Vega guides the way

PEL SECTOR LIGHTS

PRECISION SIGNALS FOR GUIDANCE OF SHIPS

UP TO 6NM BY DAY & 24NM BY NIGHT AT 0.74T

PEL-3 & PEL-6

Horizontal divergence from 3.5° to 20°

IALA AISM

ISO 9001

BUREAU VERITAS Certification

BUREAU VERITAS 1828

ABOUT SECTOR LIGHTS

PEL Sector Lights display a different colour when viewed from different angles at sea. Very sharp colour boundaries – a complete colour change typically occurs within 1 minute of arc. With optional oscillating boundary, the signal alternates between two colours in proportion to the distance across the sector. PEL Sector Lights indicate the precise vessel position in confined waterways. They are used in situations where extreme accuracy is required, or where only a single station is possible. Each light is custom-configured for its site. Range up to 6NM by day from PEL-6.

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
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
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 always less than the horizontal subtense of the light due to the way the circular beam is masked.

Boundary Resolution
On the boundary between a white and a coloured sector (eg 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 transmissivity and level of background lighting.

Oscillating Boundary
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.

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 filament lamps used at low voltage.

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

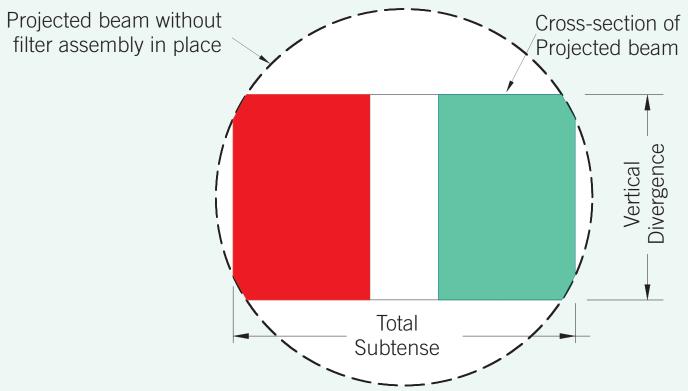


Figure 1

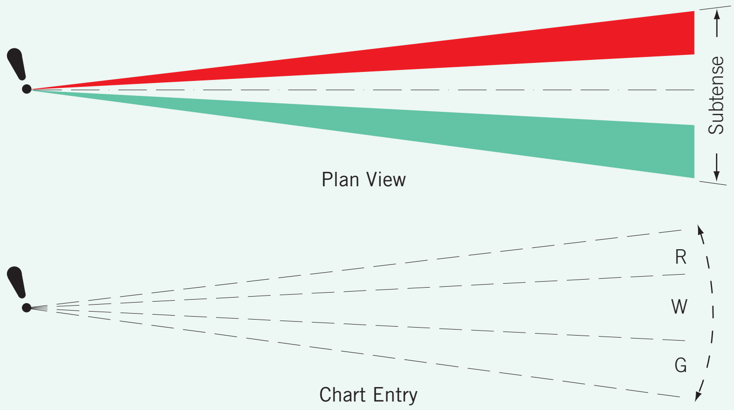


Figure 2

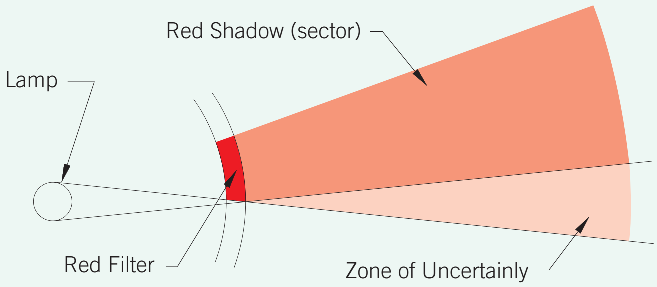


Figure 3

for sectored navigation lights. If more than three sectors are required, the Oscillating Boundary option should be used, rather than additional colours.

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 a more vague "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 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.

How Sectors are Created

Shadow Method

A coloured sector can be 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.

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 system collects light radiating from the lamp and spreads it uniformly across the coloured filter. Lamps which project light mostly in two opposing directions give better energy efficiency in this type of optic (eg "M" series halogen lamps).

An image of the exit surface of the filter (right side on diagram) 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. Small changes in lamp filament position may cause minor changes in intensity within the beam, but will have absolutely no effect on the boundary positions, which are fixed by the projection lens system.

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, smaller subtenses require larger projection lenses and longer barrel lengths.

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*.

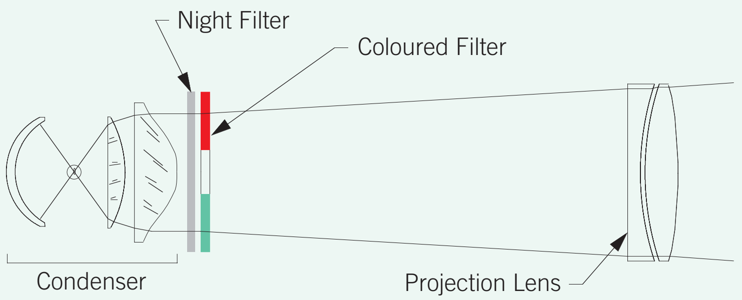


Figure 4

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.

In Vega's experience, the optimum transmission in coloured filters is about 25%. Vega uses SCHOTT optical glass for filters – OG 590 for red (27% transmission), and BG23 for blue-green (24% transmission). BG23 transmits almost no red or purple light.

Neutral Density Filter in White Sector
In a sector light having red, white and green sectors, the central white sector is about 4 times more intense than the colour sectors.

When there is little or no background lighting, it is recommended that a 50% neutral-density filter is used for white. Although this makes the white sector twice the intensity of the coloured, the eye perceives the same intensities in all three sectors. The 50% White Filter will reduce the intensity but not change the colour.

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.

Night Filters
When a sector light is used for both day and night operation, the intensity for night viewing must be reduced to between 1% and 20% of the daylight intensity for equivalent conspicuity. This is more than can be achieved by voltage reduction at the lamp alone, without having the filament turn orange, and without interrupting the halogen cycle on tungsten-halogen lamps.

At night in the PEL-6 Sector Light, a neutral-density Night Filter is automatically inserted into the beam to achieve this reduction. Night Filters can be made to any transmission value down to 5%. Voltage reduction at the lamp can also be used to reduce intensity down to 20% of peak output. These two reduction methods are multiplied together to calculate the resulting intensity as a percentage of peak intensity (eg 5% x 20% = 1%).

Anti-Reflection Coatings
Anti-reflection coatings increase light transmission through a lens or filter. PEL Sector Lights typically have 10 optical surfaces, so this becomes a useful improvement. All PEL-6 Lights have anti-reflection coatings on all surfaces except those exposed to the lamp and the exterior. These coatings are easily damaged by cleaning, and when damaged are worse than no coating at all. Coatings are only applied to PEL-3 lights where extra performance is required.

Masking of Stray Light
At least 0.5% of light is scattered by the last lens surface (more if it is not clean), and becomes stray light. This can be significant, especially in PEL-6 Lights of 5° subtense or less. An observer could think he is inside the beam when he is not. PEL-3 lights of small subtense are masked with a barrel extension. This is not practical with the larger apertures of PEL-6 lights. Panels can be placed some distance out in front of the light (like horse blinkers).

Lamps Used in PEL Sector Lights

M-Series Lamps
PEL Sector Lights use an optical condenser system to capture light from the lamp. The condenser system picks up light from within two opposing 120° cones. Lamps which emit light mostly in two directions show significantly greater efficiency in this type of optic. The use of lamps with flat filaments (eg. M-series) produces 41% more intensity than standard marine lamps with vertical filaments. Notwithstanding the above, PEL-3 lights are fitted with standard marine lamps with prefocus candelabra bases if the required size of lamp is not available in the M-series.

The PEL Sector Light is limited by the physical size of the lamp filament. Compact filaments are preferred, because the larger the filament the larger the rest of the optic must be to capture and use the available light. This is why fitting a larger lamp than the 250 Watt M36 lamp will not necessarily increase intensity, especially if the extra output has been achieved by enlarging the filament. A larger optical system would also be required, and the resultant Sector Light would be much more expensive.

Flashing Constraints with M-Series Lamps
M-series lamps are ideal for achieving high energy efficiencies in a PEL Sector Light. However, the compact, low-voltage filament has some operational constraints which must be addressed. The filaments have very low resistance when cold, and very high in-rush currents are experienced every time the lamp is turned on. The current can be well over 15 times the steady state current (over 150 Amps for M-28 and M-36 lamps). Lampchangers and flashers must be designed to carry this current. The CALC-2001 controller limits inrush current to less than 100 Amps.

