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.
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 L20 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 (L20) 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 to 10cd/m² |
| - | Urban | 4 to 10cd/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.
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 carriageway 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**
- NSV 1991 Aanbevelingen voor de verlichting van lange tunnels voor het gemotoriseerde verkeer.
- 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:

<table>
<thead>
<tr>
<th>Length of tunnel</th>
<th>No day time lighting</th>
<th>50% of normal threshold zone lighting level</th>
<th>Normal threshold zone lighting level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is exit fully visible when viewed from stopping distance in front of tunnel?</td>
<td>-</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Is daylight penetration good or poor?</td>
<td>-</td>
<td>-</td>
<td>good</td>
</tr>
<tr>
<td>Is wall reflectance high (&gt;0.4) or low (&lt;0.2)?</td>
<td>-</td>
<td>-</td>
<td>high</td>
</tr>
<tr>
<td>Is traffic heavy (or does it include cyclists or pedestrians) or light?</td>
<td>-</td>
<td>light</td>
<td>heavy</td>
</tr>
</tbody>
</table>

**Lighting required**
- 1 row above road
- 2 rows above road
- Twin opposite
- Arched type with or without fan tubes
- Framed type with or without fan tubes
- Arched type with fan tubes
- Framed type with or without fan tubes

**Typical tunnel lighting arrangements**
The table below outlines some of the mounting options available and their respective advantages/disadvantages:

<table>
<thead>
<tr>
<th>Mounting constraint</th>
<th>Arrangement type</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Tunnel profile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceiling mounting</td>
<td>Above road on several rows</td>
<td>- best utilisation factor for luminaires - glare limited</td>
<td>- luminaire concealed by signs - heavy fixings</td>
<td>- Arched type with or without fan tubes - Framed type with or without fan tubes</td>
</tr>
<tr>
<td>1 row above road</td>
<td>- less investment and maintenance</td>
<td>- closure of carriageway required</td>
<td>- utilisation factor downgraded - high glare</td>
<td></td>
</tr>
<tr>
<td>Wall mounting</td>
<td>Twin opposite</td>
<td>- easier access to luminaires - 1 lane only need be closed</td>
<td>- -</td>
<td>- Arched type with fan tubes - Framed type with or without fan tubes</td>
</tr>
<tr>
<td>Single sided</td>
<td>- less investment and maintenance</td>
<td>- -</td>
<td>- beware trucks blocking light</td>
<td></td>
</tr>
</tbody>
</table>
Wall mounting: asymmetrical lighting

Ceiling mounting: symmetrical lighting (mainly using fluorescent fittings)

Ceiling mounting: symmetrical lighting

Wall mounting: asymmetrical lighting

Ceiling mounting: asymmetrical 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

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.

**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

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.
Tough luminaires for tough environments

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 (ME) 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 I Electrical
IP65

Dimensions
370x254x179mm

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
Louvre's, 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

Dimensions
135x248x1534mm
• 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
IKOB/5 Nm
IP66

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**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-HY (LSE) Low pressure sodium.
  Cap: BY22d
- Min. 42W/Max. 57W
  T16 (FDH) Linear fluorescent.
  Cap: G5
- Min. 55W/Max. 80W
  TC-SEL (FSDH) Compact fluorescent.
  Cap: GX24q4/GX24q5

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**7823B series and 7824B series**

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**7826 series**

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Steel Gothard

• 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

15
Case study 1
Chiptchak Mosque 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]
5x 7823B ST 100W [10klm]
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 \( L_b \)**:
  - Right tube entrance: \( L_{20} = 3.500 \text{cd/m}^2 \)
  - Left tube entrance: \( L_{20} = 5.000 \text{cd/m}^2 \)
- **Lighting system**: counterbeam and symmetric fittings
- **Type of fitting**: counterbeam and symmetric fittings
- **k = \( L_b / L_{20} \)**: 0.072 for counter beam lighting system and for SD = 180m
- **Maintenance factor**: 0.70

