WHITEPAPER
PEL SECTOR LIGHTS
Precision signals for guidance of ships

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ABOUT SECTOR LIGHT

PEL Sector Lights display a different colour when viewed from different angles at sea. When sailing through hazardous waters, the PEL Sector Light will provide sharp visual feedback whether you are inside or outside a sector. If combined with oscillating boundary, the exact position within the sector will also be known.

The analogue oscillating boundary provides precise positional awareness for the navigator when the vessel deviates from optimal course. Wide vertical divergence reduces installation tower heights, reducing installation cost. Many PEL sector lights gained acceptance in New Zealand, Australia, Canada and Denmark, and gradually spread to other countries as the benefits were realized.

Definition of a Sector Light

A Sector Light is a single light which shows a different colour when viewed from different directions. The colour of the light provides directional information to the mariner. The letters PEL stand for Physics and Engineering Laboratory of the New Zealand government research facility where the first PEL light was designed.

Benefits of PEL Sector Lights include ease of location, energy efficiency and cost savings. PEL Lights only require a single station for direction-indicating, saving on the costs of a rear light, including site access, power supply and structures.

PEL Sector Lights have been applied to a wide range of uses. Although mainly used as single-station leads, they have been used to mark anchorages, turning basins, fishing zones, hazardous reefs, national boundaries and prohibited areas.

Sector Light Vocabulary

Total subtense: is the total projected angle in the horizontal plane. The basic light beam is circular in cross-section, and is masked down to a rectangle as shown *figure 1 & 2.*

Vertical divergence: is the total projected angle in the vertical plane. Stated vertical divergence applies across the full width of the beam of the PEL Light. This is generally less than the horizontal subtense of the lightdue to the way the circular beam is masked.

Boundary resolution: On the boundary between a white and a coloured sector (e.g. red) there is a small transition angle within which the colour is neither completely white nor completely red. Boundary resolution is the smallest angle over which a complete colour change occurs.

Sector accuracy: Due to manufacturing tolerances on lenses, filter glasses and lens-mounting systems, the actual location of a sector boundary may be displaced a small amount from the intended place. Accuracy is the maximum angle between intended and actual location.

Intensity and Range: Intensity is the amount of light energy emitted from a light in a given direction, and is measured in candela. Increased intensity gives increased viewing range, but typically, range also depends on atmospheric transmissitivity and level of background lighting.

Oscillating boundary: is an optional accessory to the PEL Sector Light which generates up to four additional sectors without using additional colours (only red, white and green). Refer to Oscillating Boundary section.

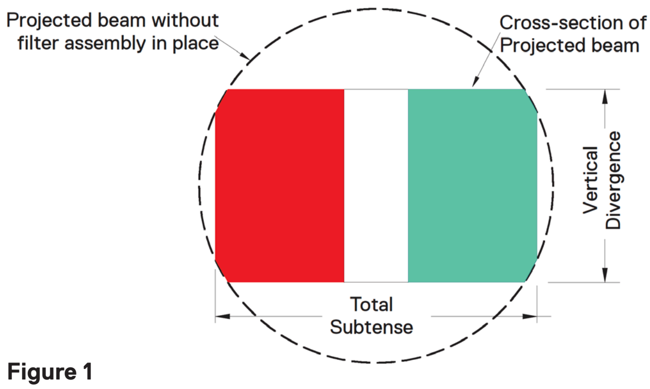


Figure 1

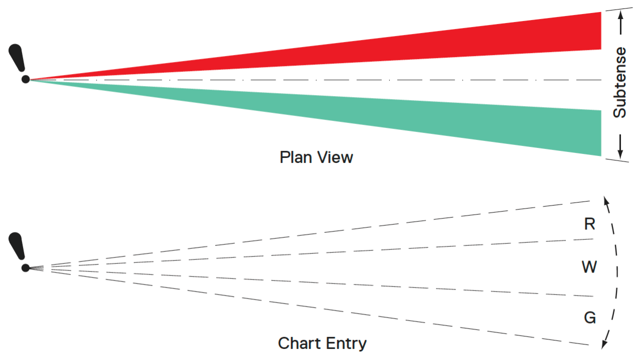


Figure 2

ABOUT SECTOR LIGHT

Facts about Boundary Resolution

As the mariner traverses from one sector to an adjacent one, the colour change must be abrupt. A vague boundary may not give useful information, because it requires a subjective assessment of colour saturation. The PEL Sector Light, with its very sharp boundaries, gives precise “digital” information rather than an “analogue” type. Where a “proportional” form of signal is required, the Oscillating Boundary system does this by having the signal alternate between two colours on a 3-second cycle.

Modern optical systems as used in the PEL Sector Light are so precise that there is no significant zone of uncertainty at all. A complete colour change will occur typically within one minute of arc – a lateral distance of only 2.7 metres at a distance of 5NM.

Moving towards a PEL Sector Light at night, with the bridge in darkness, it is not unusual to have the bridge back wall illuminated in two different colours and the sudden change in colour at the boundary clearly displayed by a vertical line up the bulkhead.

Facts about Colour Integrity

White and red are both satisfactory colours for use in navigation beacons. If a third colour is required, care must be taken to ensure that the chosen colour and filter material will maintain a consistent appearance in adverse weather conditions.

Yellow is not a suitable colour because it cannot be distinguished from white, especially with a light source with warm white colour temperature.

Fog can be a problem with coloured beacons, because fog scatters light of shorter wavelength (blue) more than of longer wavelength (red). When a yellow, green or blue beacon is viewed through fog, if there is a significant red component in the light, then red may be the main colour that is seen. This phenomenon has caused accidents at sea. Purple-coloured beacons should also be avoided. Despite the above, green remains the most suitable third colour.

There are many blue and blue-green filter glasses and plastics which also freely transmit some red light. Great care is required in the selection of filter glass for blue-green sectors to ensure that no red light is transmitted. The use of colours other than red, white and green is not recommended for sectored navigation lights. If more than three sectors are required, the Oscillating Boundary option should be used, rather than additional colours.

