THORN

Tunnel lighting

Contents

As our road networks become more crowded, the use of tunnels and underpasses is expanding, both to improve traffic flow, and to protect local environments from increased traffic exposure.

Within tunnels, where maintenance access can be limited, and where corrosive atmospheric conditions are common, reliable performance of the lighting system is critical, as is the need for the absolute minimum of operational maintenance requirements.

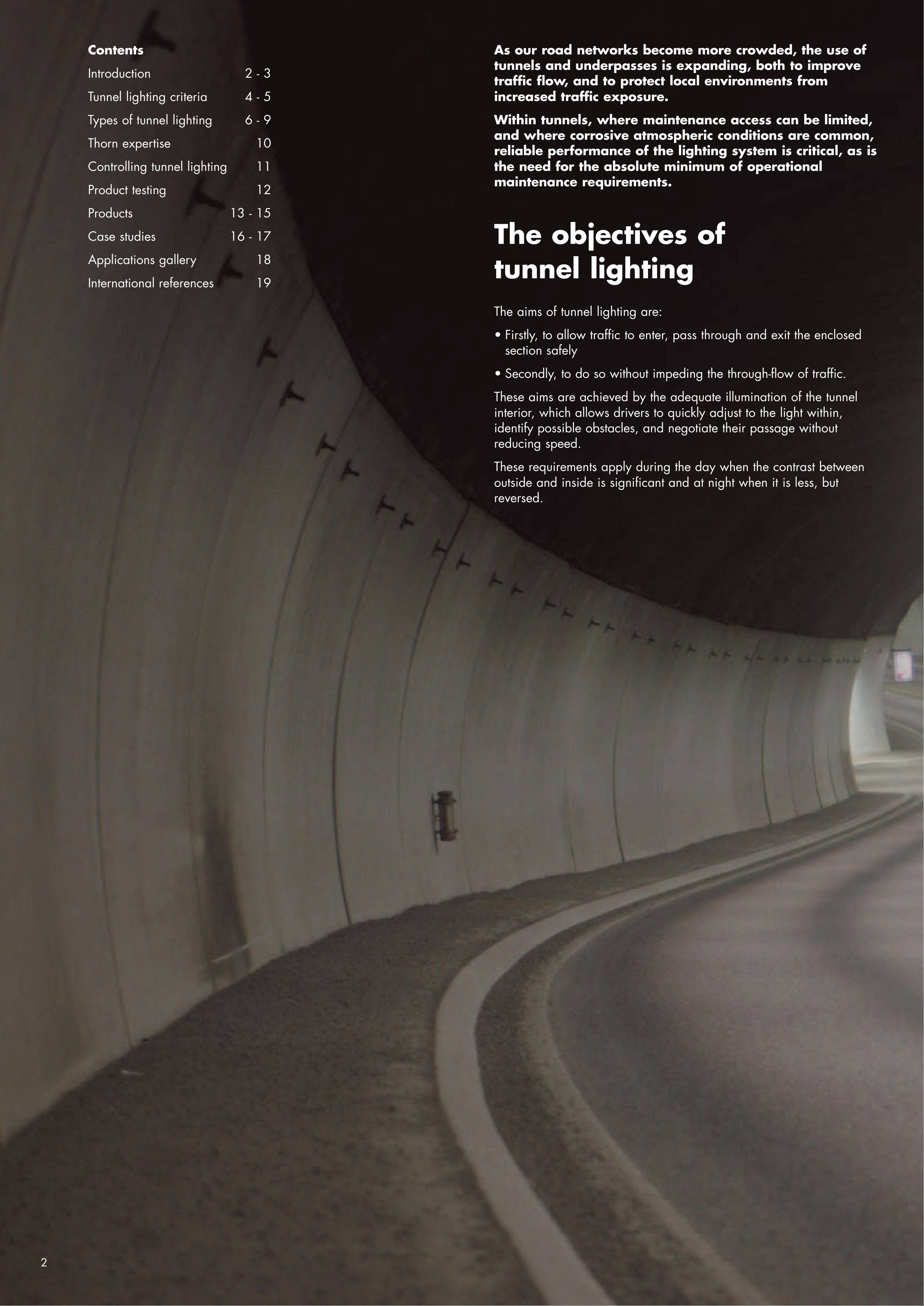
The objectives of tunnel lighting

The aims of tunnel lighting are:

- Firstly, to allow traffic to enter, pass through and exit the enclosed section safely
- Secondly, to do so without impeding the through-flow of traffic.

These aims are achieved by the adequate illumination of the tunnel interior, which allows drivers to quickly adjust to the light within, identify possible obstacles, and negotiate their passage without reducing speed.

These requirements apply during the day when the contrast between outside and inside is significant and at night when it is less, but reversed.



Tunnel lighting criteria

Good tunnel lighting allows users to enter, pass through and exit the enclosed section safely and comfortably

The 5 zones of tunnel lighting
CIE guidance (CIE 88-1990) states that the amount of light required within a tunnel is dependent on the level of light outside and on the point inside the tunnel at which visual adaptation of the user must occur.

When planning the lighting of a tunnel, there are 5 key areas to consider:

1 Access zone
Not within the tunnel itself, this is the stretch of road leading to its entrance.

From this zone, drivers must be able to see into the tunnel in order to detect possible obstacles and to drive into the tunnel without reducing speed.

The driver's capacity to adapt in the access zone governs the lighting level in the next part of the tunnel. One of the methods used by CIE to calculate visual adaptation is the L_{20} method, which considers the average luminance from environment, sky and road in a visual cone of 20°, centred on the line of sight of the driver from the beginning of the access zone (see below).

2 Threshold zone
This zone is equal in length to the 'stopping distance'. In the first part of this zone, the required luminance must remain constant and is linked to the outside luminance (L_{20}) and traffic conditions. At the end of the zone, the luminance level provided can be quickly reduced to 40% of the initial value.

3 Transition zone
Over the distance of the transition zone, luminance is reduced progressively to reach the level required in the interior zone. The reduction stages must not exceed a ratio of 1:3 as they are linked to the capacity of the human eye to adapt to the environment and, thus, time-related. The end of the transition zone is reached when the luminance is equal to 3 times the interior level.

4 Interior zone
This is the area between transition and exit zones, often the longest stretch of tunnel. Lighting levels are linked to the speed and density of traffic, as outlined in the table below.

Luminance to be maintained in interior zone

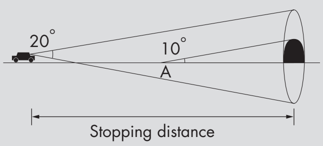
Extra urban, low traffic, low speed (<70km/h)	1.5 to 3cd/m²
Extra urban, high traffic and/or speed (>70km/h)	2 to 6cd/m²
Highway	4 to10cd/m²
Urban	4 to10cd/m²

5 Exit zone
The part of the tunnel between interior zone and portal. In this zone, during the day time, the vision of a driver approaching the exit is influenced by brightness outside the tunnel.

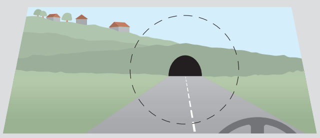
The human eye can adapt itself almost instantly from low to high light levels, thus the processes mentioned when entering the tunnel are not reversed. However, reinforced lighting may be required in some cases where contrast is needed in front of or behind the driver when the exit is not visible, or when the exit acts as entrance in case of emergency or maintenance works where part of a twin tunnel may be closed. The length is a maximum 50m and the light level 5 times the interior zone level.

Visual adjustment

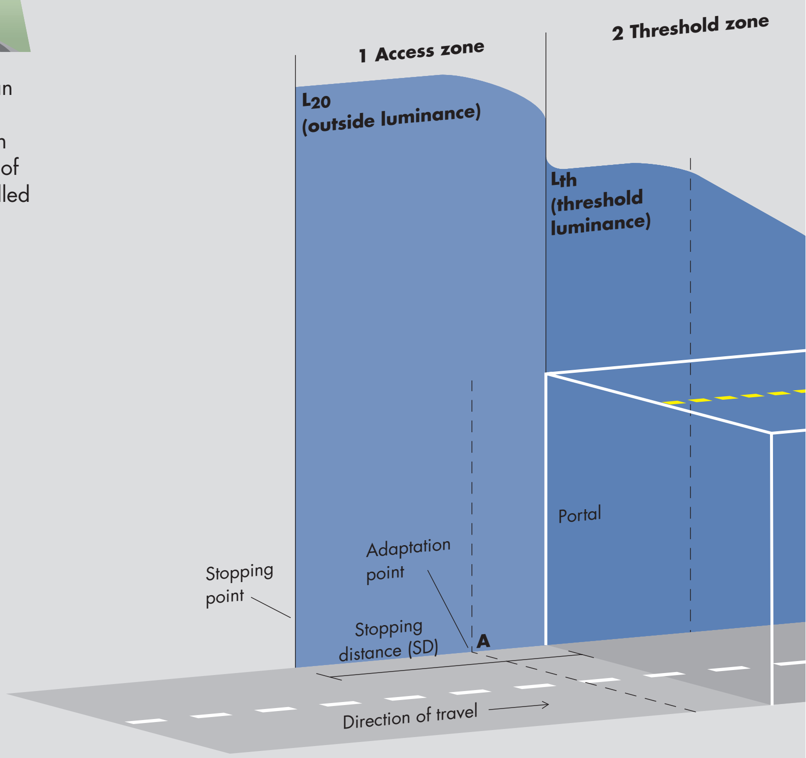
The visual adjustment from high luminance to low luminance while driving is not instantaneous.This is cause of 2 disability phenomena:



1. Spatial adaptation: the large difference in luminance between the outside and the inside of the tunnel will impede the vision of the driver when he is at the adaptation point ('A', opposite). The "Black Hole" phenomenon engenders a feeling of discomfort and insecurity.