M-series lamps require time to warm up and cool down, as they exhibit considerable thermal inertia due to the mass of metal in the filament. This limits the minimum on and off-times to:

M32	12V, 50 Watts	1.0 sec
M28	12V, 100 Watts	1.5 sec
M36	24V, 250 Watts	2.0 sec

Intensity/Time graph of M36 lamp with ISO 4s (2 sec ON, 2 sec OFF) flash character imposed

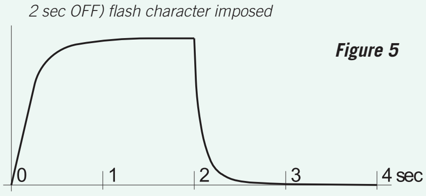


Figure 5

The effective intensity of a lamp flashed by switching on and off, with an on-period of T secs duration, is proportional to T/(T+0.2). If the range is barely adequate then long on-times should be used. See *Figure 5*.

Lamp Life and Voltage Control

Virtually all PEL Sector Lights are powered by batteries, and this is the recommended approach. Batteries can be charged by mains charger, or by solar panels. The voltage from the batteries will frequently exceed the rated voltage of the lamp. Applying such a voltage significantly reduces lamp life from their rated 2000 hours.

To prevent inadvertent lamp life reduction the CALC controller used on all PEL Sector Lights applies pulse-width modulation to lamp power, reducing the DC-rms power as necessary to ensure that the rated power of the lamp is never exceeded. When pulse-width modulation is active, the voltage measured at the lamp by a multi-meter will not be an accurate representation of the rms voltage. Meters measuring AC-rms voltage are not effective – an oscilloscope must be used to obtain an accurate reading.

Power Supplies

Voltage Spikes

Mains-powered battery chargers and other mains-driven power supplies must be free of voltage spikes. Power supplies with high internal inductance present a problem when used to drive low-voltage lighted aids to navigation.

When a lamp fails at the end of its life, this will often occur during the current inrush at startup. The sudden drop in current from a very high value (150 Amps) to zero can induce large transient voltages (100-200 Volts) if there is any inductance in the supply circuit. This will damage controllers which are only designed to withstand voltages of the order of 40 Volts.

Inductive Elements

Older power supplies were built with inductive elements (chokes) which worked in conjunction with a capacitive element to smooth the pulsed DC after rectification. These inductors store a large amount of energy in normal operation, and this energy generates the damaging voltage spikes.

Battery Protection

When initially installed and connected to a continuous battery charger, new batteries may have sufficient capacity to absorb spikes, and they do not reach the Sector Light electronics. However, as batteries deteriorate over time this capability reduces, and spike damage to electronic equipment may start occurring.

SMR Power Supplies Only

Power supplies with high internal inductance are not suitable for use with neither PEL Sector Lights nor other low-voltage lights. Switch-mode regulated battery chargers of good quality are recommended. Use the Vega VPR-39 weatherproof switch-mode power supply if in doubt.

Achieving Maximum Service Life

Life Expectancy

Many PEL Sector Lights around the world have been in service for more than 20 years. Vega routinely refurbishes PEL Sector Lights back to new condition, which includes repolishing and recoating the optics, upgrading the electronics and repainting the exterior, for a fraction of the cost of a new light.

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 (each light holds 4 psi without leakage as a factory test).

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.

Packs of properly-dried silica gel should always be left in the lampchanger area of each light between servicing, to absorb moisture introduced with each opening. Internal inspections should be no more frequent than six monthly, with twelve months being the normal.

Routine Servicing

Ensure lights are properly resealed after closing. Always inspect the condition and cleanliness of the O-ring seal and mating surface.

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. The PEL-6 Sector Light has been designed for day & night operation.

Two Models: PEL-3 and PEL-6

There are two models of PEL Sector Light, PEL-3 and the PEL-6. Both are available in a range of standard subtenses, from 3.5° to 20°. The PEL-3 is designed for night use, and uses lamps up to 100 Watts. Small prefocused lamps down to 10 Watts can be used where less intensity is acceptable and limited energy is available. The PEL-6 has much larger optics and is designed to meet the need for a day & night sector light. It carries a 250 Watt lamp, and automatically reduces intensity at night by two methods used together: night filter insertion and lamp voltage reduction.

Balancing Intensity Against Subtense

For a given lamp size 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 will meet 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.

Choosing Individual Sector Angles

For a leading line, one approach is to select a control point, like a harbour entrance. Consider the widest vessel passing the control point, and decide the width (in metres) of each sector at that point. The central white sector should be quite narrow – it is not marking the edges, but an acceptable deviation from the centre line before a colour change is seen. Use the tangent function to calculate individual sector angles.

Night Intensity Reduction (Day & Night Lights) With all PEL Sector Lights, there are 6 options for lamp voltage at night, given that voltage during the day is 100%:

Dixon Cove (16°20'N, 86°29'W) – Roatan is one of the Honduras Bay Islands in the Caribbean Sea. A PEL-3-3.5D, solar powered with on-demand switching via VHF marine radio has been deployed in the Dixon Cove Harbour of Roatan Island.

Night Step	PEL-3 Volts	PEL-6 Volts	Average Current	Night Intensity
1	12.0	24.0	100%	100%
2	11.0	22.0	88%	75%
3	10.3	20.5	80%	60%
4	9.0	18.0	65%	40%
5	7.2	14.4	47%	20%
6	6.0	12.0	36%	10%

PEL-6 lights have the night intensity further reduced by insertion of a Night Filter with a transmission between 5% and 50%. Where lamp voltage reduction and a night filter are used together, the final transmission is the product of the two values.

Example:

- 60% of peak intensity from lamp voltage reduction
- 5% transmission through night filter (when inserted)
- Night intensity = 60% x 5% = 3% of day intensity

Specification Sequence

1. 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-3 for night only, or a PEL-6 for day & night. For very short distances a PEL-3 can be used in daylight, but night dimming is only by voltage reduction.

2. Determine Required 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 Vega for assistance.

3. Choose Total Subtense
There is a tradeoff between subtense and intensity – the greater the subtense the less the intensity (for a given lamp). Refer to PEL-3 and PEL-6 tables for intensities.

4. Choose Lamp Size
For the PEL-3 the maximum size lamp is 100 Watts. The M28 100W lamp gives best performance, but smaller lamps are adequate for lower intensities. Refer to table of lamp performance for PEL-3 Lights. For the PEL-6 the M36 250 Watt lamp (24 Volts) is standard, but smaller lamps can be accommodated.

5. 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 long lamp on-periods are required for its effective operation. Refer to Oscillating Boundary.

6. 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 the vessel.

7. Check 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.

8. Specify Flash Character
Each PEL Sector Light uses a CALC-2001 controller, which has 256 flash codes. Certain lamps have minimum on and off-times. 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.

9. Specify Night Intensity Reduction (if applicable)
When the PEL Light is used day and night, intensity reduction is required at night. Night intensity is a percentage of day intensity. Lamp voltage reduction value can be adjusted in the field, but changing the Night Filter transmission requires a new filter.

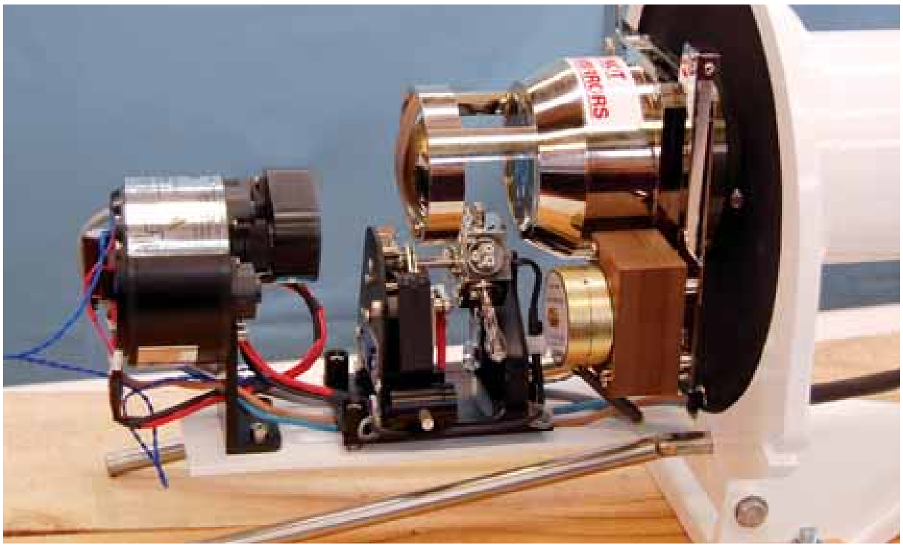
10. Reduced Intensity in White Sector: Yes or No
Intensity in the white sector can be reduced to 50% using a ND filter to match the apparent intensities in the coloured sectors.

11. Anti-Reflection Coatings (PEL-3)
These give up to 35% extra intensity in critical applications.

12. Connections to Other Devices
Synchronisation to other lights, monitoring interfaces, remote on-off or intensity control.

