10 LED navigation lights tested

Are LED tricolour lights as bright and easily seen at sea as traditional filament bulbs? And which is best? Read David Pugh's in-depth PBO test to find out

LED navigation lights caused a huge surge of interest when they were introduced to the marine leisure market 10 years ago, and the leaders of that surge were sailing boat owners. With power at a premium on board, the low current consumption and high reliability of the new technology is compelling.

One of the worst offenders for power consumption and reliability on board has always been the masthead tricolour. The COLREGs allow the use of this lamp as a special dispensation to reduce the current requirements when under sail (in place of port, starboard and stern lights), but even so it is an electrician's nightmare: a 25W bulb at the end of a long length of cable, exposed to a salty atmosphere just waiting to gnaw away vulnerable copper wire and connections. A good installation needs expensive, heavy cables to avoid voltage drop, and the filament lamp is prone to failure, demanding a fraught trip to the masthead. LEDs provide a reliable, low power alternative, but it's crucial that they provide the same or better visibility at sea as a traditional lamp.

Types of LED tricolour

Two solutions quickly developed to get LEDs to the top of the mast: custom-designed fittings, or white bulbs to replace the incandescent lamp. The latter option has the advantage of simplicity, but it quickly became clear that the cold light emitted by early white LEDs looked quite different through a filter intended for an incandescent lamp, owing to the high blue content of the light compared with the warm yellow glow of a filament. Some manufacturers solved this by making a tricolour bulb with green, white and red LEDs, while others chose to use the newer, 'warm' white LEDs. Cool white bulbs are still on the market, but only for use in anchor lights where no filters are used.

We brought together 10 LED lamps, both dedicated units and replacement bulbs, and put them through their paces in the lab and on the water to see how they fared against a traditional bulb.

The criteria

The COLREGs are extremely strict on how lights are specified. Reading through Annex 1, you soon become enmeshed in a host of colour gamuts and complex intensity calculations.

Some lights have been verified by third-party test labs, but for those which have not it is left to the boat owner to judge whether their lamp meets the specification. The problem is worst when you mix and match LED bulbs and filters designed for filament lamps, as you risk reducing the visibility of your navigation lights. Not only may the colour filters not be matched to the bulb, there is also an issue with the way these bulbs emit light. The Fresnel lenses used in incandescent fittings are designed for lamps with vertical filaments, which give a central, linear light source. Replacement LED bulbs space bright LEDs around a cylinder, making a wider emitter and upsetting the careful focusing of the lens.

The COLREGs are also clear on how sharp the transitions between sectors should be, with a maximum 3° overlap allowed between the red and green sectors, and a 5° overlap with the sternlight. Vertical sectors are also specified, with sailing boats required to show their lights at full intensity at up to 5° heel and to at least 50% intensity up to 25°.

How we tested them

On the water, two things are essential for a navigation light to fulfil its purpose of making a vessel visible at night: are the colours adequately clear, and is it bright enough to be easily seen?

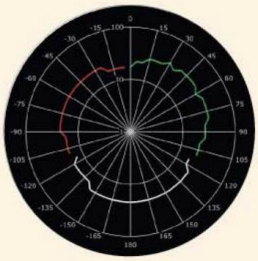
When carrying out the official tests on navigation lights to verify these points, laboratories use a highly expensive piece of equipment known as a goniophotometer. This device records colour and intensity over a 360° sweep around the light.

We attempted to replicate these tests in a series of experiments carried out in the controlled environment of a dark room, followed by a visit to Dorset's Studland Bay to verify the lights were all visible over the 2NM required by the COLREGs for boats over 12m (39ft 4in).

Light sector intensity

We set up each light on a rotating platform and measured the light intensity at a distance of 1m using an incident light meter designed for photographic use. By keeping the ISO (film speed) and F-stop (aperture) settings at constant values, we were able to measure the intensity of the lights relative to one another by reading the shutter speed from the meter.

It should be noted that as the meter was uncalibrated and had an unknown response to different colours across the spectrum, it is not possible to convert these figures into accurate intensity measurements. However, as all the lights were measured using the same meter and the same settings, the comparison between them is valid.