PEL Sector Light in Timaru Port, New Zealand

ABOUT SECTOR LIGHT

How Sectors are Created

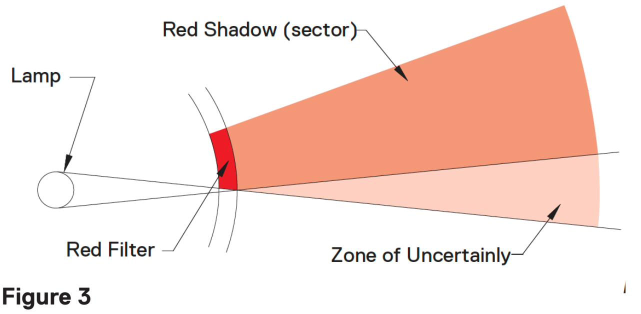


Figure 3

Shadow Method

With filament light source coloured sectors were traditionally generated by placing a piece of coloured glass or acrylic against the lantern house glazing, or against the beacon itself. This casts a coloured "shadow" out over the water. *See Figure 3.*

The shadow method is adequate if sharp sector boundaries are not required. A significant "zone of uncertainty" appears between adjacent sectors. Within this transition zone (which may be 1-2° wide) the beacon will show ambiguous colour, and intensity may also vary.

The sector boundary moves if the lamp filament is moved (even very slightly), as it might when a lamp is replaced. Filament position always varies between lamps. This method of creating sectors is not suitable for indicating a precise direction.

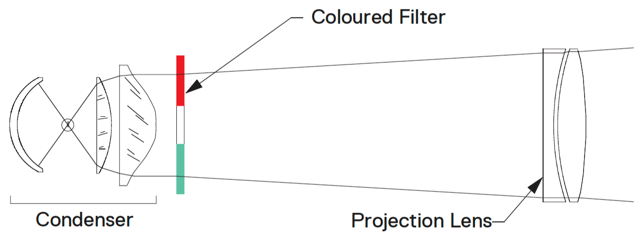


Figure 4

Projection Method

PEL Sector Lights use a "projection" method. This works the same way as a slide or movie projector, but focused at infinity. Vertical strips of coloured filter glass, optically ground and highly polished on their edges to fit closely together, are used as the "slide" or "film" to divide the beam into its different sectors.

The condenser lens collects light radiating from the LED light source and spreads it uniformly across the coloured filter. An image of the exit surface of the filter (right side on *Figure 4*) is projected out to infinity. Sector boundaries may appear blurred within the first few hundred metres as they are out of focus, but will be very sharp at working distances.

The projection lens (sometimes called objective lens) and filter assembly together determine the total subtense of the PEL Light. Different objective systems are used to obtain all the different subtenses with optimal efficiency. Generally, objective lenses with longer focal length (longer barrel) enable higher luminous intensity and longer range but narrower subtense.

The optical system in PEL Sector Lights produces very uniform intensity (before colouring) in all viewing directions. Boundary resolution and accuracy of sector boundary placement can both be as precise as 1 minute of arc. *See Figure 4.*

Colour and Neutral Density Filters

Colour Filters

A PEL Sector Light uses colour to convey information to the mariner about his angular position relative to the light. The process of "colouring" a beam involves filtering out many colours and only allowing the desired colour to pass.

If the filter does not block off enough undesired colours (wavelengths), there can be problems with the light appearing to change colour in fog. If the selection of wavelengths that is passed is too narrow, the light will not be intense enough.

Neutral Density Filter with White Sector

In a sector light having red, white and green sectors, the central white sector is generally about 4 times more intense than the other sectors.

When necessary the intensity levels of white and coloured light signals can be equalised by using a neutral density filter of suitable transmittance for a uniform white sector.

With a moderate or high level of background lighting at night, a clear filter glass is used in the white sector. Because background lighting at night is mostly white in colour, this gives comparable conspicuity within all three sectors.

ABOUT SECTOR LIGHT

Achieving Maximum Service Life

Life Expectancy

Many PEL Sector Lights around the world have been in service for more than 20 years. Sabik's PEL Sector Lights require no internal maintenance. The exterior of the PEL should be inspected and cleaned occasionally to ensure maximum intensity and that no foreign material is trapped in the heat sink on the rear of each unit.

Protection against Moisture Ingress

Users can enhance the life and performance of PEL Sector Lights by preventing ingress of moisture. This occurs whenever the light is opened for servicing, as it is otherwise completely sealed.

For longevity each light is best installed within a shelter, with just the barrel protruding. This reduces temperature changes imposed on the light from outside, and reduces bird fouling.

Routine Service

Periodically inspection check that the PEL remains firmly secured and level, and that the mounting fasteners are still in good condition. Investigate any corrosion of the mounting structure and take appropriate preventive action.

Choosing a Sector Light

Choice of Different Sizes

Each marine port and harbour is unique, so a flexible system is required. The PEL Light offers a range of subtenses and intensities to accommodate the constraints of each site. PEL Sector Lights make very efficient use of solar power on remote sites.

When a signal is required both day and night it is convenient if a single light can perform both functions. A light needs to be up to 5,000 times more intense during the day compared to night. PEL Sector Lights have been designed for day & night operation.

The switching power supply modules feeding the LEDs use a combination of LED current reduction and pulse width modulation (PWM) for intensity reduction. The intensity can be adjusted within the range from 0.3% to 100%.

Choosing Individual Sector Angles

There are two models of PEL Sector Light in Sabik Marine, PEL-4 and PEL-7. Both are available in a range of standard subtenses, from 3.5° to 20°. The PEL-4 is designed for shorter ranges and consume up to 50W. The PEL-7 has a more powerful LED with much larger optics and is designed to meet the need for the longest day & night range requirements. Power consumption of a PEL-7 light can be up to 120 W.