PEL-3 SECTOR LIGHTS

- Invented in New Zealand by Norman Rumsey, acclaimed international optical designer and astronomer.
- Modern optical design techniques and minimisation of optical aberrations achieve very sharp sector boundaries.
- Up to 19NM range at night (coloured sectors, 3.5° subtense, 100 Watt TH lamp, anti-reflection coatings).
- Great configuration flexibility – each light is customised to suit the exact requirements of the end user.
- Wide choice of subtenses, individual sector angles, lamp types and sizes, flash characters and operating modes.
- Designed for use in rugged marine environments without further protection. Sealed enclosure, built from gunmetal (marine-grade bronze) and stainless steel.
- Energy efficient – each optical system makes best use of energy available from the lamp.
- Suitable for solar power – operates from 12VDC. Light can be flashed to reduce power consumption.
- Uniform intensity from one side of the beam to the other – intensity does not reduce due to movement off axis.
- Delivered fully tested and ready to operate, complete with Vega 6-position lampchanger and CALC-2001 controller.
- Long service life – many PEL-3 Sector Lights have been in continuous service for over 20 years.



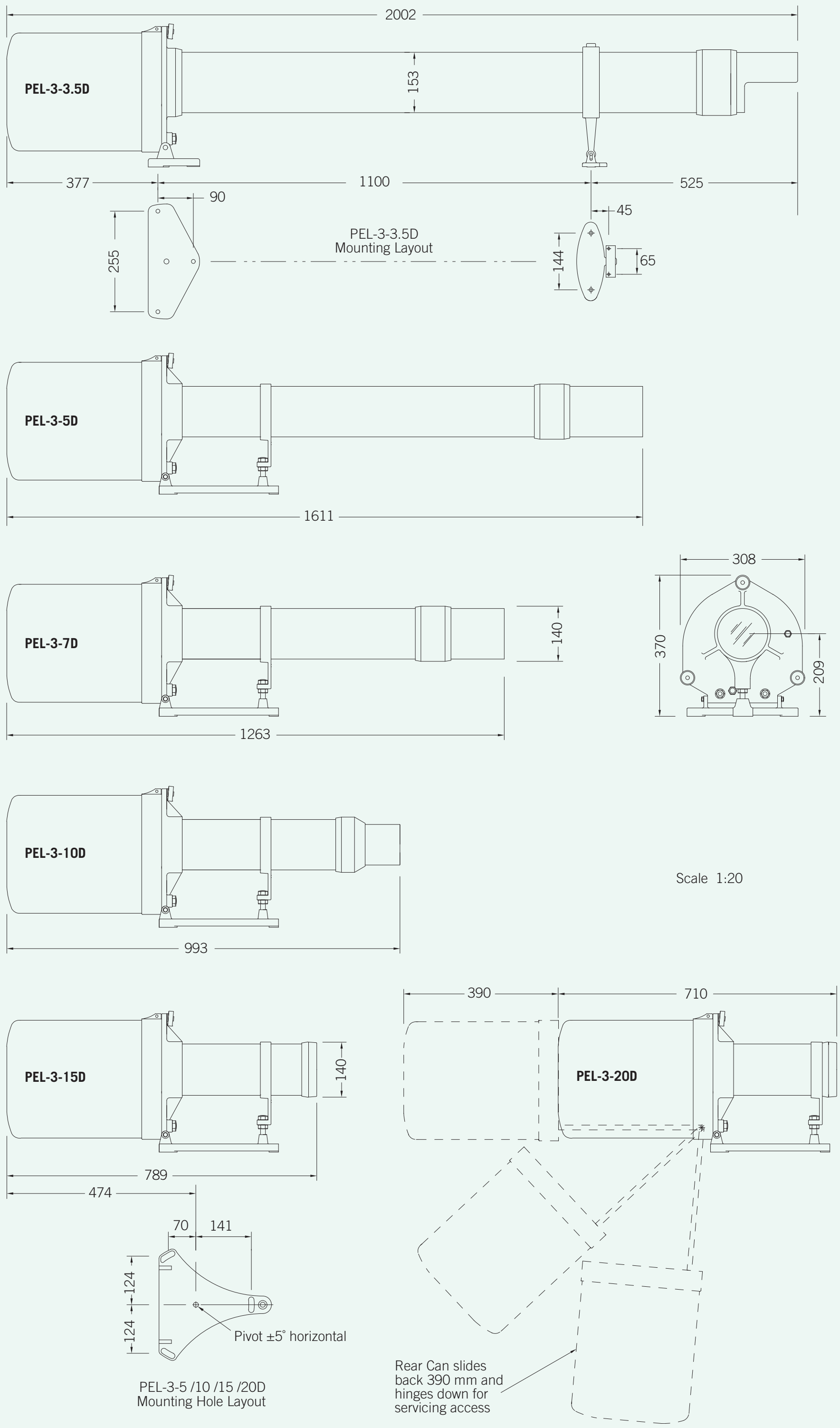
French Guiana – PEL-3

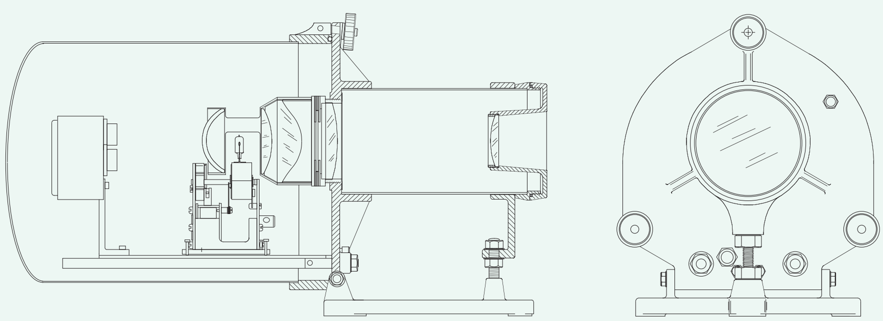
- Can be interfaced to remote switching and monitoring equipment – interfaces are available. Optical isolation recommended when connecting to other electrical equipment.

SPECIFICATIONS

Light Source	Filament lamp, max 110 Watt tungsten halogen
Lamp Mounting	Bi-pin (M-series lamps), or prefocus candelabra
Primary Reflector	First-surface spherical, aluminium coated
Condenser Type	Two element (spherical+aspheric), 120° pickup
Lampchanger	Vega VLC-152A (bi-pin), VLC-150 (pre-focus)
Power Supply	12-16VDC, battery float (mains or solar)
Anti-Reflection Coatings	Non-standard on PEL-3, available as an option
Flash Characters	Fixed +255 characters, user-selectable
Flasher/Controller	CALC-2001 computer-assisted light controller
Lamp Power Regulation	Pulse-width-modulation regulates power to lamp
Construction Materials	Gunmetal, stainless steel, copper tube
Exterior finish	Epoxy primer-surfacer, 2-pot polyurethane gloss

DIMENSIONS





Longitudinal Section of PEL-3 20D Sector Light

PEL-3 Peak Intensities in White, Red and Green Sectors

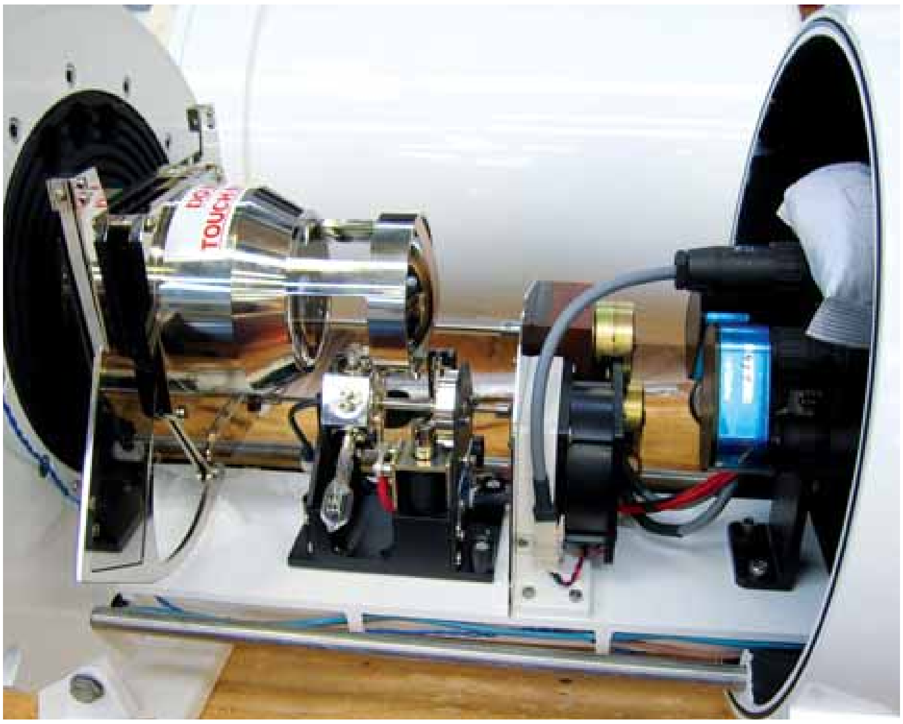
PEL-3 Total Subtense	Colour	3.5°	5.0°	7.0°	10°	15°	20°
M28 12V 100W TH (Coated Optics)	W	301,674	147,868	75,489	37,038	16,514	9,330
	R	81,452	39,924	20,382	10,000	4,459	2,519
	G	72,402	35,488	18,117	8,889	3,963	2,239
M28 12V 100W TH	W	220,430	108,045	55,159	27,063	12,066	6,817
	R	59,516	29,172	14,893	7,307	3,258	1,841
	G	52,903	25,931	13,238	6,495	2,896	1,636
M32 12V 50W TH	W	78,069	38,266	19,536	9,585	4,274	2,415
	R	21,079	10,332	5,275	2,588	1,154	652
	G	18,737	9,184	4,689	2,300	1,026	580
NAL 86 100W PF Halogen	W	149,819	73,435	37,490	18,393	8,201	4,633
	R	40,451	19,827	10,122	4,966	2,214	1,251
	G	35,957	17,624	8,998	4,414	1,968	1,112
NAL 85 75W PF Halogen	W	87,937	43,103	22,004	10,796	4,813	2,719
	R	23,743	11,638	5,941	2,915	1,300	734
	G	21,105	10,345	5,281	2,591	1,155	653
NAL 84 50W PF Halogen	W	65,139	31,928	16,300	7,997	3,565	2,014
	R	17,588	8,621	4,401	2,159	963	544
	G	15,633	7,663	3,912	1,919	856	483
NAL 83 35W PF Halogen	W	42,340	20,754	10,595	5,198	2,318	1,310
	R	11,432	5,604	2,861	1,403	626	354
	G	10,162	4,981	2,543	1,248	556	314
NAL 82 20W PF Halogen	W	22,799	11,175	5,705	2,799	1,248	705
	R	6,156	3,017	1,540	756	337	190
	G	5,472	2,682	1,369	672	300	169
NAL 81 10W PF Halogen	W	9,771	4,789	2,445	1,200	535	302
	R	2,638	1,293	660	324	144	82
	G	2,345	1,149	587	288	128	73