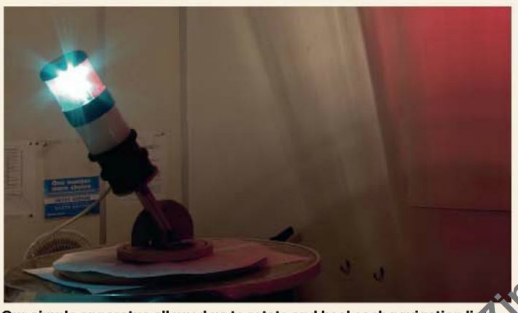


Brighter lights are closer to the edge of the intensity plot

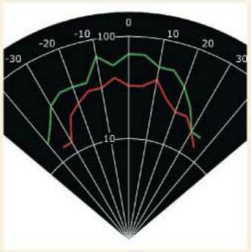
In the following product reviews, the circular plots for each light show our results. The red, green and white traces correspond to the allowed sectors (22.5° abaft the beam), with the intensity shown by how close the lines are to the outer perimeter of the graph. The intensity is plotted using a logarithmic scale to reflect the eye's response to light: for example, a light that measures an intensity of 100 is only twice as bright as one that measures an intensity of 10.

Heel intensity

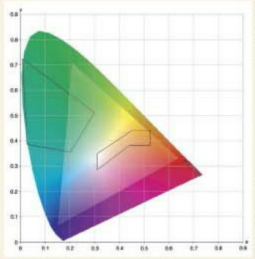
To measure heel we used the same method as described above, but with the light fixed so that the meter was viewing the light at 90°, as you would when abeam of a yacht. We measured the intensity in 5° increments at



Our simple apparatus allowed us to rotate and heel each navigation light



We measured the intensity of the red and green sectors at up to 40° heel. Lights should be visible to 25°



The allowed red, white and green gamuts and the Adobe colour space

up to 40° heel in both directions, and plotted the results on the fan-shaped graphs overleaf. Negative values are equivalent to port heel.

Showing colour

This is the hardest criterion to measure quantitatively, although a qualitative assessment by eye is remarkably accurate. The COLREGs specify the permitted colours for navigation lights as a series of gamuts, which are areas that can be plotted on the CIE (International Commission on Illumination) colour diagram.

The CIE diagram shows all the visible spectrum in the form of a tongue-shaped plot, with monochromatic colours from violet to red around the perimeter in what is called the spectrum locus. At the base of the graph are the purple shades made from mixing red and violet, while at the centre of the plot is the white point, showing the way a colour shades from monochromatic to white as it becomes less saturated. Any visible colour can then be plotted with simple *x,y* co-ordinates.

The allowed gamuts for red, white and green are shown on the diagram above. The lighter triangle in the centre is the Adobe RGB colour space, which is the range of colours that can be shown by most cameras and computers. As you can see, the red and green gamuts lie totally or partially outside this area, so any colours printed in this article are approximations to what is seen by the eye in reality.

Measuring colour

This inability of standard equipment to 'see' colours across the whole visible spectrum makes measuring colour difficult – our initial idea was to calibrate a camera to measure red, green and blue values which could in turn be converted to the *x,y* co-ordinates we needed, but the limitations of Adobe RGB and its alternative, sRGB, made this impossible. Instead we chose to measure the monochromatic component of the light, which would give us a point to plot on the spectrum locus.

Measuring colour saturation was beyond the scope of our simple equipment, but by drawing a line between the monochromatic colour and the central white point we could see whether the colour was in the right area of the spectrum by whether the line passed through the correct gamut.

We measured the wavelength of the monochromatic light using a simple experiment most people will have tried at school. By viewing the light through a 300 line/mm diffraction grating, we measured by how much the brightest colour was diffracted at a distance of 1m from the grating. As several peaks (maxima) were visible, we measured the first three. The wavelength is then the sine of the diffracted angle multiplied by the line spacing of the grating, divided by the number of the maximum measured. Of the three readings, we chose the median to avoid spurious results.

To measure white, we used the RGB values given by a camera working in the Adobe RGB colour space, calibrated using an 18 percent grey card to set the colour balance correctly. The measured white is shown as the heavy black dot in the centre of each plot.

Other measurements

Apart from these three main measurements, we also examined the colour cut-offs of each lamp by eye and took pictures. Examples are shown on the following product review pages, with the colour balanced using a grey card.