2. Temporal adaptation: human eyes need more time to adapt from brightness to darkness than the reverse. During this period of adaptation, the distance travelled is a critical factor.



Definitions

Access zone luminance L_{20}
The average value of the luminance in a 20° cone of the driver's visual field from the access zone and centred on the tunnel entrance.

Contrast revealing coefficient qc
The ratio between the luminance at the road surface and the vertical illuminance Ev at a specific location in the tunnel qc=L/Ev. The method of tunnel lighting may be defined in terms of the contrast ratio in three ways: symmetric lighting, counterbeam lighting and pro-beam lighting (see pages 6 - 7).

Entrance and exit portals
The entrance portal of the tunnel is the part of the tunnel construction that corresponds to the beginning of the covered part of the tunnel, or - when open sun-screens are used - to the beginning of the sun-screens. The exit portal corresponds to the end of the covered part of the tunnel, or - when open sun-screens are used - to the end of the sun-screens.

Exit zone
The exit zone is the part of the tunnel where, during the daytime, the vision of a driver approaching the exit is predominately influenced by the brightness outside the tunnel. The exit zone begins at the end of the interior zone. It ends at the tunnel's exit portal.

Interior zone luminance (L_{in})
The average luminance in the interior zone which constitutes the background field against which objects will be visible to users.

Parting zone
The parting zone is the first part of the open road directly after the exit. The parting zone is not a part of the tunnel but it is closely related to the tunnel lighting. It is advised that the length of the parting zone equals two times the stopping distance. A length of more than 200m is not necessary.

Stopping point (SP)
The position within the access zone on the approach road at a distance equal to the stopping distance (SD) from the tunnel entrance.

Stopping distance (SD)
The theoretical forward distance required by a driver at a given speed in order to stop when faced with an unexpected hazard on the carriageway.

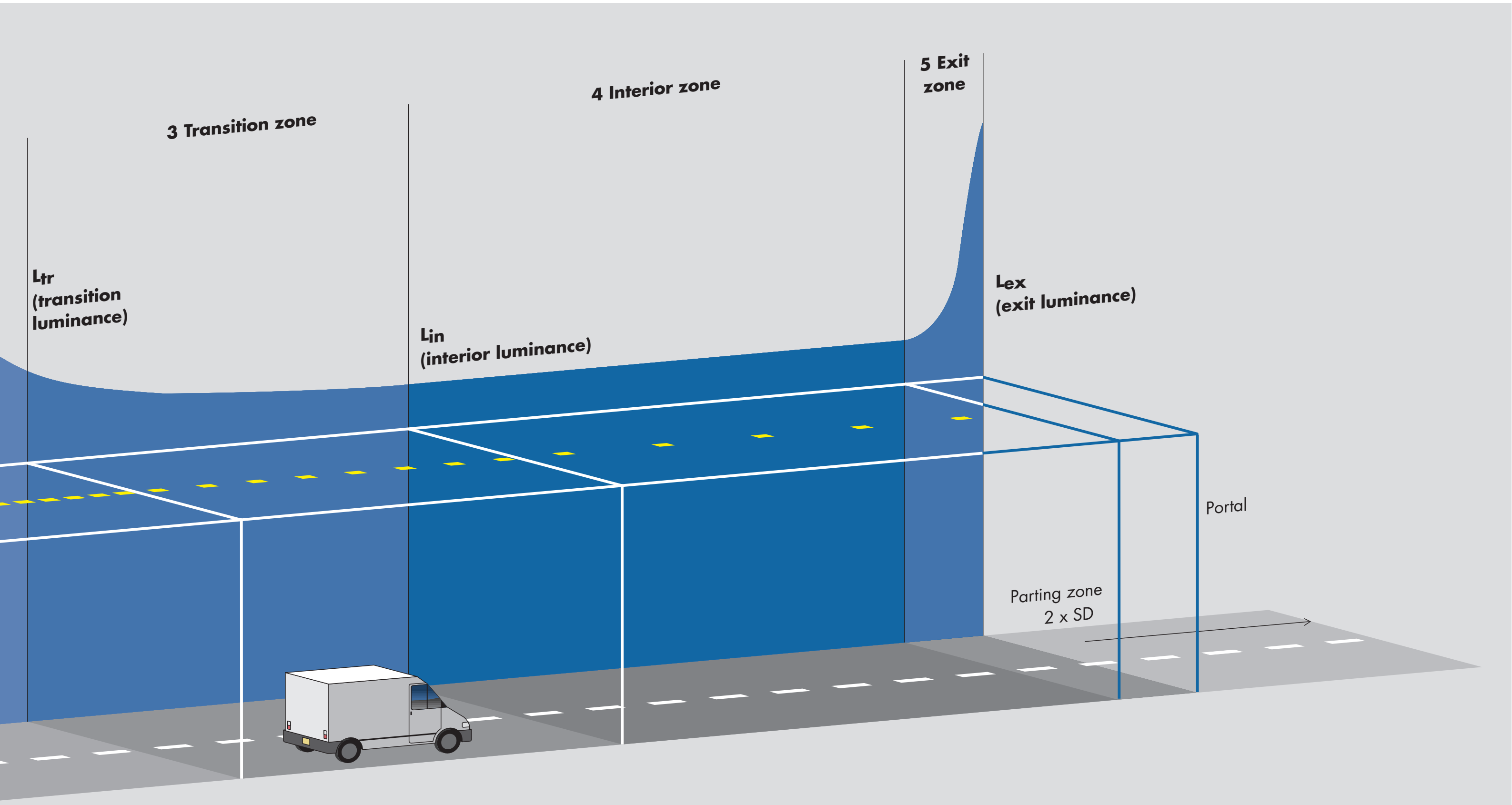
This takes into account perception and reaction time as well as road surface.

Threshold zone luminance (L_{th})
The average luminance in the threshold zone which constitutes the background field against which objects will be visible to drivers in the access zone between the stopping point and adaptation point.

Traffic flow
The number of vehicles passing a specific point in a stated time in stated direction(s). In tunnel design, peak hour traffic, vehicles per hour per lane, will be used.

Transition zone luminance (L_{tr})
The average luminance in the transition zone which constitutes the background field against which objects will be visible to drivers.

Veiling luminance
The overall luminance veil consisting of the contribution of the transient adaptation and stray light from optical media, from the atmosphere and from the vehicle windscreen.



Types of tunnel lighting

Tunnel road lighting must provide comfort and safety and maximise the visual performance of users.

Symmetrical and asymmetrical lighting
Used generally for transition and interior zones for long tunnels, and in short tunnels, or low speed tunnels for all zones.

Asymmetrical lighting can also be a means of reinforcing the luminance level in one way tunnels.

Asymmetric counter beam lighting
To reinforce the luminance level and at the same time accentuate the negative contrast of potential obstacles. Counter beam lighting is achieved with asymmetrical light distribution facing into the traffic flow, both in the direction of the on coming driver and in the run of the road. The beam stops sharply at the vertical plane passing through the luminaire. No light is directed with the flow of traffic. This generates negative contrast and enhances visual adaptation.

Pro beam lighting
In some circumstances, positive contrast must be reinforced, often in the exit zone where the exit is visible. In these cases, asymmetric light distribution is used in the same way as counter beam but *with* direction of the traffic and is called 'pro beam'. In dual carriage way tunnels, counter beam at entrance can act as pro beam at exit.
This technique is not recommended as the road luminance is very low, creating too big a disparity between the exit zone and the parting zone.

Other factors
As well as the above, further factors must be taken into consideration when preparing tunnel lighting. These include the shape of the portal, type and density of traffic, traffic signage, contribution of wall luminance, orientation of tunnel, and many others. National, European and International legislation and guidance sets out minimum standards for tunnel lighting.

Relevant legislation

CEN TC 169/WG 6
Technical Report Final Draft 08.2001.