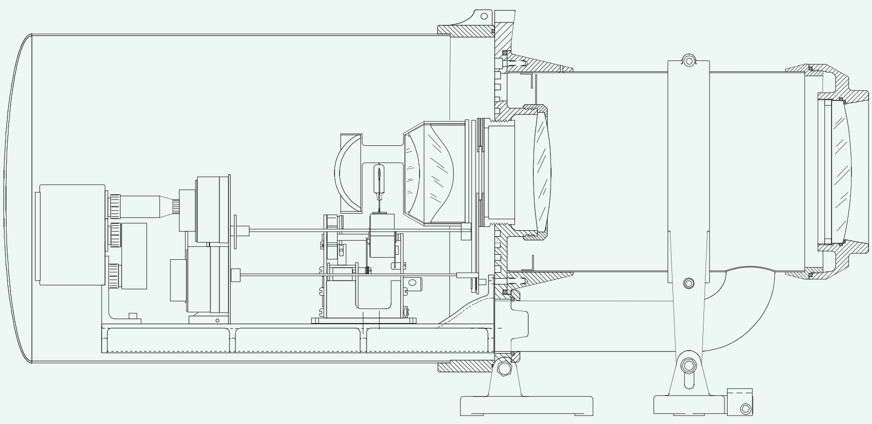
Vertical Divergence		2.0°	3.0°	3.4°	4.3°	5.0°	5.6°
Boundary Resolution		<1.0'	<1.0'	<2.0'	<2.0'	<3.0'	<3.0'
Sector Accuracy		<1.0'	<1.0'	<2.0'	<2.0'	<3.0'	<3.0'
Overall Length (mm)		2002	1611	1263	993	789	710
Shipping Weight (kg)		80	67	67	50	45	45

Port Mahon (39°53'N, 4°15'E) – The capital and principal seaport of Minorca, in the Spanish province of the Balearic Islands. Port Mahon is the longest natural port in the Mediterranean it extends into the island 5km and is up to 900m wide. The very narrow entrance and the growing traffic of large ferries required the use of a PEL-3 3.5D precision sector light.

PEL-6 SECTOR LIGHTS

- Up to 6 nautical miles range in daylight (coloured sectors, 3.5° subtense, 250 Watt TH lamp, favourable background).
- Over 21 nautical miles range at night in coloured sectors, up to 25NM in white sector (3.5° subtense).
- Automatic intensity reduction at night using lamp voltage reduction combined with insertion of neutral density filter.
- Boundary definition and sector accuracy typically better than one minute of arc (for subtenses less than 20°).
- Optional Oscillating Boundary provides up to four extra sectors and proportional indication of lateral changes.
- Colour integrity – selection of correct colour filters ensures that sectors are recognised correctly in all types of weather.
- Rugged construction and sealing – proven life exceeds 20 years in typical harsh marine environment.





Longitudinal Section of PEL-6 15D Sector Light

SPECIFICATIONS

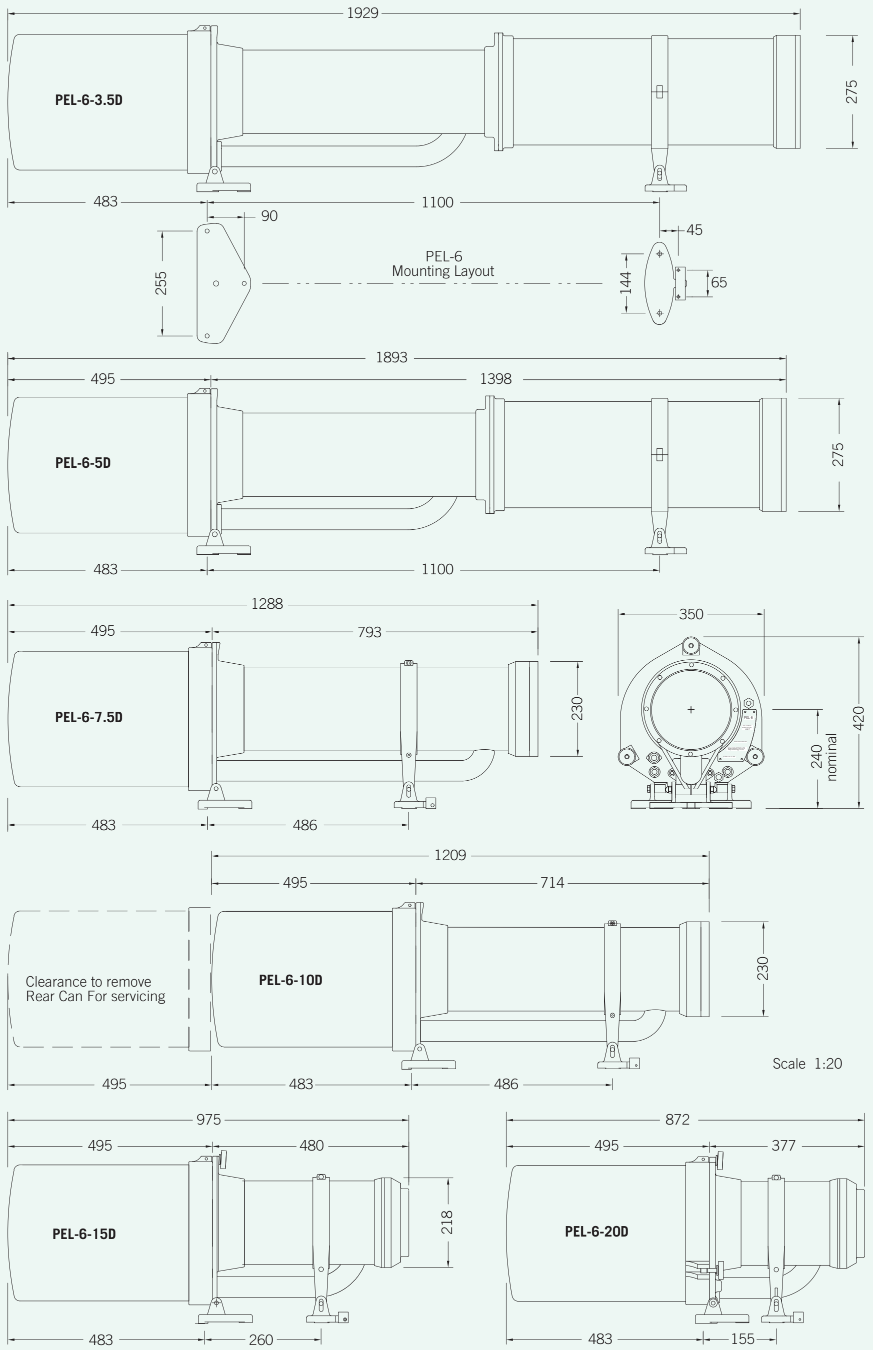
Light Source	M36 250 Watt tungsten-halogen lamp
Lampchanger	Vega 6-position, VLC-152A (bi-pin mounting)
Power Supply	24-28VDC, battery float (mains or solar)
Anti-Reflection Coatings	Standard on all PEL-6 Sector Lights
Sector Angles	Individual sectors custom-made for each light
Oscillating Boundary	Factory-fitted option for PEL-6 Sector Lights
Night Intensity Reduction	Night Filter + Lamp Voltage Reduction combined
Flash Characters	Fixed +255 characters, user-selectable
Flasher/Controller	CALC-2001 computer-assisted light controller
Lamp Power Regulation	Pulse-width modulation regulates power to lamp
Construction Materials	Gunmetal, stainless steel, copper tube
Exterior finish	Epoxy primer surfacer, 2-pot polyurethane gloss

Measurement of Intensity

When checking the intensity of PEL Sector Lights the measuring distance must be sufficient to ensure that the light source behaves as a point source, and the inverse-square law applies. One way to check this is to take several readings at slightly different distances. When accurately done, the source intensity will be independent of measuring distance.