Balancing Intensity against Subtense

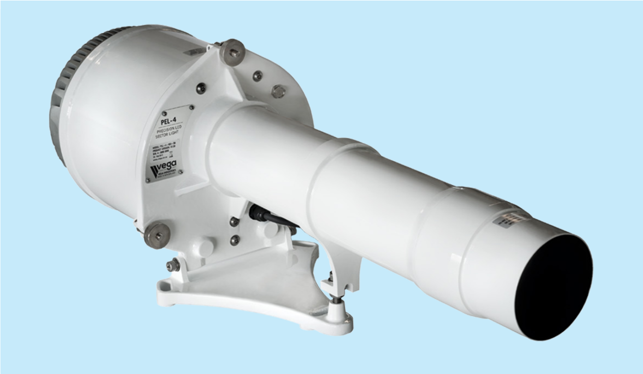
For a given LED configuration in a PEL Sector Light, the wider the beam, the less the intensity. An increase in horizontal subtense also gives an increase in vertical divergence, because the optics are circular (except with anamorphic models).

Doubling the subtense will drop intensity to one-quarter (following the inverse-square law). The narrowest subtense that meets the requirement should be used. If greater subtense or intensity is required, consider multiple lights or special anamorphic versions which spread light horizontally but keep the same vertical divergence.

Two Models: PEL-4 and PEL-7

The PEL-4 is designed for short ranges and consume up to 50W.

The PEL-7 has a more powerful LED with much larger optics and is designed to meet the need for the longest day and night range requirements. Power consumption of a PEL-7 light can be up to 120W.



PEL-4

PEL-7

ABOUT SECTOR LIGHT

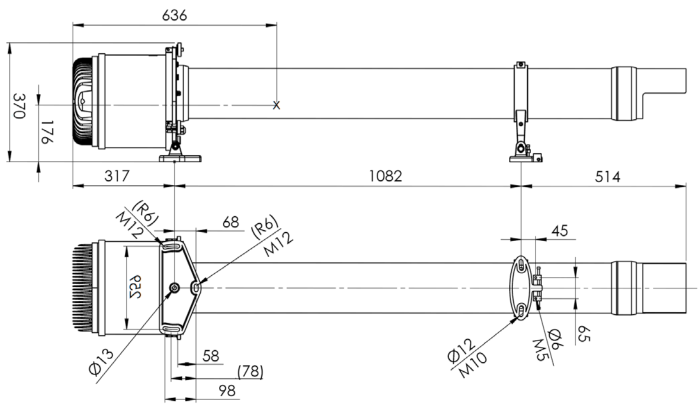
PEL-4 Specifications

Performance

Product	Horizontal divergence	Vertical divergence @ 50% peak intensity	Peak intensity red	Peak intensity green	Peak intensity white	Power consumption @ peak intensity
PEL-4-3D5	3.5°	2°	77 500 cd	77 500 cd	350 000 cd	51 W
PEL-4-05D	5°	3°	50 000 cd	50 000 cd	225 000 cd	51 W
PEL-4-10D	10°	5.3°	20 200 cd	20 200 cd	91 000 cd	51 W
PEL-4-20D	20°	12°	5 200 cd	4 400 cd	13 000 cd	51 W

PEL-4

Medium Range PEL Sector Light
22,9 NM by night
4,9 NM by day



Dimension of PEL-4 at the horizontal divergence of 3.5°

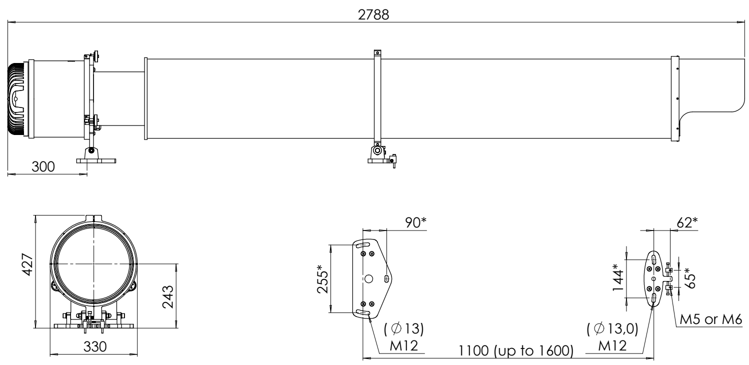
PEL-7 Specifications

Performance

Product	Horizontal divergence	Vertical divergence @ 50% peak intensity	Peak intensity red	Peak intensity green	Peak intensity white	Power consumption @ peak intensity
PEL-7-3D5	3.5°	2.8°	270 000 cd	250 000 cd	860 000 cd	120 W
PEL-7-05D	5°	3.6°	130 000 cd	130 000 cd	440 000 cd	120 W
PEL-7-07D	7°	5°	70 000 cd	70 000 cd	220 000 cd	120 W
PEL-7-10D	10°	7.1°	33 000 cd	33 000 cd	110 000 cd	120 W

PEL-7

Long Range PEL Sector Light
25,2 NM by night
6,2 NM by day



Dimension of PEL-7 at the horizontal divergence of 3.5°

ABOUT SECTOR LIGHT

Specification sequences

Night Only or Day & Night

The first decision is whether a night-only signal is required, or a day and night signal. Generally, use a PEL-4 for night only, or a PEL-7 for day & night. For very short distances a PEL-4 can be used also in daylight.

Specify Day and Night - Time Luminous Range (if applicable)

When the PEL Light is used day and night, it is recommended to specify both day and night-time operating ranges as respective luminous intensity requirements for equal range can vary up to 5,000 times. Reduction is generally required at night in order to prevent dazzling at closer distances as well as to maintain similar day and night-time luminous ranges and reduce energy consumption.

Reduce Intensity in White Sector: Yes or No

Intensity in the white sector can be reduced using a ND filter to match the apparent intensities in the coloured sectors.

Determine Require Intensity

This depends on the range required and the conditions under which viewing occurs (transmissivity of atmosphere, level of background lighting). Use IALA Recommendations for guidance, or contact Sabik for assistance.

PEL Sector Light in Houston, USA

Determine Individual Sector Angles

Each sector light is individually configured for its end use. For most applications red, white and green colours are chosen. The sector sizes are always specified reading from left to right when looking towards the light from on board of the vessel.

Determine Vertical Divergence

Sketch a vertical profile through the light and viewing area. Check that mariners on highest and lowest vessels at closest and most distant points all fall within the vertical divergence of the light.