We also set up the lights one at a time at a distance of two miles across the water as a basic check for intensity, All of them passed the test when upright and were still visible at the required 25° heel. The results are in the table below.

HEEL AND CURRENT

Light	Current (Amps)	Max heel (°)
Aqua Signal Series 40	2.15	40
Aqua Signal Series 32	0.27	45
Bebi Masina Malosi	0.08	25
Bebi Masina Malosi Vevela	0.08	25
Blue Water Lights	0.20	25
LED tricolour replacement	0.18	40
Lopolight LED tricolour	0.22	25
Nasa Marine Supernova	0.10	30
Orca Green tricolour	0.45	25
Plastimo LED tricolour	0.22	60
UTRI4 LED white bulb	0.20	45

A typical diffraction pattern from a red LED navigation light

THE BENCHMARK

Aqua Signal Series 40 (Quickfit)

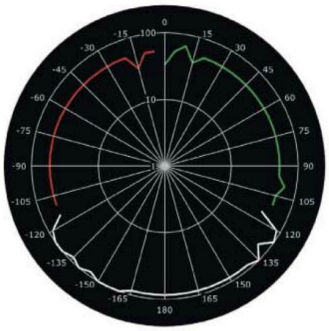
PRICE: £77.98 (tri), £124.62 (tri/anchor)

www.cquip.com; Marine Lighting 0121 770 8522

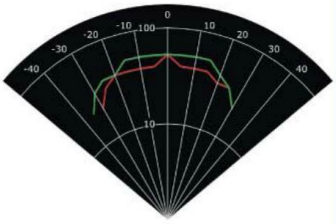
This traditional filament lamp and lens was included as a benchmark to see how closely it matched the requirements set by the COLREGs for colour, heel and intensity.

Our results show that that the lamp performs well across all the categories tested, with the colour lines passing straight through the centres of the allowed gamuts. The intensity was also the best tested overall, especially for white light, and the heel tests showed fairly constant intensity to around 15° heel, with the light cutting off at between 30° and 40°.

As expected, the biggest problem for this lamp was its high current demand at 2.15A.



Intensity



Heel

The sector cut-offs and colour tones were clear

Colour

Aqua Signal Series 32 (Quickfit)

PRICE: £206.33 (tri), £317.20 (tri/anchor)

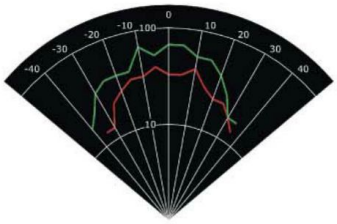
www.cquip.com; Marine Lighting 0121 770 8522

Aquasignal's LED tricolour is a natural choice for those looking for a simple replacement for an existing Aquasignal filament fitting, as it plugs directly onto their Quickfit base.

PBO BEST ON TEST

Its performance was comparable to that of the filament lamp, with colours well within gamut and green erring towards the 'greener' part of the spectrum. Light is provided by single LEDs housed in prisms, which gave bright, even illumination. The lamp showed good heeling performance to around 20° and visibility to over 40°, and the unit itself is neat, compact and well built.

Intensity



Heel

Sharp cut-offs and intense colour characterise this light

Colour

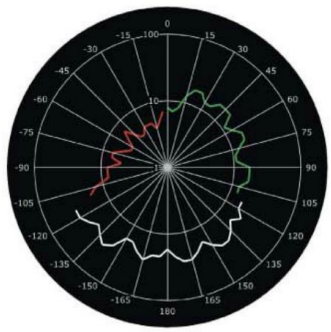
Bebi Masina Malosi

PRICE: US$58.50

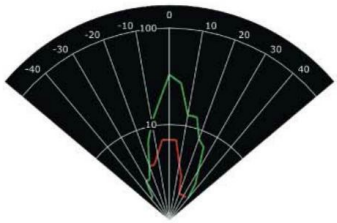
www.bebi-electronics.com

Unlike the other LED 'bulbs' tested, which fit a standard Bay15D bayonet holder, the Fijian-made Masina Malosi lights are fastened inside the fitting with cable ties. This version uses conventional 'cold' white LEDs, which give a bluish-tinged light.