For practical measurements it is acceptable to work close to the limit of the photometer's sensitivity. This could be more than 100 metres for some PEL-6 Sector Lights. Distances less than this will give false readings on the low side. An alternative method is to use a calibrated zero-range photometric facility, which simulates performance of the light at considerable distances (in far field).

DIMENSIONS



Left-to-Right Sequence of Sectors

Some PEL Sector Lights laterally invert the sector array out in front of the light. The left-to-right sequence of the sectors as they appear looking into the barrel will not necessarily be the way they are projected. Always check sector orientation from a distance.

Focus at Infinity

PEL Sector Lights are normally focused at infinity. This gives sharp sector boundaries at normal viewing distances. Within the first few hundred metres the sector boundaries will appear blurred.

Non-Compliant M36 Lamps

The original M36 lamp is ideally suited to the PEL-6 Sector Light. Some lamps now sold as M36 do not comply with the original specification regarding lamp life, filament centre height, and pin diameter tolerance. These lamps must not be used in PEL Lights, as they run at higher temperatures, are prone to explode, and can crack lenses with excessive heat.

For PEL-6 lights that are flashed, Vega recommends the use of Bailey M36 lamps, which have reinforced filament support wires. Other lamps may not give the rated service life. If in doubt, source replacement lamps from Vega.

PEL-6 Peak Intensities in White, Red and Green Sectors

PEL-6 Total Subtense	Colour	3.5°	5.0°	7.5°	10°	15°	20°
M36 Lamp 24V 250W TH Full Intensity	W	726,532	356,116	158,273	89,199	39,770	22,470
	R	196,164	96,151	42,733	24,084	10,738	6,067
	G	174,368	85,468	37,985	21,408	9,545	5,393
M36 Lamp Night Intensity Reduced to 1%	W	7,265	3,561	1,582	892	398	225
	R	1,962	962	427	241	107	61
	G	1,744	855	380	214	95	54
M36 Lamp Night Intensity Reduced to 2%	W	14,531	7,122	3,164	1,784	795	449
	R	3,923	1,923	854	482	215	121
	G	3,487	1,709	759	428	191	108
M36 Lamp Night Intensity Reduced to 5%	W	36,327	17,806	7,910	4,460	1,989	1,124
	R	9,808	4,808	2,136	1,204	537	303
	G	8,718	4,273	1,898	1,070	477	270
M36 Lamp Night Intensity Reduced to 10%	W	72,653	35,612	15,820	8,920	3,977	2,247
	R	19,616	9,615	4,271	2,408	1,074	607
	G	17,437	8,547	3,797	2,141	954	539
M36 Lamp Night Intensity Reduced to 20%	W	145,306	71,223	31,640	17,840	7,954	4,494
	R	39,233	19,230	8,542	4,817	2,148	1,213
	G	34,874	17,094	7,593	4,282	1,909	1,079
M36 Lamp Night Intensity Reduced to 50%	W	363,266	178,058	79,100	44,600	19,885	11,235
	R	98,082	48,076	21,357	12,042	5,369	3,033
	G	87,184	42,734	18,984	10,704	4,772	2,696
M28 Lamp 12V 100W TH Full Intensity	W	301,674	147,868	65,719	37,038	16,514	9,330
	R	81,452	39,924	17,744	10,000	4,459	2,519
	G	72,402	35,488	15,772	8,889	3,963	2,239
Vertical Divergence		2.1°	3.0°	3.9°	4.3°	5.0°	5.6°
Boundary Resolution		<1.0'	<1.0'	<1.0'	<1.0'	<1.0'	<1.0'
Sector Accuracy		<1.0'	<1.0'	<1.0'	<1.0'	<1.0'	<1.0'
Overall Length (mm)		1929	1893	1288	1209	975	872
Shipping Weight (kg)		120	110	95	95	95	90

Map Ta Phut (12°40'N, 101°10'E) – PEL-6-5D with oscillating boundary, solar powered with VegaWeb monitoring and on-demand control. The port is located in the Province of Rayong and it is presently the biggest industrial port in Thailand.

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 Vega website, www.vega.co.nz.

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.

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 ivisible (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 repeats 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.

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 Sectors
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.

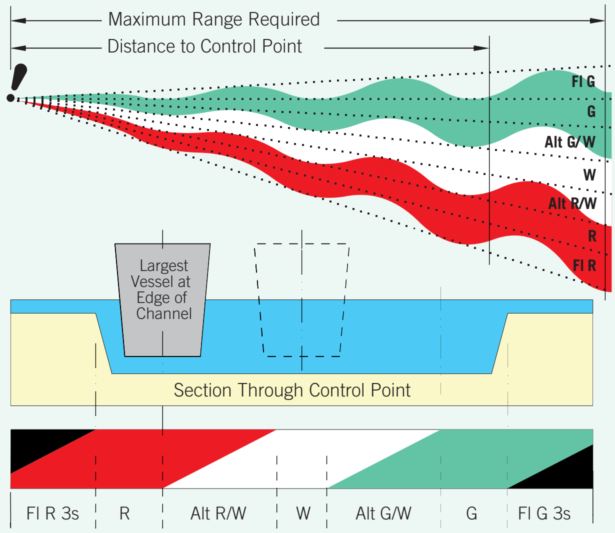


Figure 6

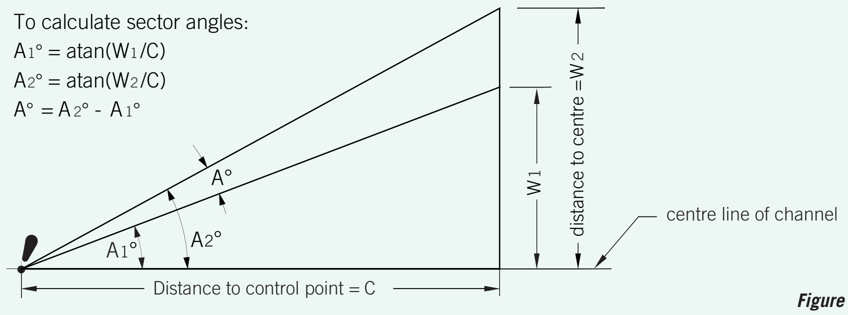


Figure 7

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 6*.

Determining 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.

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

Converting Lateral Distances to Angles
Use the arc-tangent function to convert measurements of distance from the centreline and distance to control point into angles in degrees. See *Figure 7*.

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.

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.

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. The technician needs to check the alignment of each lamp whenever the light is serviced, so safe and comfortable access is essential. The Rear Can needs to be removed to gain access – the PEL-3 can hinges down, and the PEL-6 can slides back on rails for removal. The front lens of the light must be easily accessable for inspection and cleaning, as dirt and grime on this lens will cause the light output to deteriorate.

Design of Mounting Plate

PEL-3 Lights (except the 3.5D size) have a triangular mounting plate as in photo below left. The PEL-3-3.5D and all PEL-6 lights have two mounting feet to support the weight of the barrel. Refer to the PEL-6 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.