CETU
Dossier pilote des tunnels - November 2000.

CIE 88-1990
Guide for the lighting of roads, tunnels and underpasses.

DIN 67524:8 1992
Beleuchtung von Straßen tunnels and Unterfuhrugen Teil 1: Allgemeine Gutemerk-male and Richtwerte Teil 2: Berechnung und Messung.

SN 150915:1997
Offentliche Beleuchtung Straßentunnels, - Galereinunterfuhrungen.

NSV 1991
Aanbevelingen voor de verlichting van lange tunnels voor het gemotoriseerde verkeer.

BS 5489-2: 2003
Roadlighting Part 2: Code of Practice for the design of road lighting.

UNI 11095:2003
Luce e illuminazione - Illuminazione delle galerie.

Day time lighting of tunnels for different lengths
(CIE-Guide for the lighting of tunnels and underpasses)

When lighting a tunnel, its length, geometry and immediate environment must be taken into account as well as traffic densities.
Differing light levels are set for each project, according to the governing standards summarised below:

Length of tunnel	<25m	25-75m					75-125m						>125m
Is exit fully visible when viewed from stopping distance in front of tunnel?	-	yes	yes	no	no	no	yes	yes	no	no	no	no	-
Is daylight penetration good or poor?	-	-	-	good	good	poor	-	-	good	good	good	poor	
Is wall reflectance high (>0.4) or low (<0.2)?	-	-	-	high	low	-	-	-	high	high	low	-	-
Is traffic heavy (or does it include cyclists or pedestrians) or light?	-	light	heavy	light	-	-	light	heavy	light	heavy	-	-	-
Lighting required	No day time lighting	No day time lighting	50%	No day time lighting	50%	50%	50%	normal	50%	normal	normal	normal	normal

No day time lighting

50% of normal threshold zone lighting level

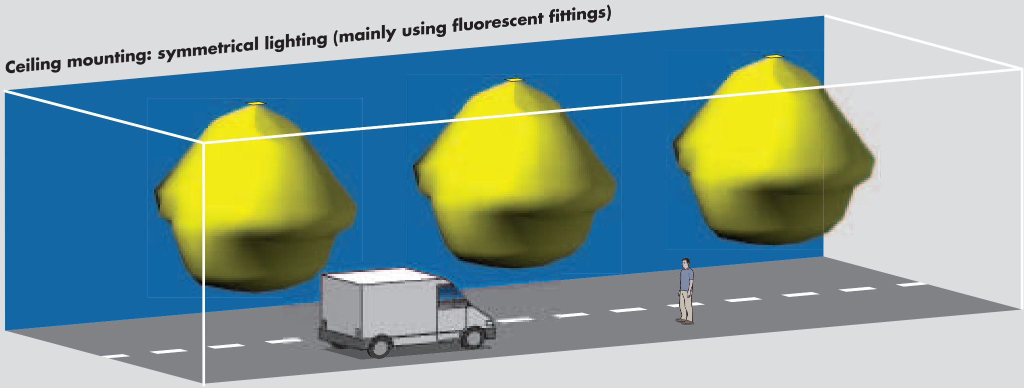
normal threshold zone lighting level

Typical tunnel lighting arrangements

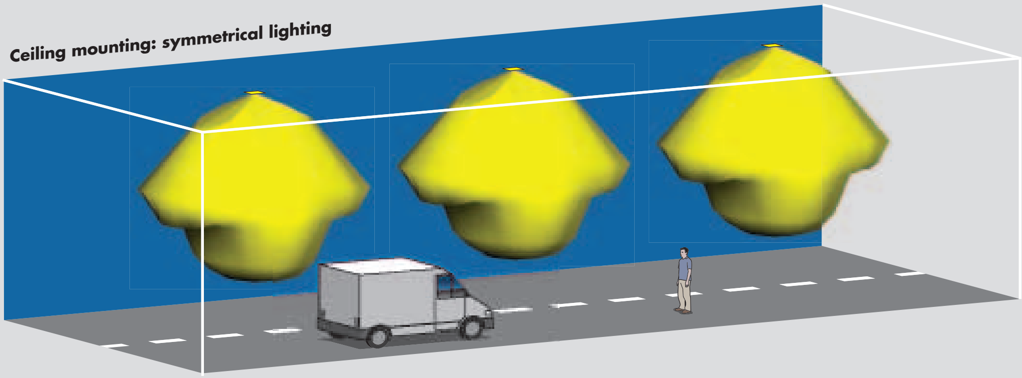
The table below outlines some of the mounting options available and their respective advantages/disadvantages

	Mounting constraint	Arrangement type	Advantages	Disadvantages	Tunnel profile
Ceiling mounting	Enough spacing above legal and protection minimum height	Above road on several rows	- best utilisation factor for luminaires - glare limited	- luminaires concealed by signs - heavy fixings	- Arched type with or without fan tubes - Framed type with or without fan tubes
		1 row above road	- less investment and maintenance	- closure of carriageway required	
Wall mounting	Not enough spacing above legal and protection minimum height	Twin opposite	- easier access to luminaires - 1 lane only need be closed	- utilisation factor downgraded - high glare	- Arched type with fan tubes - Framed type with or without fan tubes
		Single sided	- less investment and maintenance	- beware trucks blocking light	

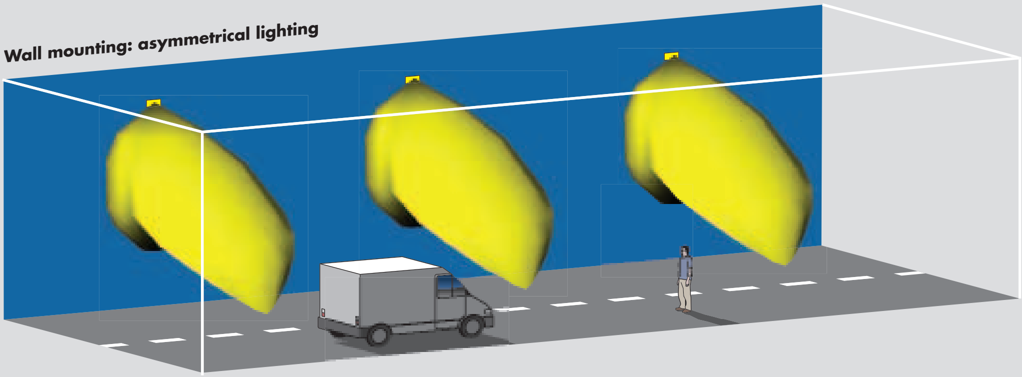
Ceiling mounting: symmetrical lighting (mainly using fluorescent fittings)