### Right tube details
- **Threshold zone**
  - \( L_{20} \times k = 252 \text{cd/m}^2 \)
  - Length = 180m
  - \( L_b = 252 \text{cd/m}^2 \)
  - \( L_b / L_{20} = 0.072 \)
- **Threshold zone 1**: 132m \( L_b = 252 \text{cd/m}^2 \)
- **Threshold zone 2**: 48m \( L_b = 176 \text{cd/m}^2 \)
- **Transition zone**
  - \( L_{20} = 3.500 \text{cd/m}^2 \)
  - Length = 220m
  - \( L_b = 28 \text{cd/m}^2 \)
- **Interior zone**
  - Length = 524m
  - \( L_b = 10 \text{cd/m}^2 \)
- **Exit zone**
  - Length = 180m
  - \( L_b = 50 \text{cd/m}^2 \)

### Lighting fitting arrangement

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

<table>
<thead>
<tr>
<th>Zones</th>
<th>Length (m)</th>
<th>No of fittings per tube</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Counter beam</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Threshold 1</td>
<td>180</td>
<td>276</td>
</tr>
<tr>
<td>Transition 2</td>
<td>220</td>
<td>104</td>
</tr>
<tr>
<td>Interior right</td>
<td>524</td>
<td>256</td>
</tr>
<tr>
<td>Exit</td>
<td>180</td>
<td>86</td>
</tr>
</tbody>
</table>

*common to day time and night time*

#### Night time
- **All zones are lit by symmetric fittings.**

<table>
<thead>
<tr>
<th>Zones</th>
<th>Length (m)</th>
<th>No of fittings per tube</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Symmetric</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Threshold 1</td>
<td>180</td>
<td>32</td>
</tr>
<tr>
<td>Transition 2</td>
<td>220</td>
<td>36</td>
</tr>
<tr>
<td>Interior right</td>
<td>524</td>
<td>88</td>
</tr>
<tr>
<td>Exit</td>
<td>180</td>
<td>30</td>
</tr>
</tbody>
</table>
International references

Norway
Lerdal Tunnel
1,400 fittings
(ST 1x70-400W, LS-E 1x35W, FD 58 W)

Sweden
3,100 fittings
(ST 1x70W, 1x150W, 1x250W, 1x400W, FD 58W HF)

Iceland
500 fittings
(ST 1x250W, LS-E 1x35W)

Faeroe Islands
150 fittings
(ST 1x250W, LS-E 1x35W)

UK
Medway Tunnel
1,149 fittings
(ST 1x400W, FD 58W HF dimmable)

France
Gometz la Ville
386 fittings
(ST 2x70W, 2x250W, 2x400W)

Croatia
Sopac
655 fittings
(ST 150/100W, power reduction)

Greece
Taxiarchis Tunnel
1,054 fittings
(ST 1x150W, 1x250W 1x400W)

Israel
Har Hatzdanim Tunnel
400 fittings
(ST 2x400W, 2x250W, 2x100W ST 1x400W, 1x250W, 1x150W, 1x100W)

U.A.E.
Kalba Tunnel (Sharjah)
464 fittings
(ST 2x250W, 2x400W, 150W+400W, ST 1x150W, 1x250W)

Singapore
Holland/ Farrer Road Tunnels
350 fittings
(FD 58W HFD)

Taiwan
2nd Freeway Port II
1,023 fittings
(ST 1x150W, 1x400W)

Hong Kong
KCRC West Rail CC
1,474 fittings
(ST 2x400W, 250W, FD 58W HF2)

U.A.E.
Kalba Tunnel (Sharjah)
464 fittings
(ST 2x250W, 2x400W, 150W+400W, ST 1x150W, 1x250W)

Brunei
Pasar Utak radial road
740 fittings
(ST 1x400W, 2x400W 42B FD 58W HF)
Thorn Lighting Main Offices

**Head Office**
Thorn Lighting Holdings Limited
Silver Screens, Screen 2, Elstree Way, Borehamwood, Hertfordshire, WD6 1FE
Tel: (44) 1708 776633
Fax: (44) 1708 776238
Email: 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
Email: info@thornlight.com.au
Website: www.thornlight.com.au

Thorn DNT Airfield Lighting Pty Limited, P O Box 548, Unit 2, 2-7-9 Newcastle Road, Bayswater, Melbourne, Victoria 3153, Australia
Tel: (61) 3 9720 3233
Fax: (61) 3 9720 8233
Email: 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
Email: 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
Email: gathorn@public.guangzhou.gd.cn

Thorn Lighting (Tianjin) Company Ltd, 332 Hongqi Road, Tianjin 300190, China
Tel: (86) 22 8369 2306
Fax: (86) 22 8369 2302
Email: thorn@public.tpt.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
Email: thorn@public.sh.cn