Combined with the green filter, this bluish tinge was accentuated to make this the only bulb whose output fell clearly outside the green gamut. Performance was within gamut for red and white, but the intensity was low, particularly for red light. This would be expected from a blue-tinged bulb, as it lacks the warmer hues. Heel was disappointing, cutting off at 25°.



Intensity



Heel

The 'green' light looked blue to the naked eye

Colour

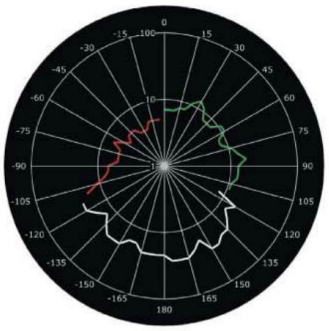
Bebi Masina Malosi Vevela

PRICE: US$58.50

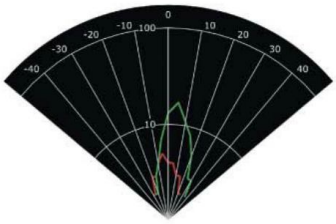
www.bebi-electronics.com

This was the only white light tested to use 'warm' LEDs, and was introduced to remedy the problem with the green sector found with the Masina Malosi light. The solution works and brings the colour back within gamut, but unfortunately the LEDs are of lower intensity than their cool-toned counterparts.

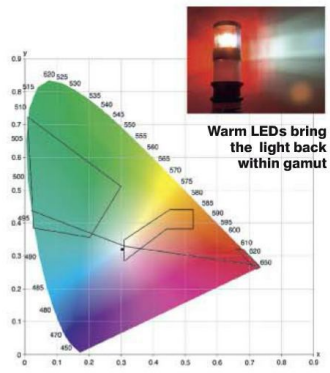
When heeled performance was similar to the cool version of the bulb, although with generally lower intensity. As the light heeled the intensity dropped rapidly to cut off at 25°, perhaps owing to the wide diameter of the 30-LED cylindrical bulb not matching the Fresnel lens of the Aquasignal fitting.



Intensity



Heel



Colour

Warm LEDs bring the light back within gamut

Blue Water tri/anchor

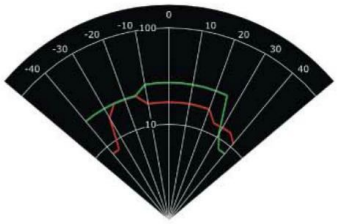
PRICE: £318.64 (tri), £437.82 (tri/anchor)

www.cquip.com

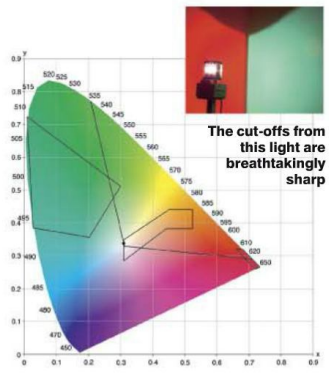
This well-made unit was one of the smartest-looking on test. The red and green sectors are each lit with single ultra-bright LEDs, with two LEDs in the white sector. A circle of white LEDs at the top allow it to double as an anchor light.

The Blue Water wasn't the brightest light tested, but showed consistent illumination all round with excellent, sharp cut-offs between the sectors. When heeled it was equally consistent, reaching the required 25° heel at nearly 100 percent brightness, although beyond this point the light was sharply cut off by the top of the unit. Our colour test showed all the colours to be within gamut.

Intensity



Heel



Colour

The cut-offs from this light are breathtakingly sharp

LED tricolour replacement

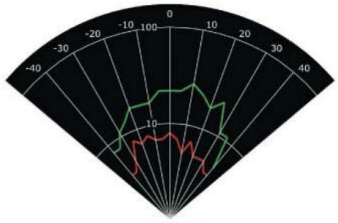
PRICE: £45.60

www.ecs-marine-equipment.co.uk

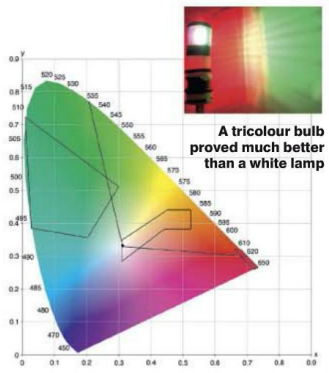
This bulb aims to overcome the problem of mismatched filters by using red, green and white LEDs in their respective sectors. To align the bulb a replacement bulb holder is provided which can be angled to align the sectors.