With projector sector light it is important to note that there is absolutely no light outside (above or below) the light beam "frame". This parameter often determines the PEL version required.

When determining the appropriate divergence and inclination angle for the lantern, various factors affecting the visibility range of the light signal need to be taken into consideration, including the installation height of the lantern, distance between the light to the nearest point of the useful segment and maximum and minimum heights of the observer's eye above sea level (maximum bridge height of the vessel expected to navigate within the range of the lantern's signal).

Choose Total Subtense

There is a trade-off between subtense and intensity – the greater the subtense, the less the intensity (for a given light version). Refer to PEL-4 and PEL-7 tables for intensities.

Oscillating Boundary Option: Yes or No

This option is used in critical applications where early warning of deviation from a central line is required. On solar-powered sites it may be less attractive because Fixed light character is required for its effective operation. Refer to Oscillating Boundary.

Specify Flash Character

Each PEL Sector Light is pre-programmed with 246 standard characters. Additional flash characters can be included if advised at time of order. For Oscillating Boundary (OB) use a fixed character, or one with at least 8 seconds on-time to allow at least two full OB cycles.

Connection to Other Devices

Synchronisation to other lights, monitoring interfaces, remote on-off or intensity control are available.

OSCILLATING BOUNDARY AND SECTOR ANGLES

Oscillating Boundary

Definition

Oscillating Boundary is a factory-fitted option for any PEL Light. It provides up to four additional sectors without any new colours, and proportional indication of lateral movement within a sector. The Oscillating Boundary is best appreciated using a moving model, as shown on the Sabik website - https://marine.sabik.com/oscillating-boundary.

Benefit

The Oscillating Boundary provides early warning of deviation from the centre line, and enables extremely precise navigation. It is ideal for use by large ships moving in very narrow channels, especially when there is adverse wind or tide.

Flash Character

It is recommended that a PEL Light with Oscillating Boundary does not have any flashing character imposed on the lamp, as this combination could be confusing.

A character with a longer on-period (for example, 8.0 seconds) could be tolerated, followed by a brief off-period.

This character would help to confirm the light identity to a mariner when holding position in the white sector, especially if there was significant background lighting at night.

Maximum Size of Individual Sector

There is no restriction on size of fixed sectors.
The maximum width of an oscillating sector is limited to 20% of total subtense, and all oscillating sectors must be the same size.

By placing the outer flashing sectors outside the total subtense of the light, they are masked out and not seen. Partial masking is also possible. *See Figure 5.*

Signal Format

In the oscillating sector the colour oscillates between the colours of the sectors on either side. A complete oscillation occurs every 3 seconds.

The oscillation is seen by an observer within the sector as an abrupt change of colour from red to white (for example), and back to red. The period of time that one colour is visible (relative to the other colour) is a measure of the closeness of the fixed sector of that colour.

The signal is easily and intuitively grasped by the mariner. A longer red flash and a shorter white flash means that the mariner is closer to the red sector, and vice versa. Judging the proportion of time in which each colour is displayed is quite straightforward, and the cycle is repeated every three seconds.

The Oscillating Boundary signal does not change when viewed through binoculars. It is a time-based digital signal, rather than one based on relative lateral displacement.

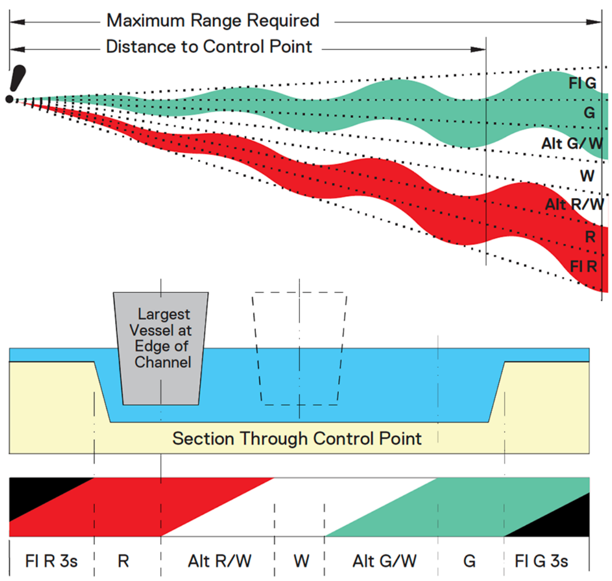


Figure 5

OSCIALLATING BOUNDARY AND SECTOR ANGLES

Determine Individual Sector Angles

Largest Vessel at Control Point

The control point is any convenient point at which the required width of each sector is established. This could be a restricted part of the approach, such as the heads at the harbour entrance or the entrance to a narrow channel.

At the control point consider the largest vessel on the extreme edge of its safe manoeuvring area. Take the centre-line of the vessel at this point, and set the outer edge of the oscillating sector. Refer to example above. When the mariner encounters the fixed red or green sectors (while standing at the centre of the vessel) he has reached the limit of his safe manoeuvring space.

Narrow Centre Sector

At the centre, allow the smallest practical white sector. Half the width of the largest vessel when at the control point is a useful starting value.

This format gives a very early indication of any deviation from the central sector, as the mariner sees a flash of red or green depending on whether the vessel has moved left or right.

Converting Lateral Distances to Angles

Use the arc-tangent function to convert measurements of distance from the centre line and distance to control point into angles in degrees. *See Figure 6.*

Sector Light Alignment

When selecting individual sector angles, it is a good idea to place one sector edge across a defined location, preferably one that can be reached by land. An observer at this location can easily check the alignment of the entire light from time to time.

Specifying Sector Angles

When specifying individual sector angles, always list by colour and size (in degrees), working from left to right as viewed from the position of the vessel, looking towards the light.

Flashing Sectors

With the Oscillating Boundary system, there is the option to use part or all of the two outside flashing sectors.