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 12Vdc or 24Vdc cables up the tower, for the following reasons:

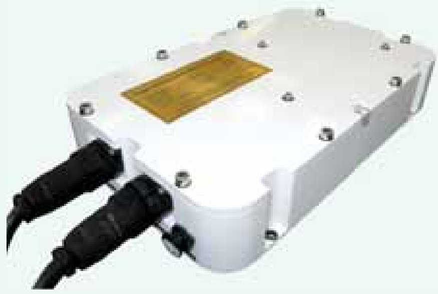
- no significant voltage drop in the cables
- avoids introducing “inductance” into the low-voltage circuit
- reduces susceptibility to lightning damage

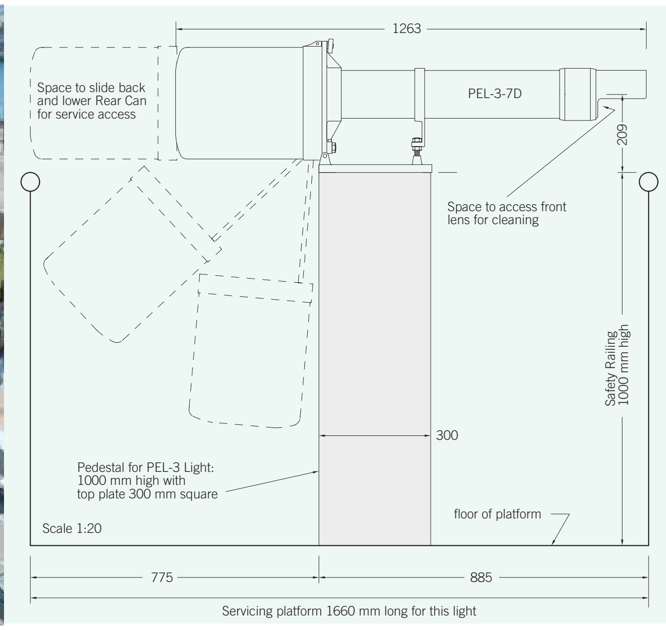
In addition, it is strongly recommended that a battery is inserted between the power converter and the PEL Sector Light to provide a measure of autonomy in the event of a power failure, and further insulate the PEL Light from mains voltage spikes. It is well worth making provision for lifting batteries up to the platform.

Cable lengths between power converter, battery and PEL Light should be kept as short as possible – ideally less than 1m.

Vega VPR-39 Power Supply

This is a weatherproof switch-mode power converter suitable for PEL Sector Lights operated from commercial power. It accepts 110Vac or 240Vac input, and can be set to 13.8Vdc or 27.6Vdc output. The VPR-39 can be used to power the PEL Light directly or it can be used as a charger when a battery is fitted.





CALC-2001 & LOGIC INVERTER

The CALC-2001 is a multi-purpose microprocessor-based controller, and is field programmable. With other plug-in devices it provides all the functionality required by sector lights and other flashed beacons.

Lamp switching is via two 40Amp TOP FET's in parallel. This generous over-rating ensures a low voltage drop and looks after the high inrush current on lamp start up. TOP FET's provide faster short-circuit and over-voltage protection. Pulse width modulation is used to control lamp voltage.

A Switch Mode Regulator of 1A capacity provides a constant 12Vdc output independent of the input (step up and step down) for driving the oscillating boundary, night filter, cooling fan, and other devices.

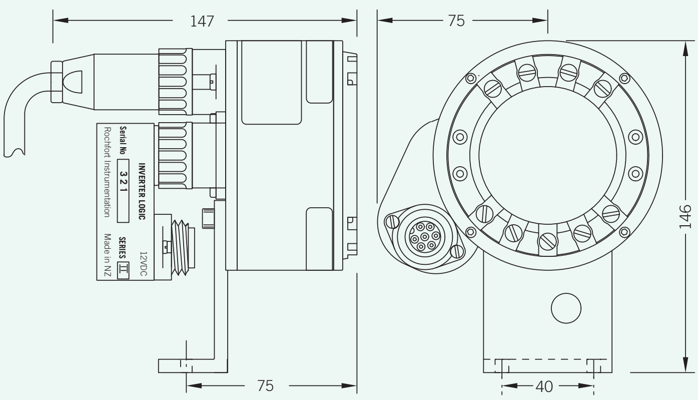
User-Selectable Programs are accessed via four hex switches located under a screw-in plug. Two hex switches select any of the 256 available flash characters. The third (user) selects the operating mode (day/night, day only, or night only), and selects sync if required. The fourth switch is for selecting one of the five voltage reduction steps for night time use, and works for either the 12 or 24V input.

Photocell sensitivity is adjusted via two DIP switches mounted beside the hex switches. There are four different settings for the light level at which switching occurs. Photocell hysteresis is fixed by a resistor.

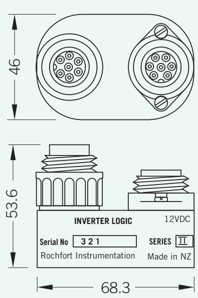
Synchronizing multiple lights is available within one of the user programs. The signal is carried by a cable between the lights. The distance between synchronised lights should not exceed standard RS232 parameters. Type 1 sync allows any or all lights to operate together. Type 2 sync requires a return sync pulse from a second light, otherwise the light is disabled.

Logic Inverters control 4-phase stepper motors used to drive oscillating boundary and night filters. They also provide the logic for night filter placement.

Lamp Inhibit allows an external signal to switch off the lamp. This is useful for remote control of the lamp to save power.



CALC- 2001



Inverter

CALC- 2001

Temperature Range	-40°C to 90°C
Housing type	O-ring Sealed
Microprocessor type	MC68HCO5C8 Plug in
Clock speed	2.4576 MHz
Quiescent Current (total)	65 mA
Address method	Hex Sw x 4 SS pot
Voltage range	10 - 28VDC,
Output switching devices	2 x 40 Amp TOP FET's
Resistive switching load	Softstart, Current limit
Input protection	Softstart, R.P.P & S.S.P
Motor drive output	Regulator type, S.M.R.
S.M.R. protection	3 amp fuse, R.P.P
S.M.R. load max.	1 amp
P.W.M.	12V & 24V ±1%

Logic Inverter

Switching I.C.	SAA1027
Oscillating boundary	200mA (approx)
Intensity filter	200mA (intermittent)
PEL Fan	120mA
Range	2.5sec - 4.5sec cycle

LAMPCHANGERS FOR PEL SECTOR LIGHTS

Vega High-Wattage Lampchangers

- current rating 10.5Amps continuous
- lamp power up to 24Vdc, 250W
- lamp turret machined from solid brass
- excellent heat sinking
- high-temperature mica insulation
- silver alloy electrical contacts
- soft stop to prevent filament damage
- reliable and precise indexing mechanism
- optional alarm contact on 5th/6th position
- dual mounting system on all bases

Vega VLC-150 Lampchanger

The VLC-150 lampchanger is standard equipment on PEL-3 Sector Lights when supplied with pre-focus lamps. It is designed to fit within the condenser system of PEL Sector Lights, hence the wide gap between turret and escapement mechanism. Other types of lampchanger would interfere with the mirror.

The VLC-150 accepts six marine pre-focus lamps up to 110 Watts (12Vdc, 10.5Amps). Failure of a lamp is remotely detected and a 60 degree turret rotation is actuated by a linear solenoid and driven by a stainless-steel coil spring. The Vega soft-stop system is included. When the last lamp comes into use, an optional alarm output signal is available.

Vega VLC-152AR Lampchanger

The VLC-152AR lampchanger is standard equipment on PEL-3 and PEL-6 Sector Lights when supplied with bi-pin tungsten halogen lamps. It is designed to fit within the condenser system of PEL Sector Lights, as the VLC-150 above.

The VLC-152AR accepts six lamps up to 250 Watts (24Vdc, 10.5 Amps). Failure of a lamp is remotely detected and a 60 degree turret rotation is actuated by a linear solenoid and driven by a stainless steel coil spring. The Vega soft-stop system is included.

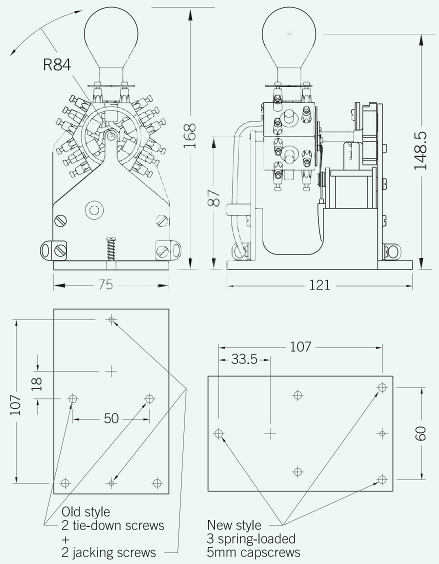
The VLC-152AR is fitted with spring-loaded collets which ensure the lamp pins are gripped tightly and with minimum resistance. It is recommended that lamp pins are cleaned with very fine sandpaper before insertion. A special hand tool for opening the collets is stowed on the side of the lampchanger, and is unscrewed for use during relamping. A cylindrical “sight gauge” is stowed in the same place, and is slipped over each lamp after insertion to check for correct positioning of the filament.

The silver plating on the collets has been replaced with a rhodium-plated surface to prevent “welding” of the tungsten lamp pins into the collets when the lamps were flashed.

VLC-152BR lampchanger

The optional VLC-152 BR lampchanger, available to special order, can include isolated monitoring contacts on an extended shaft. These lamp monitoring contacts can be fitted to turret positions 5 and 6 to give a closed contact indication for a remote monitoring system.