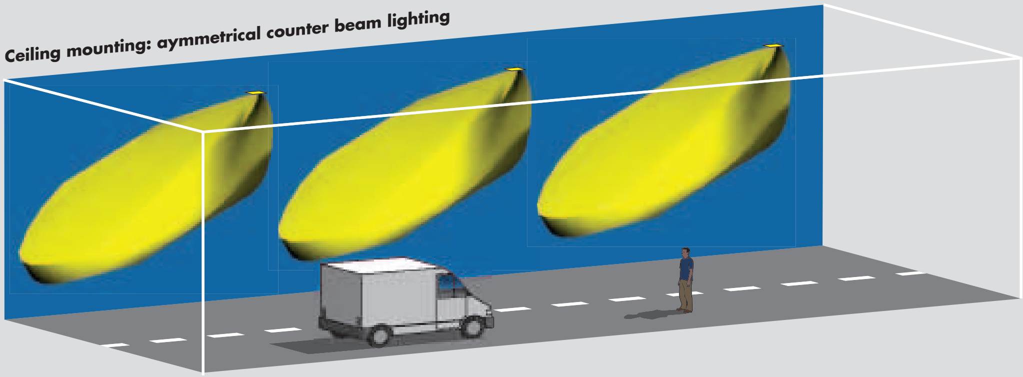
Ceiling mounting: symmetrical lighting



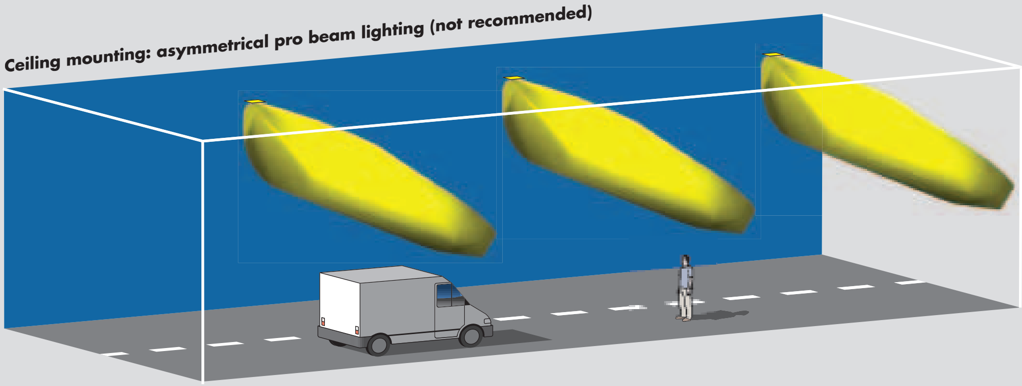
Wall mounting: asymmetrical lighting



Ceiling mounting: aymmetrical counter beam lighting



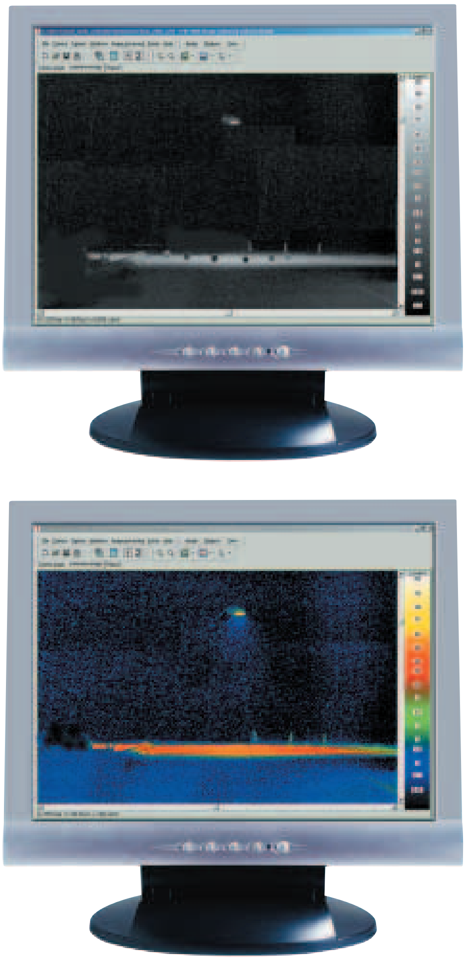
Ceiling mounting: asymmetrical pro beam lighting (not recommended)



Tunnel lighting must allow vehicles to enter, pass through and exit the enclosed section safely without impeding the through-flow of traffic.

Thorn expertise - creating the best tunnel lighting and visibility

Our in-house development programmes employ specialised software that helps produce highly engineered optics, to optimise lighting systems and to allow our lighting engineers to provide maximum safety and comfort for tunnel users.



Thorn visibility modelling software indicates the 'real' visibility of objects as perceived by the tunnel user, as well as the mathematically calculated levels required to meet the relevant standards.

Lighting a tunnel is a complex and specialised task. Thorn has developed dedicated lighting systems and services to assist planners from concept to implementation, management and servicing.

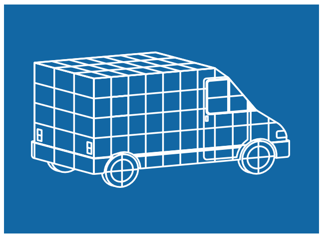
While luminance levels are used for accurate theoretical assessment, in practice, illuminance is more often used. Thorn assessment studies, therefore, are executed using luminance values, with results presented as illuminance values.

It is commonly accepted in road lighting that, even with the most accurate calculations and modelling to give the lighting levels required by the most stringent standards, there is a substantial difference between what the mathematical lighting conditions are, and what each individual driver subjectively sees in reality. This is especially true for tunnel lighting, where such sharp contrasts in light levels prevail.

Thorn in-house visibility modelling software

At Thorn we have addressed this problem head on. Continuous research and development has led to more sophisticated and detailed understanding of lighting and its effects on vision. Along with rapid advances in IT, this has allowed us to develop dedicated in-house software which combines mathematical models of physiological stimuli with conventional lighting modelling parameters to generate results which are, visually, as well as mathematically, accurate beyond alternative visual modelling techniques.

Thanks to an impressive number of variables, our software is a unique and accurate tool. It verifies the ability of a given lighting system to meet the visual criteria set by all national and international standards regarding detection of obstacles on the road, within the allocated time.



Thorn software measures anticipated light falling on a series of facets, in order to calculate luminance gradients on target objects.

Helping lighting designers and tunnel users

Taking into account criteria from the tunnel exterior and interior, the software generates a table of visibility levels (VL) that shows the extreme influence of daylight on the values of VL on targets in the entrance and threshold zones of the tunnel.

Experiments demonstrate that the minimum Level of Visibility (VL) should have a value equal to or greater than 7 to ensure detection of planar or spherical targets. Though in Thorn's current calculations, the target size may not exactly represent a potential obstacle in a tunnel, they show the behaviour of light on real, multifaceted objects whose diffuse reflectance can be modified and therefore they represent a real visual scenario for tunnel users.

The design of the lighting system needed for a tunnel is the job of experienced designers who define the scheme, the choice of the lighting system, the type and number of luminaires and their appropriate light distribution. Thorn's visibility software provides invaluable new input into the design of optics for tunnel fittings making it easier for designers to create lighting systems and light distribution schemes for tunnels that maximise the visual performance and comfort of users.

Controlling tunnel lighting

For the light-critical approach areas and interiors of tunnels, close control of light levels is essential. Levels of light outside the tunnel, time of day, speed and density of traffic, all influence the lighting requirements within. We offer fully integrated control systems to meet these demands.

Thorn tunnel lighting control

Thorn offers a comprehensive range of tunnel luminaires paralleled by a wide variety of lighting controls adapted to tunnel applications:

- From basic to technologically advanced, highly innovative systems
- Fluorescent and HID lamp solutions
- Integration of up to date gear options
- Easy to install and operate systems
- Cost efficient systems
- Optimisation of safety conditions

From simple standard on/off operation, to complex step dimming or security networks, Thorn provides the best professional assistance in advising and offering the right system to meet the requirement.

DSI and DALI controls for fluorescent lamps

- Digital dimming for HF gears operating fluorescent lamps
- Unique cabling

Benefits

- Group management
- Extendible installation
- Capability to interface DSI and DALI controls with analogue 1 - 10V command on existing installations
- Ease of installation thanks to non-polarised command wires
- Enhanced safety of operation as signals not subjected to interference

Power switch controls for HID lamps

- Manual or automated power reduction for HS lamps

Benefits

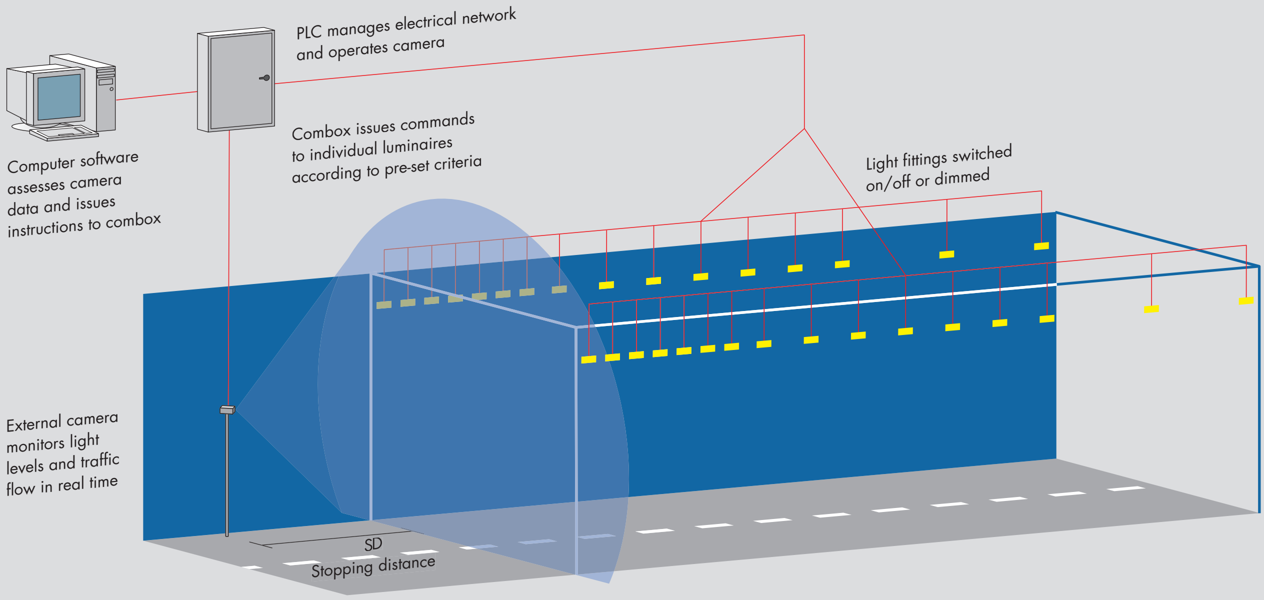
- Ease of installation as integrated in control gear
- Cost efficient options
- Suitable for threshold and central zones

Power line controls for HID lamps

- Automated but re-programmable controls
- Detailed feedback on supply, status logs, dates, times and burning hours

Benefits

- Group management
- Individual control and monitoring
- Upgradable installation
- Possible remote access option via central server
- Capacity to interface the system with data base
- Low installation and operation costs
- Reduced maintenance schedules

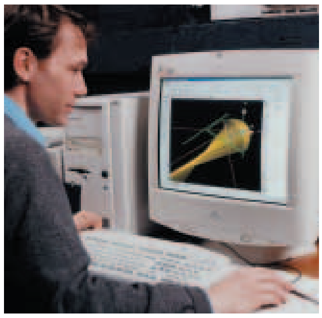


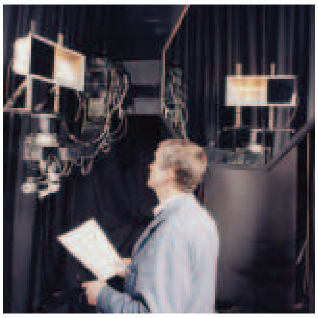
Tough luminaires for tough environments

Salts, sulphur pollutants, exhaust fumes consisting of hydrocarbons and organics in tunnels can result in the presence of sulphuric or nitric acid.