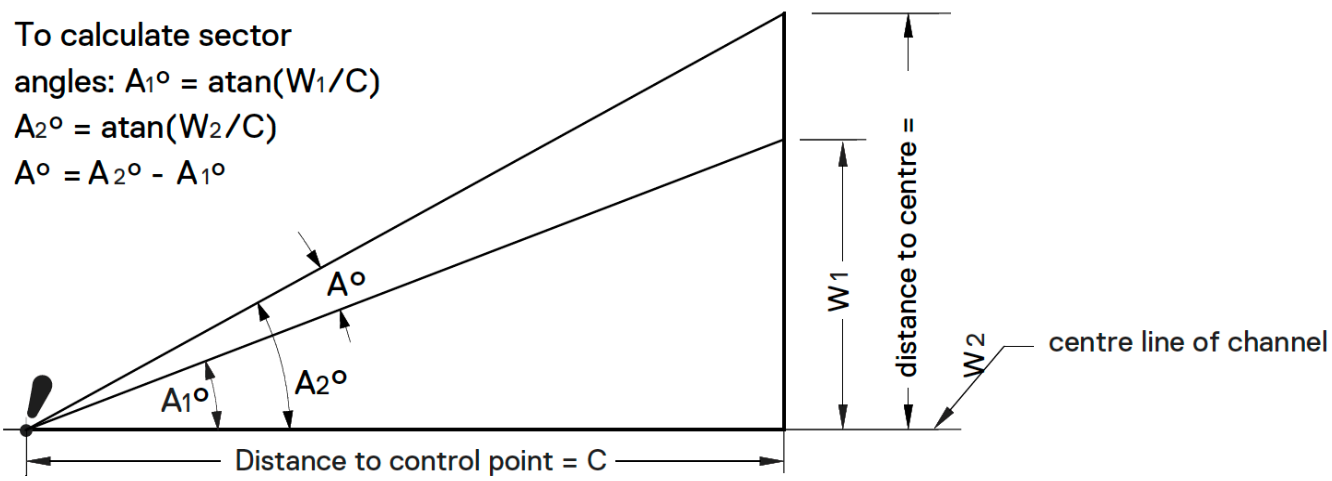


Figure 6

INSTALLATION GUIDE

Installation of PEL Sector Lights

Location of Tower

The tower can be located at any convenient place on the extended centreline of the required track. Moving the tower back from the point of closest approach can help to reduce the unhelpful effect of the beam becoming narrower and more intense at the point closest to the light.

Other considerations are ease of site access for maintenance, security against unauthorised access, availability of existing structure, and level of background lighting in the viewing direction (considering day and night separately).

Height of Tower

The best elevation for the PEL Light is at the same height as the bridge of the largest vessel. This enables the PEL Sector Light to be set horizontal. Check for adequate vertical divergence.

The Sector Light must be visible from all the required positions. The barrel can be inclined or declined a few degrees if necessary. The barrel is exactly parallel to the centreline of the beam.

Design of Mounting Plate

PEL Lights can have either a single triangular mounting plate or two mounting feet to support the weight of the barrel.

Refer to the PEL dimension drawings for more detail. Unless the holes in the platform can be aligned very accurately they should not be drilled until the PEL Light is positioned and aligned. Some fine adjustment (azimuth and elevation) is available in the PEL Sector Light mounting. The beam would easily pass over the top of the safety railing.

Outside in All Weathers

The PEL Light is designed to operate outside in all climates so no further protection is necessary. If installed inside a lighthouse or other building avoid having the beam pass through a glass window.

This will reduce the intensity of the beam and could reduce the boundary sharpness. Allow the barrel to protrude and seal around it with a flexible membrane.

Safe Access for Servicing

The PEL Light is best mounted on a stable plate 1000 mm above the floor of the servicing platform for safe and comfortable access.

In general PEL lanterns do not require any internal maintenance. Only the exterior of the PEL light should be inspected and cleaned occasionally to ensure maximum intensity and that no foreign material is trapped in the heat sink on the rear of each unit.

The front lens of the light must be easily accessible for inspection and cleaning, as dirt and grime on this lens will cause the light output to deteriorate.

PEL Sector Light on the sea

INSTALLATION GUIDE

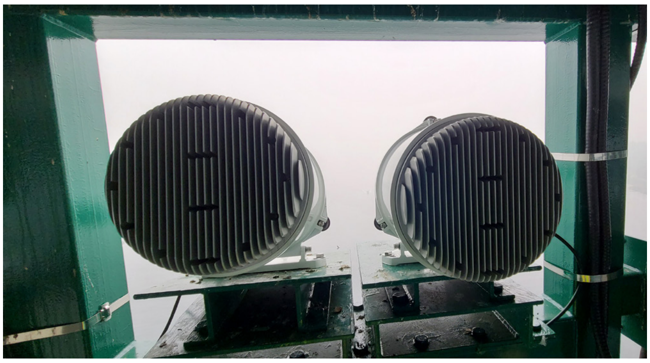
Installation of PEL Sector Lights

Operating from Commercial Power

When an alternating-current (commercial or mains power) source is used, it is strongly recommended that the commercial power cable is continued right to the top of the tower. This is better than terminating at the base of the tower and running 12 VDC or 24 VDC cables up the tower, for the following reasons:

- No significant voltage drop in the cables
- Avoids introducing “inductance” into the low-voltage circuit
- Reduces susceptibility to lightning damage

In addition, it is strongly recommended that a battery or UPS device is inserted between the power converter and the PEL Sector Light to provide a measure of autonomy in the event of a power failure, and further insulate the PEL Light from mains voltage spikes. It is well worth making provision for lifting batteries up to the platform. Cable lengths between power converter, battery and PEL Light should be kept as short as possible – ideally less than 1m.



Case study: Lions Gate, Vancouver, Canada

Main challenge was the height of the Lions Gate Bridge above the First Narrows passage which creates a vertical divergence challenge. The Sector Light needed to be mounted below the bridge superstructure at the centre of the channel and maintain visibility at relatively short range and yet still be visible at longer ranges.

The solution was using two PEL lights to increase the overall vertical divergence of the system by installing the PEL-4 lights tandem with one light angled to service vessels at a distance and the other one angled to service vessels closer to the bridge.