Overall this solution worked well for our test. The most obvious result is how the green moves right away from the blue spectrum to almost miss the greenest edge of the allowed gamut. Red and white were both acceptable, and the intensity, although a little low, was fairly consistent between colours and at different angles. Heel performance was good, reaching 25° before noticeable intensity roll-off.

Intensity



Heel



Colour

A tricolour bulb proved much better than a white lamp

Lopolight LED tricolour

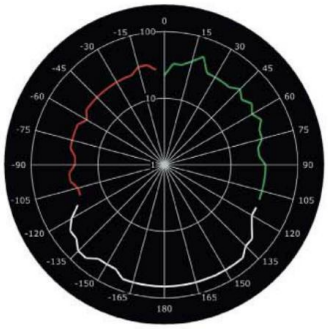
PRICE: £294.08 (tri), £354.22 (tri/anchor)

www.improducts.co.uk

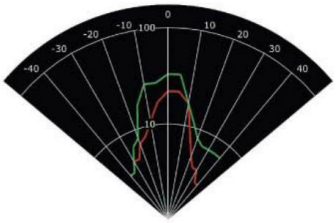
Lopolight's sleek designs have won favour with many boat owners. The unit we tested has 86 ultra-bright LEDs carefully arrayed around the edge to ensure even light output.

Our measurements showed all three colours to be within gamut, while the intensity graph gives even values for red and green and a brighter stern sector. Heel results showed the intensity dropping rapidly as the light heeled.

The light we tested was from Lopolight's range for yachts up to 12m, requiring visibility to 1NM, but we found the colours clearly visible at 2NM. The 12-20m lights cost £354.22 for a tricolour and £530.23 for a combined lantern.



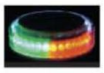
Intensity



Heel

The carefully chosen LED array gives clear cut-offs between sectors

Colour



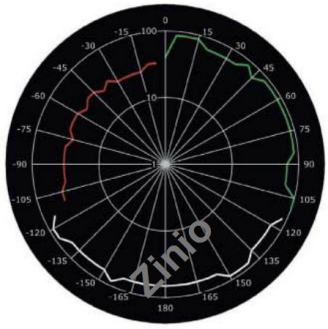
Nasa Marine Supernova

PRICE: £49.50

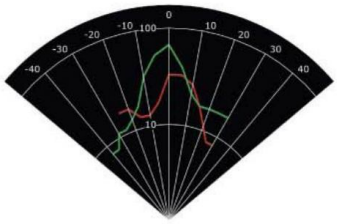
www.nasamarine.com

Nasa's LED tricolour uses a single line of ultra-bright LEDs arrayed around a wide, flat fitting. A short post below the unit is provided for attachment and to raise it sufficiently to avoid the mast cap obscuring the light when heeled.

Colour representation was good for all three colours, and the sectors were surprisingly clear despite a lack of masks or lenses. Intensity was also good – this was the only LED unit to produce readings which matched that of the incandescent fitting at any point. However, the intensity of the red was lower than the other colours, and intensity roll-off was rapid when heeled, perhaps due to the single line of LEDs.



Intensity



Heel

The cut-offs proved surprisingly sharp

Colour

Orca Green tri/anchor

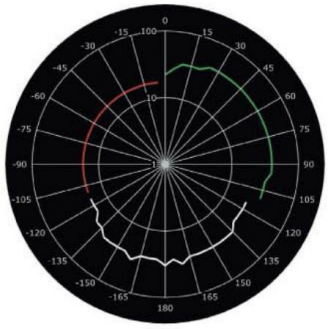
PRICE: US$389

www.orcagreen.com

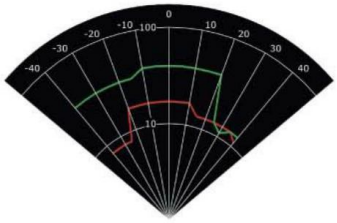
This smart unit uses single, ultra-bright LEDs in each sector, with additional white LEDs in the red and green sectors to allow it to double as an anchor light.