Thorn Lighting (Guangzhou) Limited, Beijing Branch Office, Room 519, China World Tower 1, China World Trade Centre, Beijing 100004, China
Tel: (86) 10 6505 4601
Fax: (86) 10 6505 4603
Email: thornbj@public.bta.net.cn

**Czech Republic**
Thorn Lighting CS, spol., Jasionka 6, Praha 6, 160 00 Czech Republic
Tel: (42) 02 2431 5252
Fax: (42) 02 3322 6313
Email: thorn@thornakhabson.cz
Website: www.thorn.cz

**Denmark**
Thorn & Jakobsson, Industrivej Vest 41, DK-6000 Aarhus, Denmark
Tel: (45) 7966 3600
Fax: (45) 7969 3601
Email: thorn@thornakhabson.dk
Website: www.thornakhabson.dk

**Estonia**
Thorn Lighting Oy Esti Filiial, Laki 1308, 10261 Tallinn, Estonia
Tel: (372) 656 3505
Fax: (372) 656 3227
Email: anda@thorn.ee

**Finland**
Thorn Lighting Oy, Airport Plaza Business Park, Ayrtele 12A, 01510 Vantaan, Finland
Tel: (358) 9 549 2222
Fax: (358) 9 549 22300
Email: asukapalkku@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
Email: info@thorn.com.hk
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, 93 Choice Business Park, Louth Village, Drogheda, Louth, Ireland
Tel: (353) 1 4922 877
Fax: (353) 1 4922 724
Email: enquiries@thornlight.com
Website: www.thornlight.com

**Italy**
Thorn Europhane SpA, Via G Di Vittorio, 2, Codrino di Granaro, Bologna 40057, Italy
Tel: (39) 051 763391
Fax: (39) 051 763088
Email: info@thornlighting.it
Website: www.thornlighting.it

**Latvia**
Thorn Lighting Oy, Representative Office, Skolas Street 21-216, Riga LV 1010, Latvia
Tel: (37) 3 332 660
Fax: (37) 3 332 660

**Lithuania**
Thorn Lighting Oy, Representative Office, Kalvarijos g. 1, Vilnius 2005, Lithuania
Tel: (370) 5 2 750 701
Fax: (370) 5 2 731 480

**New Zealand**
Thorn Lighting (NZ) Ltd, 339 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, Skøyen 1483, Norway
Tel: (47) 6706 4433
Fax: (47) 6706 0351
Email: s.kvernberg@thornlight.no

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

**Russia**
Thorn Lighting Oy, Park Place, Lesninskiy Pros., 113/1 Office D 110, Moscow 117198, Russia
Tel: (7) 095 956 59 39
Fax: (7) 095 956 59 40
Email: office.moscow@thorn.ru
Website: www.thorn.ru

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

**Singapore**
Thorn Lighting (Singapore) Pte Ltd, 5 Kaki Bukit Crescent, 0402 Kaytech Building, 416238 Singapore
Tel: (65) 644 3808
Fax: (65) 6745 7707
Email: info@thornlight.com.sg
Website: www.thornlight.com.sg

**Sweden**
Thorn Lighting AB, Industrigatan, Box 305, SE-261 23 Landskrona, Sweden
Tel: (46) 418 50 605
Fax: (46) 418 265 74
Email: thornlight@thornlight.com
Website: www.thornlight.se

**United Arab Emirates**
Thorn Lighting Ltd Dubai, Al Shoaab Building, Office 301, Block E, PO Box 1200, Deira, Dubai, UAE
Tel: (971) 4 2940181
Fax: (971) 4 2948838
Email: tuuse@emirates.net.ae

Thorn Gulf LLC, Al Shoaab Building, Office 301/2, Block E, PO Box 1200, Deira, Dubai, UAE
Tel: (971) 4 2949838
Fax: (971) 4 2948838
Email: thorn@emirates.net.ae

**United Kingdom**
Thorn Lighting Limited, Silver Screens, Screen 2, Elstree Way, Borehamwood, Hertfordshire, WD6 1FE
Tel: (44) 1708 765033
Fax: (44) 1708 776238
Email: 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 776265
Email: airfield@thornlighting.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
Email: international.sales@thornlight.com

**www.thornlighting.com**