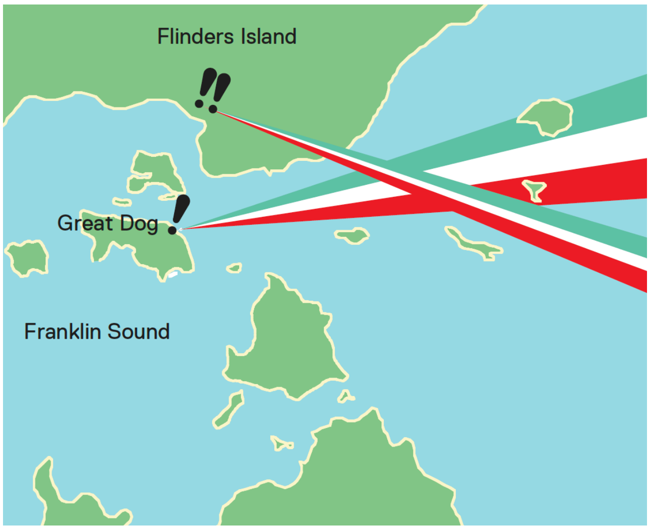
Read more about the Lions Gate reference case *- https://media.sabik.com/media/precision-sector-light-pel-4-installed-on-the-iconic-lions-gate-bridge-vancouver-canada*

INSTALLATION GUIDE

Single PEL Sector Light Application

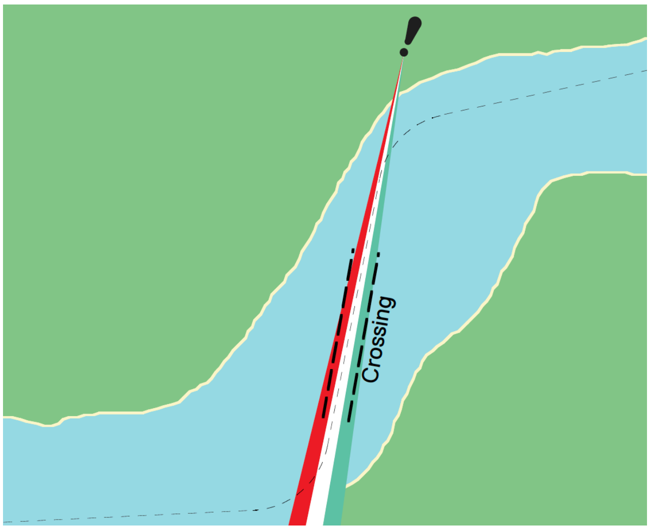
Mark a Leading Line

This is the most common application for a sector light. The light can be mounted at any elevation on the desired track, preferably above street-level background lighting, and in a secure location. There is complete flexibility regarding individual sectors, and sectors do not need to be symmetrical. For extra intensity use two lights mounted one above the other. For very long and narrow channels refer to Parallel Channel example, as two lights arranged in this way may be required to give adequate sensitivity at full range.



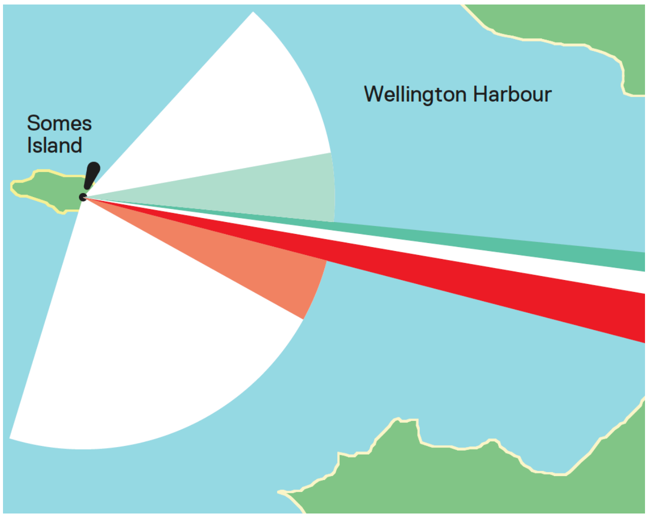
Mark a River Crossing (USA)

Vessels cross from one side to the other as deep water follows the outside of bends. Crossings move during floods, and aids often need to be realigned. Rear towers for transit lights are expensive, especially if they need to be moved from time to time. A PEL light can be located on the riverbank, and rotated or repositioned with relative ease. A PEL-3.5D light with automatic night dimming (and coated optics to extract maximum energy) provides day and night use over 1-2 NM in several solar-powered installations.



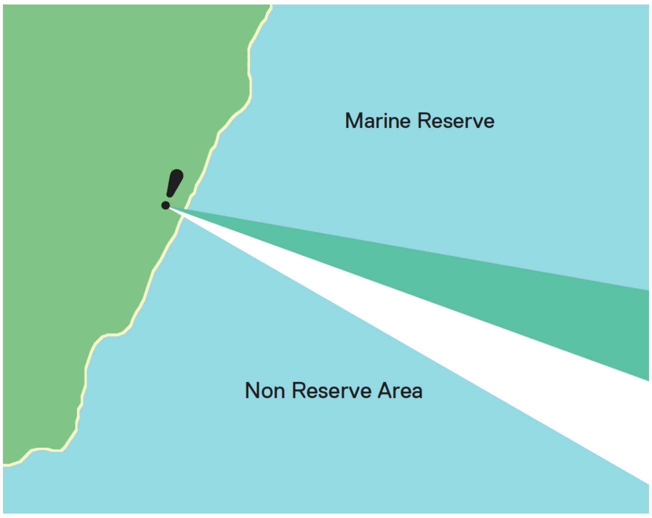
Supplement a Flashing Beacon (Wellington, NZ)

A small flashing beacon (with shadow-type filters) projects light through a large angle, and a PEL Light supplements the beacon in the direction of interest, by increasing intensity and sharpening the sector boundaries to define the safe passage. The harbour entrance has many rocky shoals, and accurate directional guidance is necessary. In the sector in which it is visible, the PEL light overpowers the signal from the flashing beacon. Flashing of the lights is synchronised.