Water ingress protection testing

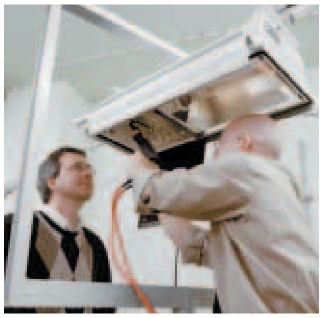

Impact resistance testing


Optic design


Photometric measurement


Assembly and quality control


Corrosion testing


Gear testing

In any given tunnel environment, there may be moisture, salts, sulphur pollutants, exhaust fumes consisting of hydrocarbons and organics, fuels and oils, soot, dust and strong washing detergents from jet cleaning.

Furthermore, analysis of water samples identifies the following compounds: toluene, sulphate, zinc, sulphide, molybdenum, cadmium, beryllium and mercury.

Clearly some of these compounds are the result of corrosion products. Sodium chloride and other chlorides used for road de-icing can add to the chemical cocktail.

Depending on the region (marine atmospheres or long mountain tunnels, for instance), these chemical combinations can result in the presence of sulphuric or nitric acid!

Luminaires installed in such environments can get rapidly contaminated. There is no rainfall to wash away the deposits that settle, condense or get splashed on their surfaces. Regular maintenance can alleviate the conditions, but, in general, this is usually impractical due to the logistics of access, tunnel closure and cost.

In such hostile environments, it is vital to choose designs and materials that create luminaires whose function and effectiveness will not be compromised.

Thorn's tunnel luminaire ranges are designed to withstand 'tunnel life' and are made of the highest quality materials, integrating the latest developments in terms of ingress protection, shock and vibration resistance as well as a range of features to facilitate ease of access and maintenance.

Titan

- Sturdy construction
- Quick change gear tray design
- Shallow profile
- Set of attachments

Applications
Ideal for lighting service or emergency areas.
Suitable for traffic, pedestrian and train tunnels.

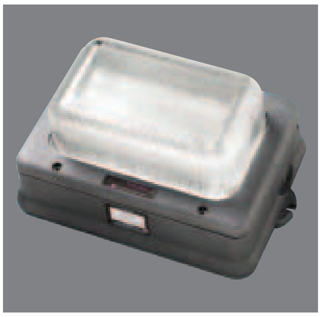
Equipment
Glare hoods, wire guards, pole mounting brackets.

Lamps
Max. 70W HSE-I (SE/I) High pressure sodium internal ignitor.
Cap: E27
Min. 70W/Max. 100W HST (ST) High pressure sodium.
Cap: E27/E40
Max. 110W HSE (SE) High pressure sodium. Cap: E27
Min. 70W/Max. 100W HIE (ME) Metal halide.
Cap: E27/E40
Min. 80W/Max. 125W HME (QE) Mercury. Cap: E27
Min. 2x18W/Max. 2x26W TC-D (FSQ) Compact fluorescent.
Cap: G 24d-2/G: 24d-3
Max. 1x200W A80/m (IAA-80/m) Incandescent.
Cap: E27

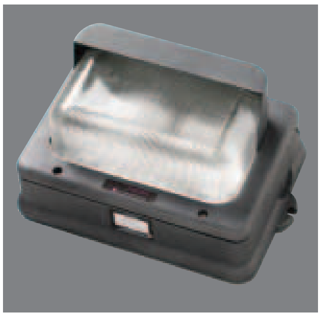
Materials/Finish
Housing - LM6 marine grade aluminium powder coat finish
Hinges, locks and fixings - stainless steel
Enclosure - borosilicate glass lens.

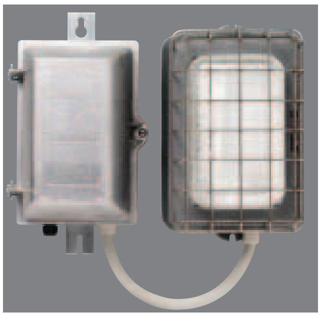
Standards
Class 1 Electrical
IP65/ IP66

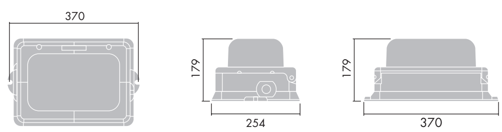
Dimensions
370x254x179mm


Sturdy one piece bulkhead


Titan DIP with wire guard


Titan with glare hood


Emergency version of Titan



Titus

- Dedicated to FDH 49W lamps
- 4 long closing plates
- Slim lightweight profile
- Axial or lateral surface mounting

Applications
Symmetrical and asymmetric light distribution.
Suitable for urban tunnels, underpasses and galleries.

Equipment
Louvres, dimming devices, mounting brackets supplied to meet project requirements.

Lamps
Max. 2x49W T16 (FDH) Linear fluorescent. Cap: G5

Materials/Finish
Housing - powder coated galvanised steel with anodised aluminium locking plates, or stainless steel with anodised powder coated locking bars.
Enclosure – 4mm thick toughened flat glass.
Reflector in 99.8% pure aluminium.

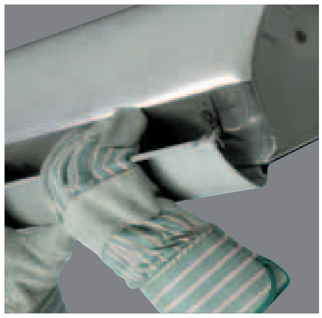
Standards
Designed to comply with EN60598-1/IEC598-1 and EN60598-2-3/IEC598-2-3
Class I Electrical
IK08/5 Nm
IP65

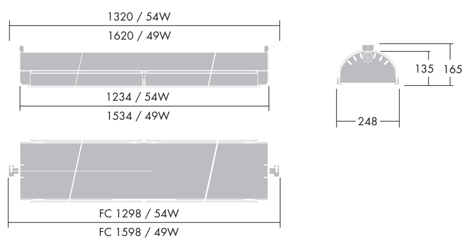
Dimensions
135x248x1534mm


Titus - galvanised steel version

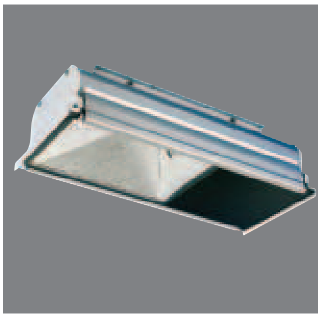

Louvre attachment for light control


Adjustable mounting bracket


Easily operated, strong locking bar offers security and ingress protection



Aluminium Gothard



7823B series

Continuous locking bar

Counter beam optics

Easily accessible gear tray and lamp

- Lightweight construction
- Continuous closing clip
- Front opening without tools
- Removable gear and easy access to lamp and connections

Equipment
Terminal block, fuse, cable glands, sockets, cable length, fixing brackets supplied to meet project requirements.

Materials/Finish
Housing – extruded AlMgSi aluminium powder coated 80 microns
Hinge and locking bar of extruded AlMgSi anodised aluminium.
Enclosure – 5mm thick, toughened flat glass.
Reflector – 99.8% pure aluminium.

Standards
Designed to comply with EN60598-1/IEC598-1 and EN60598-2-3/IEC598-2-3
Class I Electrical
IK08/5 Nm
IP66

7823B series
Applications
Asymmetrical light distribution, counter beam, pro beam.
For road tunnels, urban tunnels
Adaptation and transition zones.

