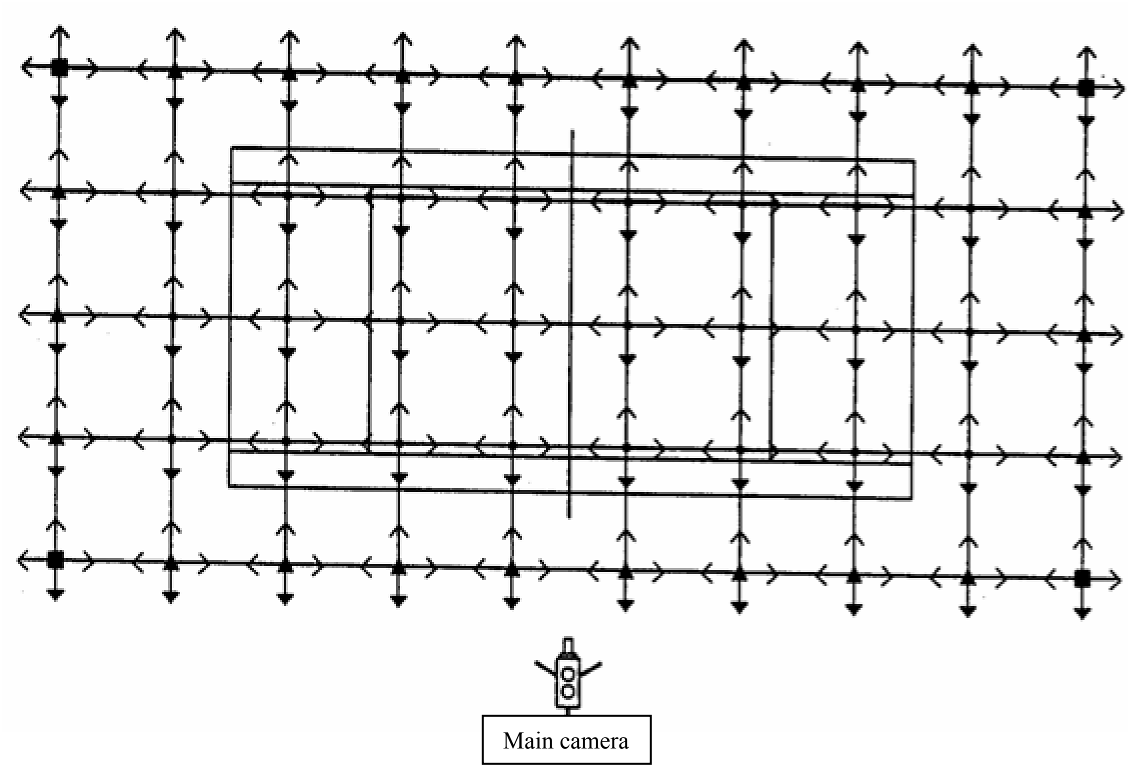
2.2.1. Lightning measuring net of tennis court consists of 50 measuring points and is stipulated in figure 29.

Figure 29: Lightning measuring net for tennis court

a. The outline of measuring points



b. The vertical illumination direction



Note:

→ Vertical direction toward the main camera of measuring illumination level

→ Other direction of measuring illumination level.

2.2.2. If field structure and lightning system have symmetric design through the glide path of the field, we need to measure all measuring points on ½ of the field and then deriving the measuring result for the other half.

2.2.3. To maintain and manage lightning system, we should select some model measuring points to measure. On that establishment, we can monitor changes of lightning level of field when used.

2.3. Measuring method:

2.3.1. The average horizontal illumination level of tennis court follows the formula:

$$En(tb) = \frac{1}{144}\left(\sum_{i=1}^{4} E_{\blacksquare} i + 2\sum_{i=1}^{22} E_{\blacktriangle} i + 4\sum_{i=1}^{24} E_{\bullet} i\right)$$

Note:

- En(tb): The average horizontal illumination level of tennis court (lx).

- $E_{\blacksquare i}$: The horizontal illumination level at measuring points at court corner at field height (lx).

- $E_{\blacktriangle i}$: The horizontal illumination level at measuring points at court edge at field height (lx).

- $E_{\bullet i}$: The horizontal illumination level at measuring points at court center at field height (lx).

2.3.2. The average vertical illumination level of tennis court follows the formula:

$$Ed(tb) = \frac{1}{50} \sum_{i=1}^{50} Ed\,i$$

Note:

- Ed(tb): The average vertical illumination level of tennis court (lx).

- Ed i: The vertical illumination level at measuring points at 1,5m height in the direction toward the main camera (lx).

3. **Other outdoor sports fields:**

Measuring other outdoor sports fields can follow the same method.

APPENDIX 9

Table 33: Technical parameter of popular bulbs using for lightning

Bulb type	Capacity P (W)	Luminous flux F (lm)	Luminescent effect (lm/W)	Color temperature T (K)	Color transmitting index CRI	Average duration (h)
Incandescent haloid	100	1600	16,0	2800 - 3200	100	2000
	150	2400	16,0			
	200	3520	17,6			
	300	5600	18,7			
	500	9900	19,8			
	1000	24200	24,2			
	1500	36300	24,2			
	2000	48400	24,2			
Pipe fluorescence	20	1350	67,5	2700 - 6500	85	1000
	40	3350	83,8			
	60	5200	86,7			
Compact fluorescence	15	900	60,0	2700 - 4000	85	1000
	20	1200	60,0			
	23	1500	65,2			
CA Mercury	80	3700	46,3	3900 - 4300	33 - 49	2500
	125	6200	49,6			
	250	12700	50,8			
	400	22000	55,0			
CA Sodium	70	5600	80,0	2100 - 2500	25 - 65	8000
	150	15000	100,0			
	250	28000	112,0			
	400	48000	120,0			
	1000	125000	125,0			
Metal Halide	70	5100	72,8	3000 - 6500	65 - 90	4000
	150	11000	73,3			
	250	17000	68,0			
	400	30500	76,3			
	1000	81000	81,0			
	2000	183000	91,5			

Note:

Depending on technical standards of different manufacturers, technical parameters of some bulbs can have different values with values in the table above. Values in table 33 can be used as reference. When designing, we should refer technical documents of manufacturers for each type of bulb used in the project.

Reference

1. BS 5489: Road lighting. Guide to the general principles.
2. BS 5489: Road lighting - Part 3. Code of practice for lighting for subsidiary roads and associated pedestrian areas.
3. BS 5489: Road lighting - Part 9. Code of practice for lighting for urban centres and public amenity areas.
4. JIS Z 9110: 1979 - Recommended level of illumination.
5. JIS Z 9120: 1995 - Lighting for outdoor tennis courts and outdoor baseball fields.
6. JIS Z 9121: 1997 - Lighting for outdoor tracks and fields, outdoor soccer fields and rugby fields.
7. JIS Z 9123: 1997 - Lighting for outdoor, indoor swimming pools.
8. Illuminating engineering society of North America - Recommended practice for Sports and Recreational area lighting.
9. Lighting guide - The outdoor environment.