Mark a Fishing Zone or Machine Reserve

In this example a single line is drawn out perpendicular to the coast, with a different colour each side of the line. A narrow subtense produces greater intensity, but viewing angle is reduced. A PEL light is used, so the signal can be read both day and night. The light is flashed to conserve energy, as the installation is on a remote piece of coast, and must be solar powered.



INSTALLATION GUIDE

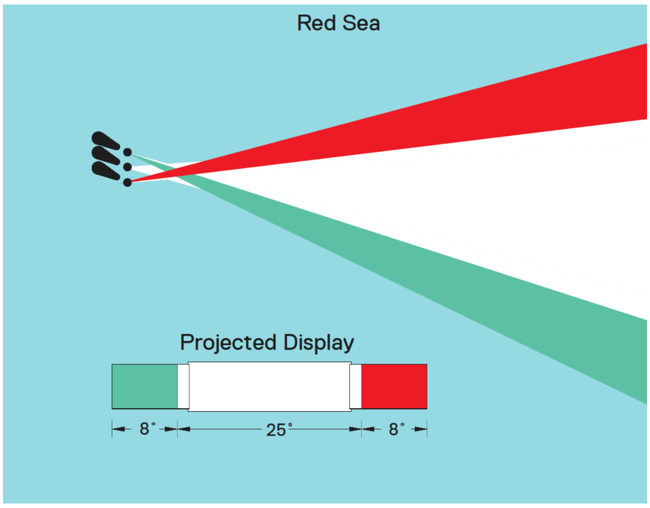
Single PEL Sector Light Application

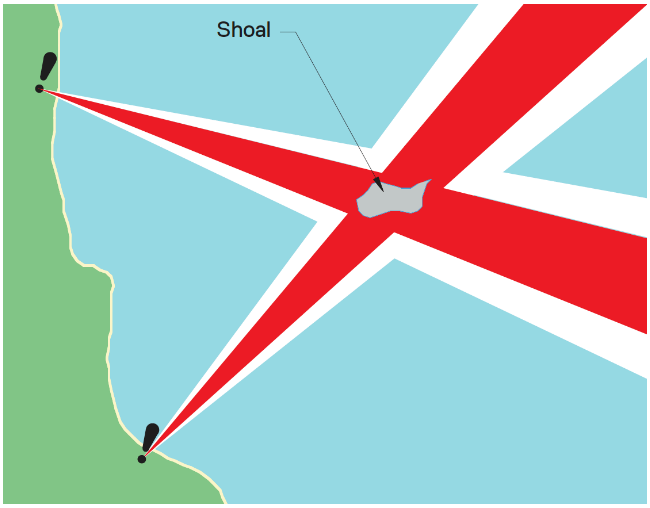
Provide Extra Subtense (Red Sea)

One PEL 20D light and two PEL lights with 10.75º subtense are mounted on a single station and project a total subtense of 41º. An overlap of 0.25º between lights ensures the full sector is covered. A wider coverage is achieved than could be provided with a single light, and vertical divergence is less. The relationship between subtense, intensity and colour filter transmission is used to good effect – the intensity from the 10.75º lights (in coloured sectors) is about the same as the 20º light (in white sector).

Mark a Restricted Area

Two or more lights can be used to provide a fix over a restricted area. The lights are read as a pair (or group), and may also be flashed in sync to aid identification. The area defined by the lights may be quite irregular. Sectors can be any size and in any sequence, limited only by the total subtense of the light. Restrictions can be to keep vessels inside (anchoring area, turning basin) or exclude entry (no-anchoring zone, hidden shoal or other danger area). Floating buoys may not be required.



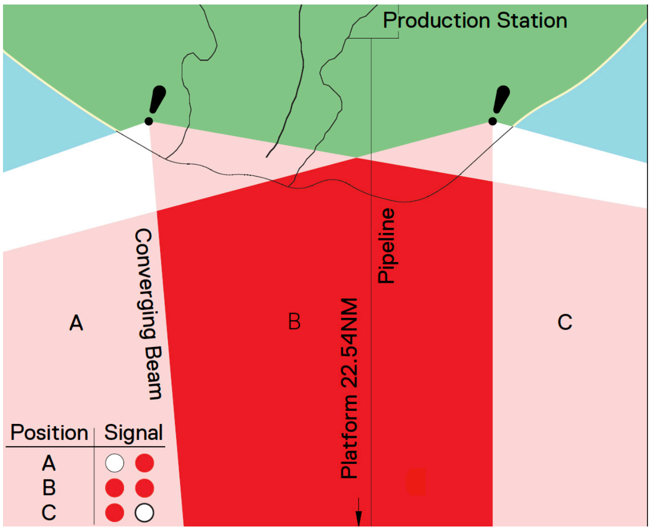


Mark a Parralel Channel

The channel can also be convergent or divergent, and the same lights used by a dredge. Each light has two sectors, and the lights are read as a pair, perhaps flashing in sync. An oscillating sector inside of each boundary is possible. This example is used when the taper shape of a single sector is too much compromise. The advantage of this method over leading lights is that both sector lights only require the intensity of a front lead, and that even at great viewing distances the sensitivity is not reduced.

Mark an Undersea Pipeline (Taranaki, NZ)

Two wide-angle anamorphic PEL Sector Lights are used to define a no-trawling corridor between an offshore oil production platform and the shore station. This is to protect the underwater pipeline connecting the two. The restricted area is defined when both lights are red. In this case the lights are not synchronised, but have different characters, and because the background is unlit farmland, relatively low intensities are adequate. Marker boards are used to define the corridor during the day.