Lamps
Min. 1x50W/Max. 2x400W
HST (ST) High pressure sodium.
Cap: E27/E40
Min. 1x250W/Max. 2x400W
HIT (MT) Metal halide.
Cap: E40
Min. 36W/Max. 66W LST-HY
(LSE) Low pressure sodium.
Cap: BY22d
Min. 28W/Max. 54W T16
(FDH) Linear fluorescent.
Cap: G5
Min. 36W/Max. 58W T26 (FD)
Linear fluorescent.
Cap: G13
Min. 55W/Max. 80W TC-SEL
(FSDH) Compact fluorescent.
Cap: 2G7

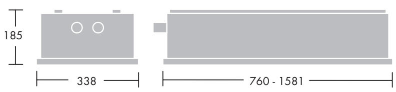
7824B series
Applications
Symmetrical light distribution.
For road tunnels, urban tunnels, underpasses, galleries, adaptation and transition zones.

Lamps
Min. 1x50W/Max. 2x400W
HST (ST) High pressure sodium.
Cap: E27/E40
Min. 1x250W/Max. 2x400W
HIT (MT) Metal halide.
Cap: E40
Min. 36W/Max. 66W LST-HY
(LSE) Low pressure sodium.
Cap: BY22d
Min. 28W/Max. 54W T16
(FDH) Linear fluorescent.
Cap: G5
Min. 36W/Max. 58W T26 (FD)
Linear fluorescent.
Cap: G13
Min. 55W/Max. 80W TC-SEL
(FSDH) Compact fluorescent.
Cap: 2G7

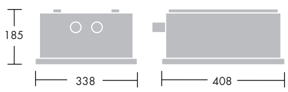
7826 series
Applications
Symmetrical light distribution.
For urban tunnels, underpasses, galleries.

Lamps
Min. 1x50W/Max. 1x100W
HST (ST) High pressure sodium.
Cap: E27/E40
Min. 35W/Max. 55W LST (LS)
Low pressure sodium.
Cap: BY22d
Min. 42W/Max. 57W TC-TEL
(FSMH) Compact fluorescent.
Cap: GX24q4/GX24q5

7823B series and 7824B series



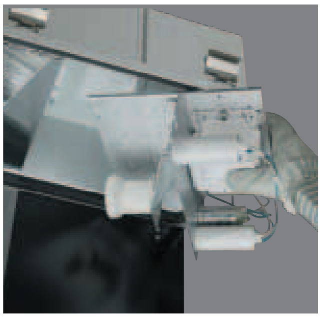
7826 series



Steel Gothard

7830 series

One piece enclosure for easy front access



Easily removable gear tray

Secure stainless steel clips allow tool-free operation

- 3 reinforced high strength closing clips
- Front opens without tools
- Removable gear and easy access to lamp and connections
- Shallow profile

Equipment
Terminal block, fuse, cable glands, cable length, fixing brackets supplied to meet project requirements.

Materials/Finish
Housing – stainless steel (EN1.4404) powder coated 80pm.
Hinges and locks – stainless steel.
Enclosure – 5mm thick toughened flat glass.
Reflector – 99.8% pure aluminium.

Standards
Designed to comply with EN60598-1/IEC598-1 and EN60598-2-3/iEC 598-2-3
Class 1 Electrical
IK08/5 Nm
IP65

7827 series
Applications
Asymmetrical, counter beam, pro beam light distribution.
For road tunnels, urban tunnels, underpasses, adaptation and transition zones.

Lamps
Min. 1x50W/Max. 2x400W HST (ST) High pressure sodium.
Cap: E27/E40
Min. 36W/Max. 66W LST-HY (LSE) Low pressure sodium.
Cap: BY22d
Min. 55W/Max. 80W TC-SEL (FSDH) Compact fluorescent.
Cap: 2G7
Min. 1x250W/Max. 2x400W HIT (MT) Metal halide.
Cap: E40

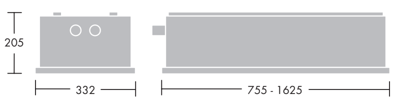
7828 series
Applications
Symmetrical light distribution.
For road tunnels, urban tunnels, underpasses, adaptation and transition zones.

Lamps
Min. 1x50W/Max. 2x400W HST (ST) High pressure sodium.
Cap: E27/E40
Min. 36W/Max. 66W LST-HY (LSE) Low pressure sodium.
Cap: BY22d
Min. 55W/Max. 80W TC-SEL (FSDH) Compact fluorescent.
Cap: 2G7
Min. 1x250W/Max. 2x400W HIT (MT) Metal halide.
Cap: E40

7830 series
Applications
Symmetrical light distribution.
For road tunnels, urban tunnels, underpasses, adaptation and transition zones.

Lamps
Min. 28W/Max. 54W T16 (FDH) Linear fluorescent.
Cap: G5
Min. 36W/Max. 58W T26 (FD) Linear fluorescent.
Cap: G13

7827 series and 7828 series



7830 series

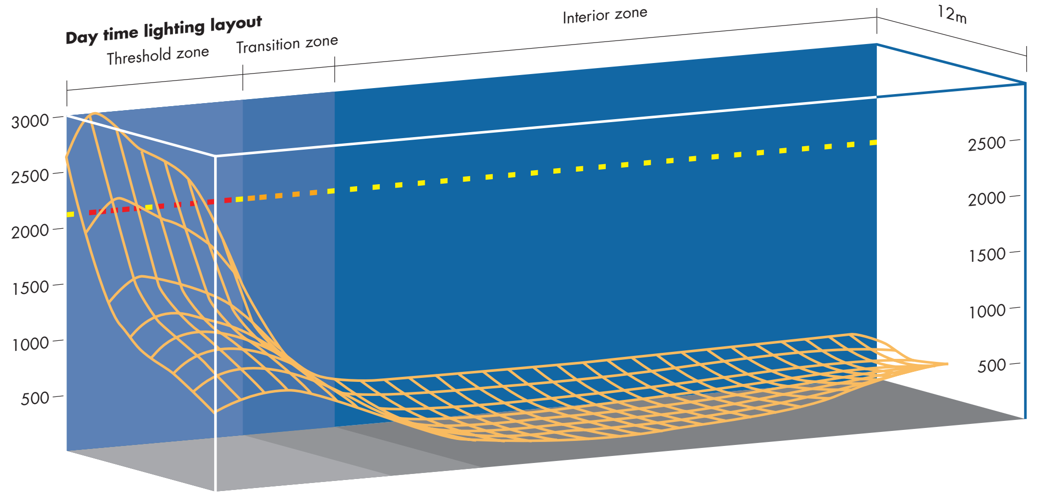
Case study 1
Chiptchak Mosquee Tunnel, Turkmenistan

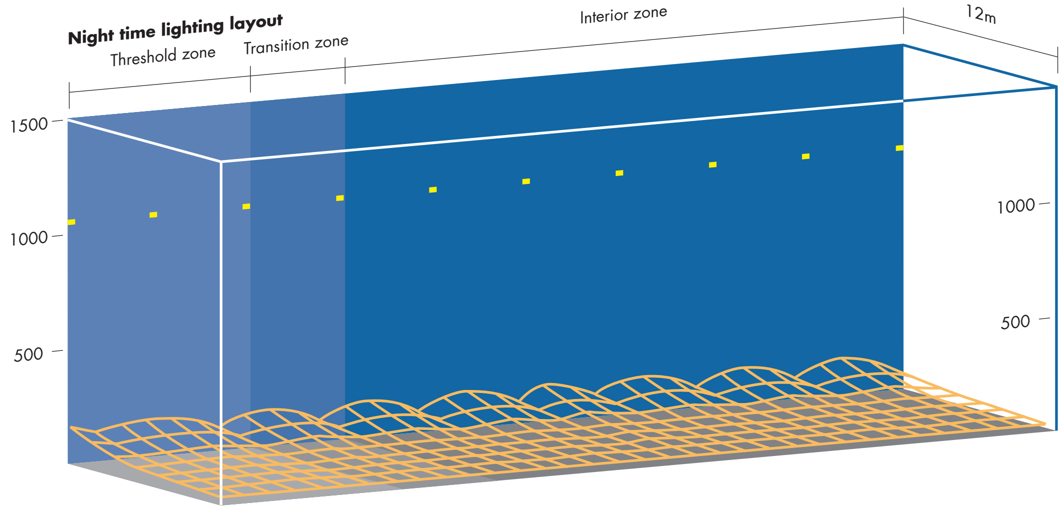
Tunnel type
Urban underpass
2 way traffic
One tube