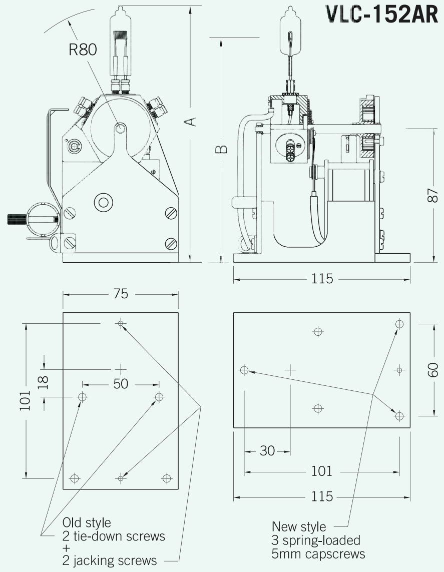
VLC-150



Lamp Type

Dim	M28	M32	M36
A	156	155	166
B	143	143	147

VLC-152AR



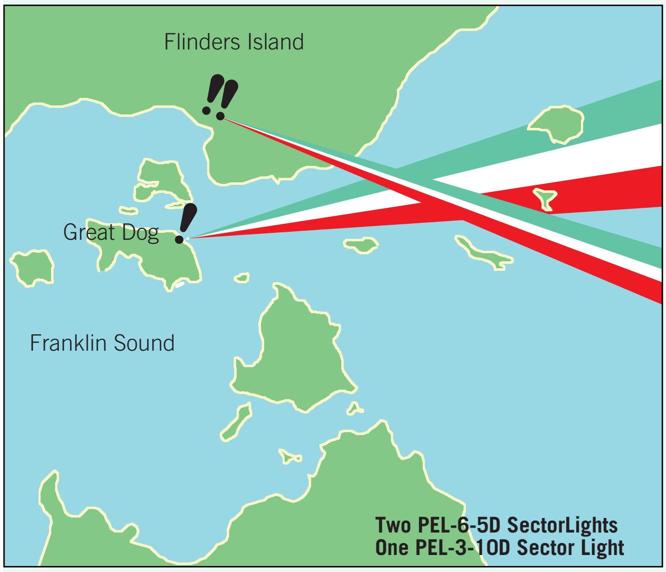
SINGLE PEL SECTOR LIGHT APPLICATIONS

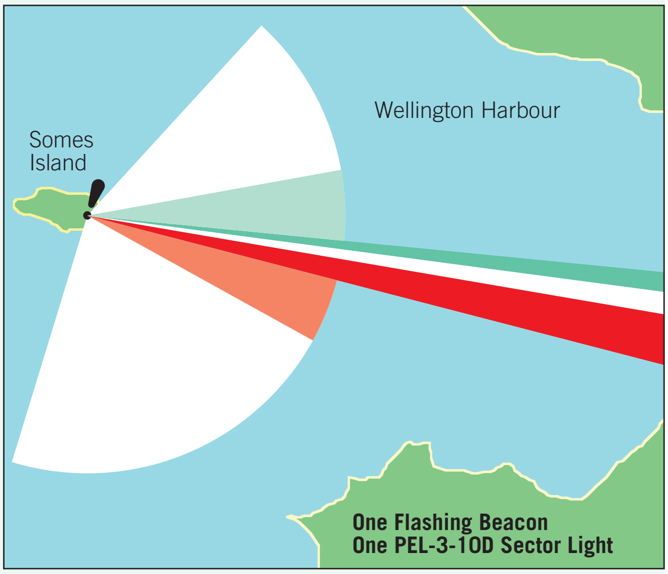
Mark a Leading Line

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 need not 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.

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. Both lights have CALC-2000 controllers and flash in sync.



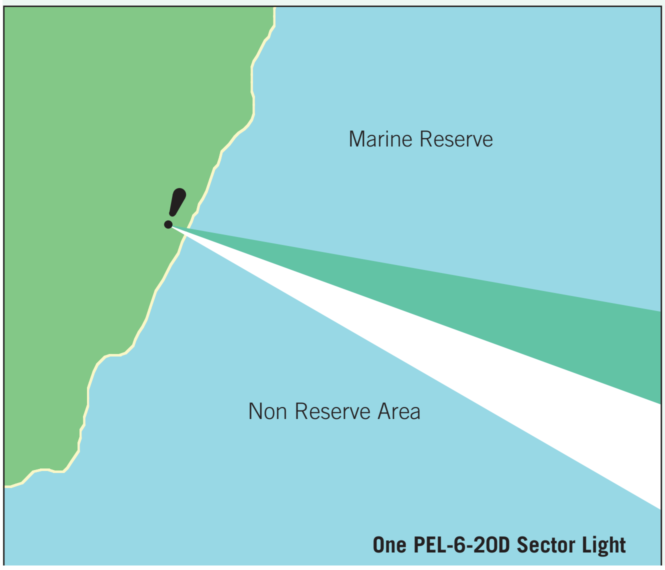


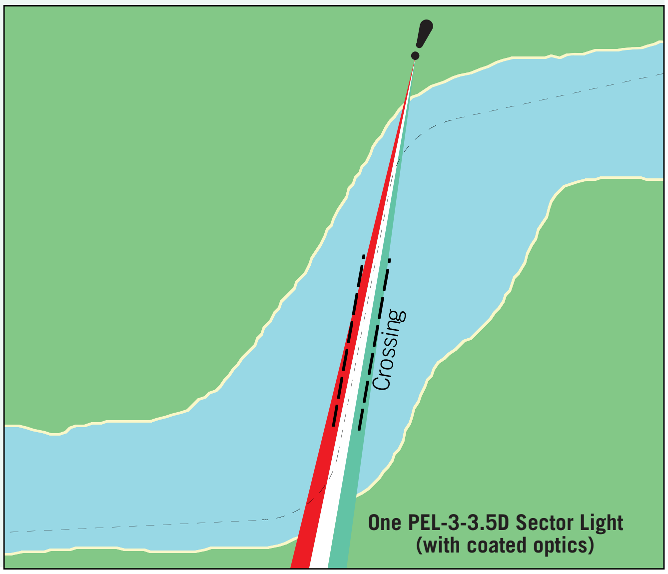
Mark a Fishing Zone or Marine Reserve

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-6 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. The on-period of 2 seconds is the minimum that can be used with the 250 Watt lamp to allow time for the lamp to achieve full brilliance.

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-3-3.5D light with automatic night dimming (and coated optics to extract maximum energy) provides day+night use over 1-2NM in several solar-powered installations.

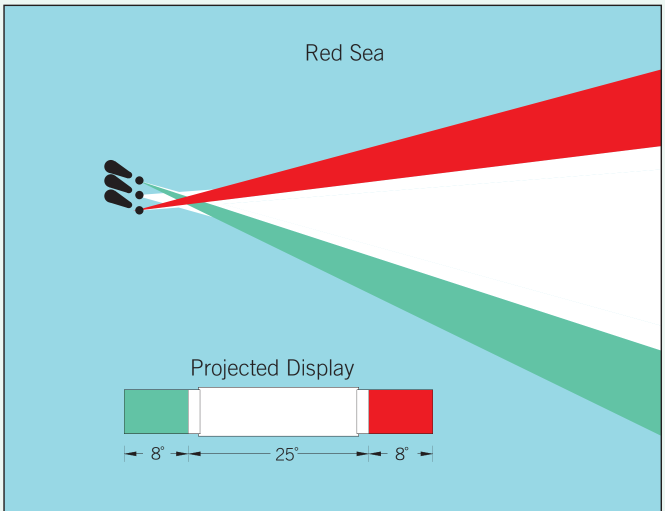




MULTIPLE PEL SECTOR LIGHT APPLICATIONS

Provide Extra Subtense (Red Sea)

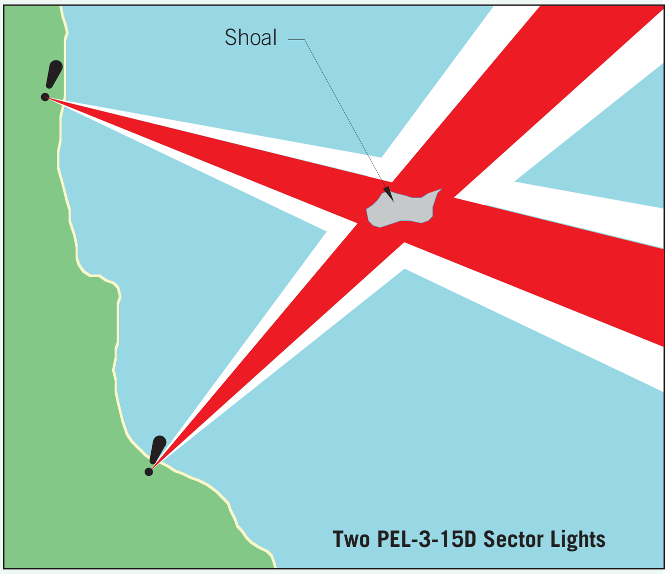
One PEL-6-20D light and two PEL-6 lights with 10.75° subtense are mounted on a single station and project a total subtense of 41°. An overlap of 0.25° between lights ensures the full sector is covered. A wider coverage is achieved than could be provided with a single light, and vertical divergence is less. The relationship between subtense, intensity and colour filter transmission is used to good effect – the intensity from the 10.75° lights (in coloured sectors) is about the same as the 20° light (in white sector).