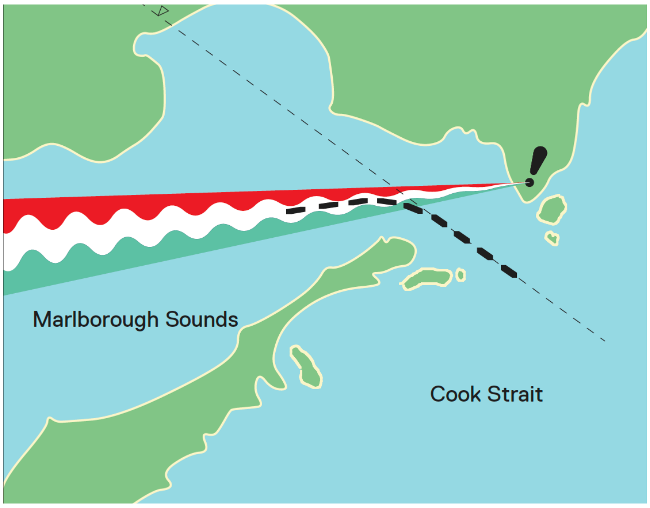


INSTALLATION GUIDE

Oscillating Boundary Application

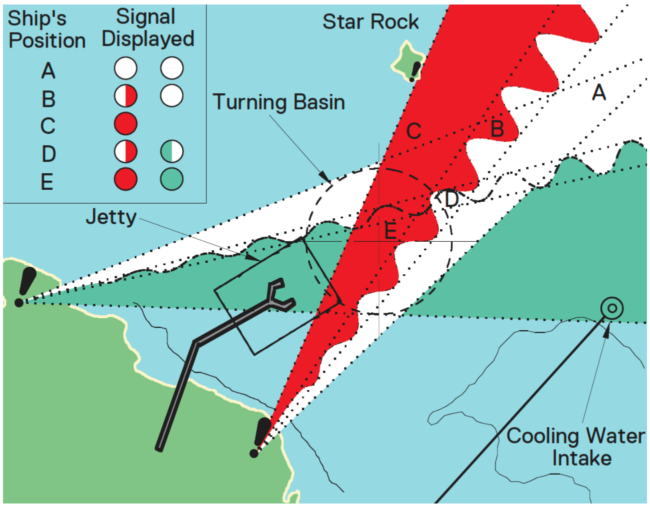
Mark a Turning Track (Tony Channel, NZ)

Cook Strait, between the two islands of New Zealand, is a very rough stretch of water with strong tidal rips, and is exposed to strong winds. A regular inter-island rail ferry must initiate a turn from inside the sound to exit through an unlit narrow passage, while remaining clear of rocks on each side of the channel. The PEL Sector Light fitted with oscillating boundary provides the pilot of the relatively cumbersome ferry with a progression of distinct sectors to turn through as he emerges into the strait.



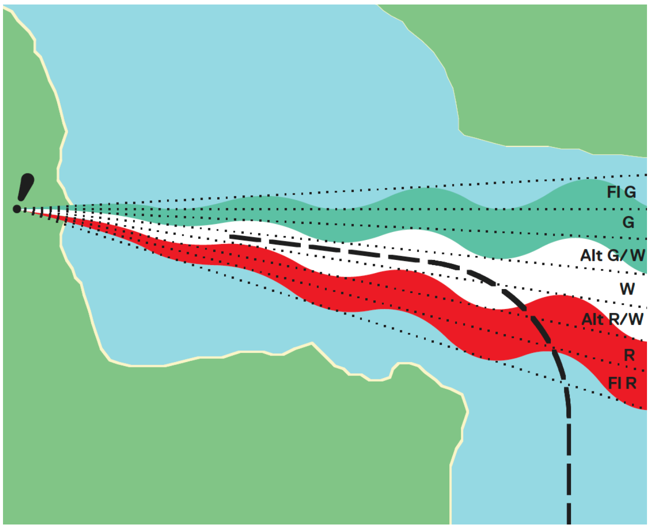
Turning Circle (Mermaid Sound)

Two PEL Sector Lights are located at a petroleum terminal, and the lights are enclosed in flameproof enclosures. The restricted area of the turning basin is defined by these sector lights. Each white and alternating sector is 100 metres wide at the centre of the basin. The oscillating boundary gives a clear indication of progress around the turning track in either direction, assisting the tanker to arrive at the jetty in the correct position. This system is simpler, more reliable and less costly to maintain than a buoyage system.



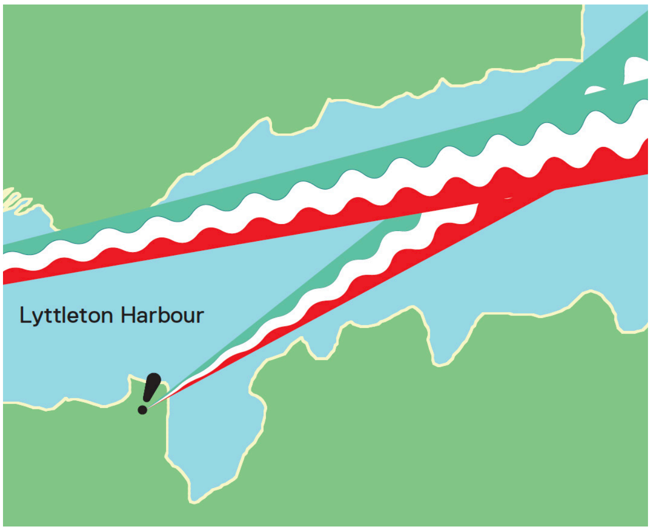
Difficult Turn Onto Narrow Track (All 7 Sectors used)

Adverse wind and current makes turning large vessels difficult. Speed is required to maintain steerage, and extra information is needed to execute the turn safely. The use of all seven possible sectors in a PEL Sector Light gives the mariner the best information. Flashing red on first encounter initiates the start of the turn. The transition to steady red occurs halfway through the turn, the alternating red/white sector is next traversed, and final alignment is gradually achieved within the narrow white sector.



Multi-leg Entrance into a Harbour (Lyttleton, NZ)

A 10° PEL Sector Light with oscillating boundary provides the main lead into this harbour. The oscillating boundary system makes it easier to maintain the correct track, by giving early warning of lateral deviation. Once within the inner harbour, a second PEL Light (of 5 degrees total subtense for greater intensity) is used to mark a narrow dredged channel. This simple system of two PEL Sector Lights replaced a more complicated and costly arrangement of shore-based lights and floating buoys.



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