Technical data
Length: 74m
Width: 24m
Speed limit 80km/h

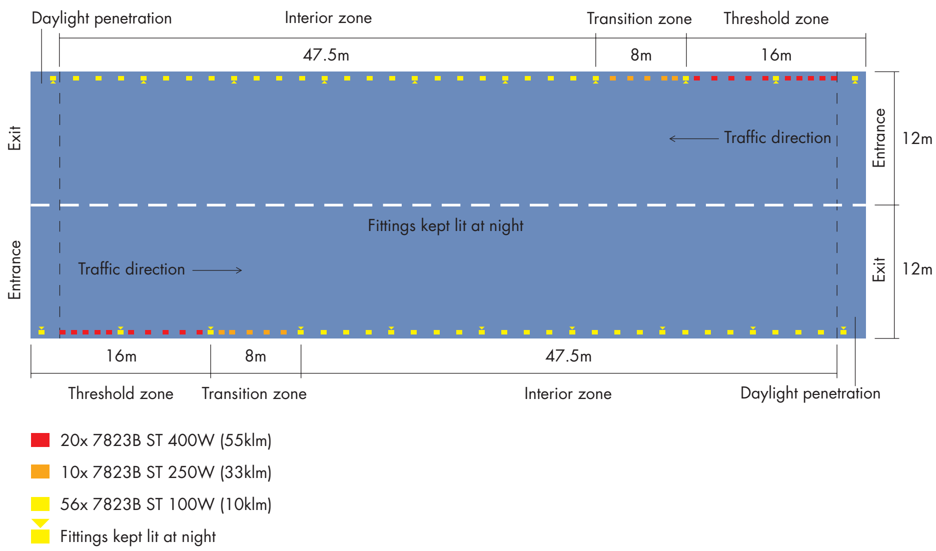
Lighting system
Aluminium asymmetric Gothard
Wall mounted, tilted 15º

20x 7823B ST 400W (55klm)
10x 7823B ST 250W (33klm)
56x 7823B ST 100W (10klm)



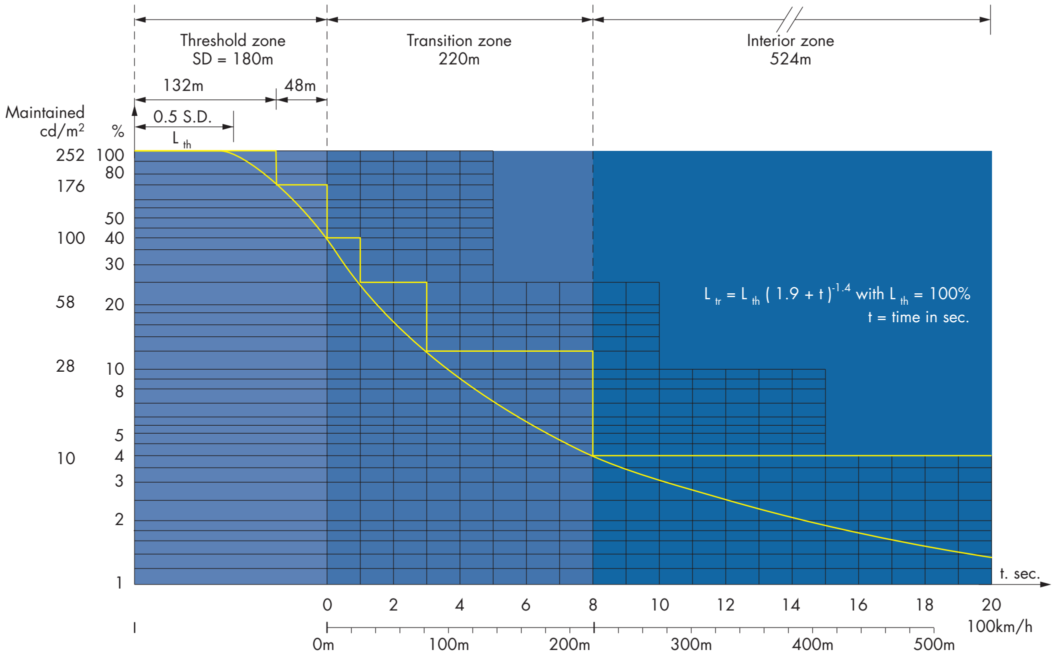


Plan schematic showing day time lighting layout



Case study 2
Katerini Tunnel, Greece

The national motorway, when completed, will run across Greece from Patras to Evzoni, via Athens and Thessaloniki. Three tunnels requiring a full tunnel lighting system are constructed in the Katerini area.



Tunnel description

Long motorway tunnel.
2 tubes - 3 lanes carriageway.

Technical data

Length: Right tube - 1100m
Left tube - 1100m

Speed limit: 100 km/h

Traffic flow: medium less than 1,000 vehicles per hour.

Stopping distance (SD): 180m on wet road.

Determination of L_{th}:
Right tube entrance:
L_{20} = 3.500cd/m²
Left tube entrance:
L_{20} = 5.000cd/m²

Lighting system: counterbeam and symmetric
Type of fitting: counterbeam and symmetric fittings

$k = L_{th}/L_{20} = 0.072$ for counter beam lighting system and for SD = 180m

Maintenance factor: 0.70

Right tube details

Threshold zone
Lth to be maintained: $L_{20} \times k$ = 252cd/m²
Length = 180m = SD
Threshold zone 1: 132m L_{th} = 252cd/m² maintained
Threshold zone 2: 48m L_{th} = 176 cd/m² maintained

Transition zone
The end of the transition zone is reached when the luminance is 3 times the interior luminance level

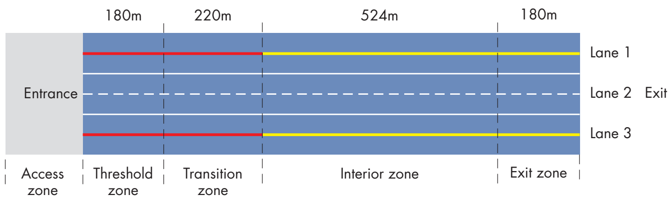
As the traffic flow is medium, the maintained level in the interior zone shall be 10cd/m² or 4% of the threshold zone level.
Length = 220m = given by CIE curve
Transition zone 1:
30m L_{tr} = 100cd/m² maintained
Transition zone 2:
55m L_{th} = 58cd/m² maintained
Transition zone 3:
135m L_{th} = 28cd/m² maintained

Interior zone
Length = 524m
L_{in} = 10cd/m² maintained

Exit zone
Luminance of the exit zone is equal to 5 times the interior zone luminance
Length = 180m
L_{ex} = 50cd/m² maintained

Lighting fitting arrangement

Day time
Threshold and transition zones are lit by counter beam fittings. Interior and exit zones are lit by symmetric fittings.

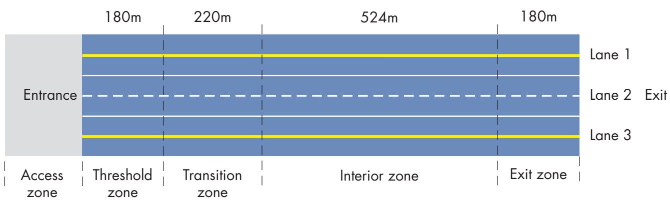


counter beam asymmetric   asymmetric beam

Day time						
Zones	Length (m)	No of fittings per tube	Counter beam 400W	Counter beam 250W	Symmetric 150W	Symmetric 250W
Threshold 1	180	276	276			
Transition	220	104	40	64		
Interior right	524	256			196*	60
Exit	180	86			30*	56

*common to day time and night time

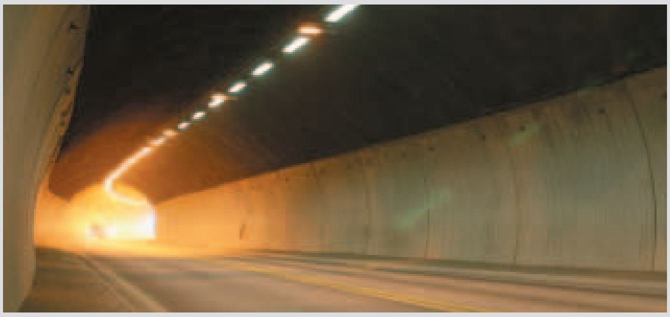
Night time
All zones are lit by symmetric fittings.