One PEL-6-20D Sector Light
Two PEL-3-10.75D Sector Lights

Mark a Restricted Area

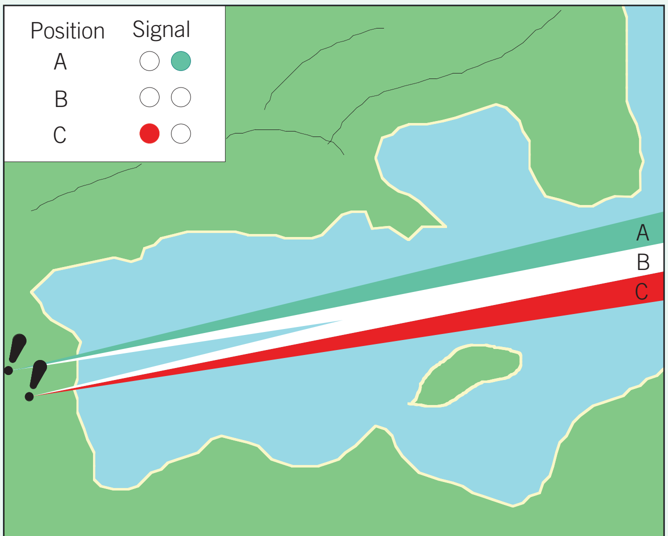
Two or more lights can be used to provide a fix over a restricted area. The lights are read as a pair (or group), and may also be flashed in sync to aid identification. The area defined by the lights may be quite irregular. Sectors can be any size and in any sequence, limited only by the total subtense 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.



Two PEL-3-15D Sector Lights

Mark a Parallel Channel

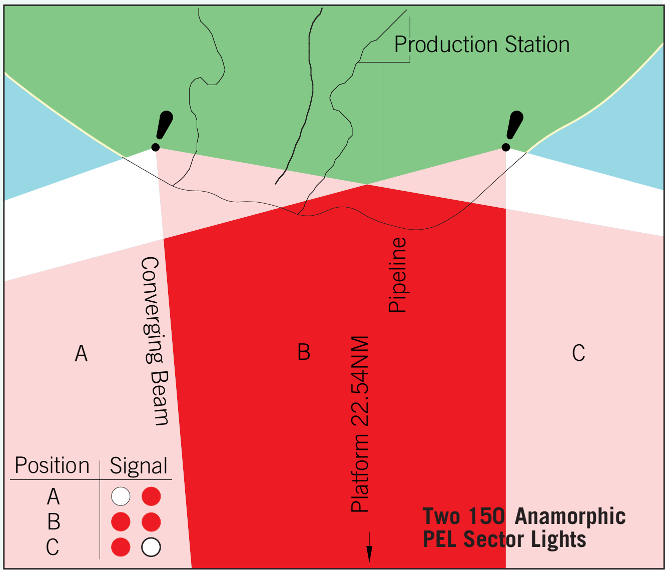
The channel can also be convergent or divergent, and the same lights used by a dredge. Each light has two sectors, and the lights are read as a pair, perhaps flashing in sync. An oscillating sector on the inside of each boundary is possible. This example is used when the taper shape of a single sector 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.



Two PEL-6-5D Sector Lights

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.



Two 150 Anamorphic PEL Sector Lights

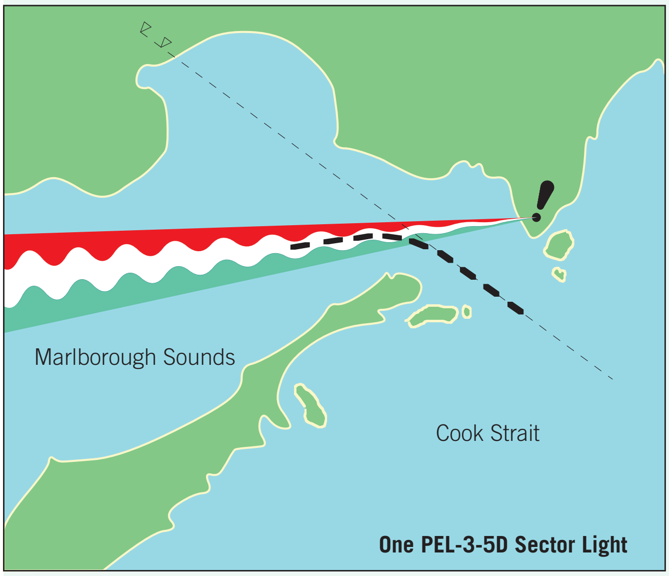
OSCILLATING BOUNDARY APPLICATIONS

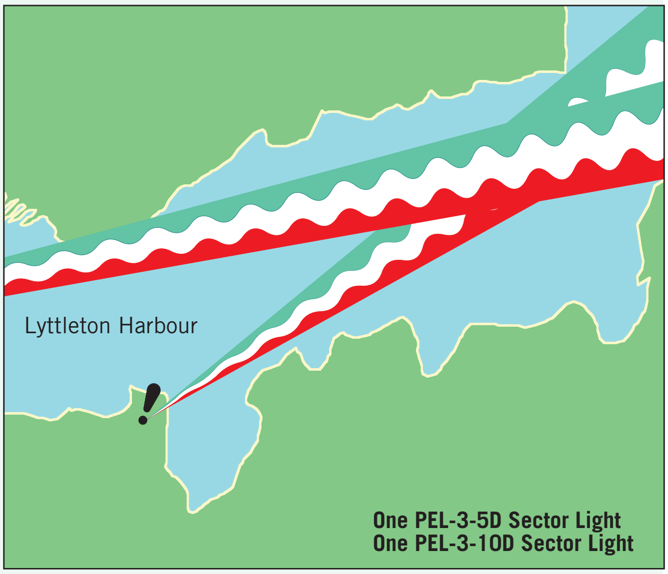
Mark a A Turning Track (Tory Channel, NZ)

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.

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.



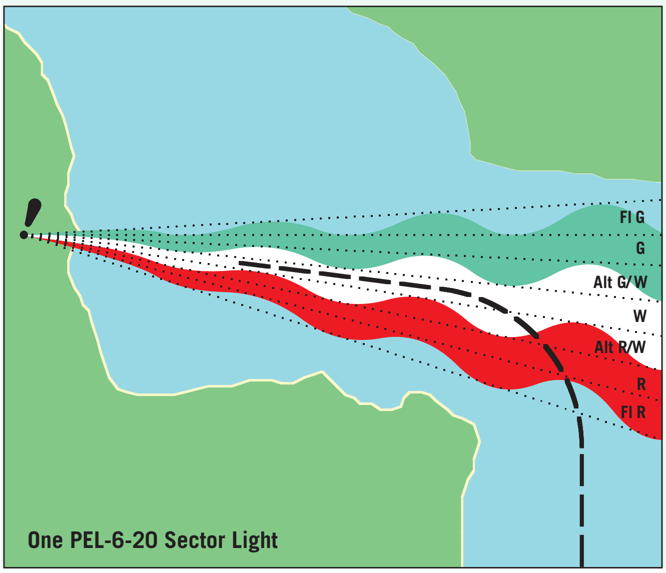


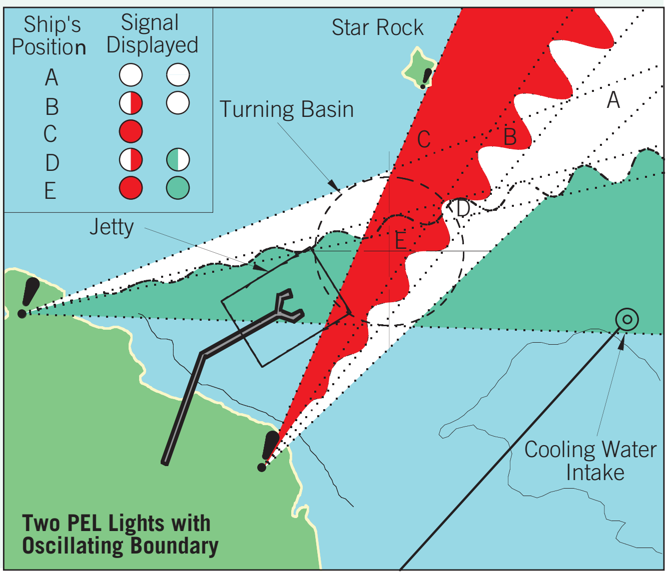
Difficult Turn Onto Narrow Track (all 7 sectors used)

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 half-way through the turn, the alternating red/white sector is next traversed, and final alignment is gradually achieved within the narrow white sector.

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.





Enfilacion de Bayona (42°7'N, 8°51'W) – *Bayona, Galicia, Spain,* Autoridad Portuaria de Vigo, *built 2007, PEL-3 5°*. Purpose built lighthouse especially for the Vega PEL light. Marks the entrance into Bayona a very pretty town with fantastic natural conditions for leisure boating and fishermen.

DISTRIBUTOR

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