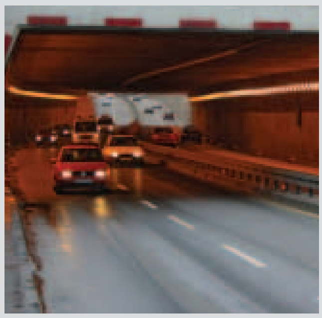
counter beam asymmetric   asymmetric beam

Night time						
Zones	Length (m)	No of fittings per tube	Counter beam 400W	Counter beam 250W	Symmetric 150W	Symmetric 250W
Threshold 1	180	32			32	
Transition	220	36			36	
Interior right	524	88			88	
Exit	180	30			30	

International references





THORN

Lighting people and places

Thorn Lighting Main Offices

Head Office
Thorn Lighting Holdings Limited
Silver Screens, Screen 2, Elstree Way,
Borehamwood, Hertfordshire, WD6 1FE
Tel: (44) 1708 766033
Fax: (44) 1708 776238
E-mail: info@thornlight.com
Website: www.thornlighting.com

Australia
Thorn Lighting Pty Limited, 13 Cooper Street,
P O Box 188, Smithfield, NSW 2164, Australia
Tel: (61) 2 9604 4300
Fax: (61) 2 9604 4588
E-mail: info@thornlight.com.au
Website: www.thornlight.com.au

Thorn DNT Airfield Lighting Pty Limited,
P O Box 548, Unit 2, 7-9 Newcastle Road, Bayswater,
Melbourne, Victoria 3153, Australia
Tel: (61) 3 9720 3233
Fax: (61) 3 9720 8233
E-mail: enquiries@thornlight.com.au
Website: www.thornairfield.com

Austria
Thorn Licht GesmbH, Erzherzog Karl-Straße 57,
Wien A-1220, Austria
Tel: (43) 1 202 66 11
Fax: (43) 1 202 66 11 12
E-mail: office@thorn.at

China
Thorn Lighting (Guangzhou) Limited,
(Factory & Guangzhou Office), No 1 Yi Heng Road,
Eastern Section, GETDD, Guangzhou 510760, China
Tel: (86) 20 8224 1706
Fax: (86) 20 8224 5777
E-mail: gzhthorn@public.guangzhou.gd.cn

Thorn Lighting (Tianjin) Company Ltd, 332 Hongqi Road,
Tianjin 300190, China
Tel: (86) 22 8369 2303
Fax: (86) 22 8369 2302
E-mail: thorntj@public.tpt.tj.cn

Thorn Lighting (Guangzhou) Limited,
Shanghai Branch Office, Room 2609, Union Building,
100 Yanan Road East, Shanghai 200002, China
Tel: (86) 21 6323 0800
Fax: (86) 21 6373 1626
E-mail: thornsha@public.sta.net.cn

Thorn Lighting (Guangzhou) Limited,
Beijing Branch Office, Room 519, China World Tower I,
China World Trade Centre, Beijing 100004, China
Tel: (86) 10 6505 4601
Fax: (86) 10 6505 4603
E-mail: thornbj@public.bta.net.cn

Czech Republic
Thorn Lighting CS, spol., Jaselska 6, Praha 6,
160 00 Czech Republic
Tel: (42) 02 2431 5252
Fax: (42) 02 3332 6313
E-mail: thorn@thornlight.cz
Website: www.thornlight.cz

Denmark
Thorn & Jakobsson, Industrivej Vest 41,
DK-6600 Vejen, Denmark
Tel: (45) 7696 3600
Fax: (45) 7696 3601
E-mail: thorn@jakobsson.dk
Website: www.thorn-jakobsson.dk

Estonia
Thorn Lighting Oy Eesti Filiaal, Laki 12-308,
10621 Tallinn, Estonia
Tel: (372) 656 3505
Fax: (372) 656 3227
E-mail: ando@thorn.ee

Finland
Thorn Lighting Oy, Airport Plaza Business Park,
Ayritie 12A, 01510 Vantaa, Finland
Tel: (358) 9 549 222
Fax: (358) 9 549 22300
E-mail: asiakaspalvelu@thornlight.fi
Website: www.thornlight.fi

France
Thorn Europhane SA, 156 Boulevard Haussmann,
Cedex 08, Paris 75379, France
Tel: (33) 1 49 53 6262
Fax: (33) 1 49 53 6240
Website: www.thorn.fr

Hong Kong
Thorn Lighting (Hong Kong) Limited, Unit 4301,
Level 43, Tower 1, Metroplaza, 223 Hing Fong Road,
Kwai Chung, N.T., Hong Kong
Tel: (852) 2578 4303
Fax: (852) 2887 0247
E-mail: info@thorn.com.hk
Website: www.thorn.com.hk

Thorn Lighting (HK) Ltd
Macau Branch, Room 306, 3/F Marina Gardens,
876 Avenida da Amizade, Macau, China
Tel: (853) 702 971/702 972
Fax: (853) 702 970
E-mail: thorn@macau.ctm.net
Website: www.thorn.com.hk

Hungary
Thorn Lighting Hungary Kft, West Gate Business Park,
Torokbalint, To Park H-2045, Hungary
Tel: (36) 23 501 570
Fax: (36) 23 418 120

Ireland
Thorn Lighting (Ireland) Limited,
320 Harold's Cross Road, Dublin 6W, Ireland
Tel: (353) 1 4922 877
Fax: (353) 1 4922 724
E-mail: enq.dublin@thornlight.com

Italy
Thorn Europhane Spa, Via G Di Vittorio, 2,
Cadriano di Granarolo, Bologna 40057, Italy
Tel: (39) 051 763391
Fax: (39) 051 763088
E-mail: info@thornlighting.it
Website: www.thornlighting.it

Latvia
Thorn Lighting Oy, Representative Office,
Skolas Street 21-216, Riga LV 1010, Latvia
Tel: (37) 7 332 660
Fax: (37) 7 332 660

Lithuania
Thorn Lighting Oy, Representative Office,
Kalvariju Street 1, Vilnius 2005, Lithuania
Tel: (370) 5 2 750 701
Fax: (370) 5 2 731 480

New Zealand
Thorn Lighting (NZ) Ltd, 399 Rosebank Road,
P O Box 71134, Rosebank, Auckland 7, New Zealand
Tel: (64) 9 828 7155
Fax: (64) 9 828 7591

Norway
Thorn Lighting AS, Industriveien 11, P O Box 63,
Skytta 1483, Norway
Tel: (47) 6706 2233
Fax: (47) 6706 0351
E-mail: s.kvernberg@thornlight.no

Poland
Thorn Lighting Polska Sp.z.o.o., Ul. Gazowa 26A,
Wroclaw 50-513, Poland
Tel: (48) 71 7833 740
Fax: (48) 71 3366 029
E-mail: thorn@thornlight.pl
Website: www.thornlight.pl

Russia
Thorn Lighting Oy, Park Place, Leninskiy Prosp.,
113/1 Office D 110, Moscow 117198, Russia
Tel: (7) 095 956 59 39
Fax: (7) 095 956 59 40
E-mail: office.moscow@thorn.ru
Website: www.thorn.ru

Thorn Lighting Oy, Representative Office, Europa House,
1 Artilleriiskaya, St Petersburg 191104, Russia
Tel: (7) 812 118 8112
Fax: (7) 812 118 8119
E-mail: office.petersburg@thorn.ru
Website: www.thorn.ru

Singapore
Thorn Lighting (Singapore) Pte Ltd, 5 Kaki Bukit Crescent,
04-02 Koyotech Building, 416238 Singapore
Tel: (65) 6844 5800
Fax: (65) 6745 7707
E-mail: info@thornlight.com.sg
Website: www.thornlight.com.sg

Sweden
Thorn Lighting AB, Industrigatan, Box 305,
SE-261 23 Landskrona, Sweden
Tel: (46) 418 520 00
Fax: (46) 418 265 74
E-mail: thorn@thornlight.se
Website: www.thornlight.se

United Arab Emirates
Thorn Lighting Ltd Dubai
Al Shoala Building, Office 301,
Block E, PO Box 1200, Deira, Dubai, UAE
Tel: (971) 4 2940181
Fax: (971) 4 2948838
e-mail: tlluae@emirates.net.ae

Thorn Gulf LLC
Al Shoala Building, Office 301/2,
Block E, PO Box 1200, Deira, Dubai, UAE
Tel: (971) 4 2948938
Fax: (971) 4 2948838
e-mail: thorng@emirates.net.ae

United Kingdom
Thorn Lighting Limited, Silver Screens, Screen 2,
Elstree Way, Borehamwood, Hertfordshire, WD6 1FE
Tel: (44) 1708 766033
Fax: (44) 1708 776238
E-mail: brochures@thornlight.com
Website: www.thornlighting.co.uk

Thorn Airfield Lighting, Silver Screens, Screen 2,
Elstree Way, Borehamwood, Hertfordshire, WD6 1FE
Tel: (44) 1708 776289
Fax: (44) 1708 776285
E-mail: airfield@thornlight.com or thornagluk@aol.com
Website: www.thornairfield.com

Export Sales
Thorn Lighting Limited, 156 Boulevard Haussmann,
Cedex 08, Paris 75379, France
Tel: (33) 1 49 53 6262
Fax: (33) 1 49 53 6240

Thorn Lighting Limited, Silver Screens, Screen 2,
Elstree Way, Borehamwood, Hertfordshire, WD6 1FE
Tel: (44) 1708 776284
Fax: (44) 1708 741827
e-mail: international.sales@thornlight.com

www.thornlighting.com

Publication No: 283(INT) Publication Date: 8/04