The colour representation was among the best on test, producing similar results to the incandescent lamp. Intensity was consistent across all angles, if lower than some, with excellent cut-offs between the sectors. When heeled the lamp performed well, although as the graph shows we did find that the top of the lamp cut the light sharply at over 20° heel.

Some users have reported VHF interference, but Orca are currently resolving this issue.



Intensity



Heel

The Orca showed exceptionally sharp cut-offs between sectors

Colour

Plastimo LED tricolour

PRICE: £199.99 (tri), £269.99 (tri/anchor)

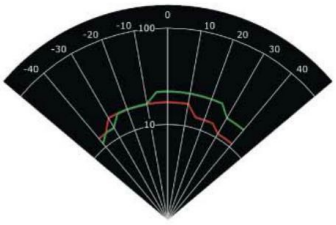
www.plastimo.com/uk

Plastimo's tricolour is similar to the Nasa in using a single, flat array of LEDs, but is a smaller unit with 18 LEDs to the Nasa's 32. The whole circuit is encapsulated in clear resin.

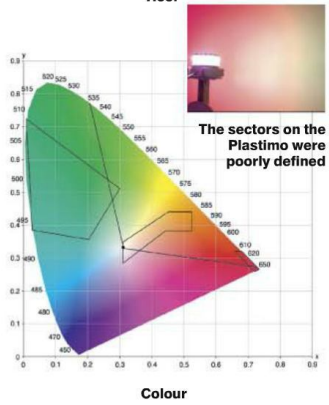
The colours were within gamut, with green erring towards the greenest end of the spectrum, and the intensity was consistent at all angles. Likewise, heel performance was good, among the best tested, with a gentle roll-off at 25° and remaining visible to an impressive 60° on our on-water test.

However, the cut-offs between the sectors were vague, with significant colour mixing, perhaps owing to the resin capsule.

Intensity



Heel



Colour

The sectors on the Plastimo were poorly defined

UTRI4 LED white bulb

PRICE: £24.46

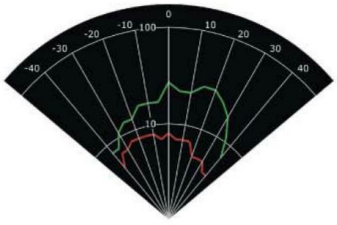
www.ultraleds.co.uk

When white LED bulbs first came on the market they were sold as direct replacements for filament lamps. We decided to test a white bulb in Aquasignal's standard fitting to see whether direct replacement is a viable option. This bulb is not deliberately sold for use in a tricolour.

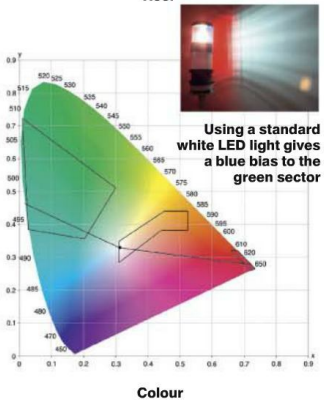
As expected, the cold LEDs shining through the green filter gave the light a blue bias, but it remained within gamut, as did the red and white lights. Heel performance was good, but the intensity was low, particularly for red light.

Ultra Leds have recently released a warm white bulb which would improve the colours seen through the lens.

Intensity



Heel



Colour

Using a standard white LED light gives a blue bias to the green sector

PBO'S VERDICT

One of the most reassuring aspects of this test was that all the lights are visible at a range of two miles, meeting the requirements set by the COLREGs for vessels over 12m and exceeding them for smaller vessels, which only require one mile for the red and green sectors.

Excepting the cool white Masina Malosi light, all of them also met the colour requirements in so far as we could assess.

Bulb or dedicated fitting?

One of the questions we hoped to answer was whether it is enough just to buy an LED bulb for your existing tricolour, or if the expense of a dedicated unit is a necessary investment.

Our experiments showed that the white replacement LED bulbs, including those using 'warm' white LEDS, all displayed a much bluer light than any of the other units. This colour bias also impacted the visibility of the red sector, which although of the right colour was of low intensity. The unfiltered white sternlight was unaffected and easily visible.

The colour problem is partly solved by using a tricolour bulb such as that from ECS, but on our test the intensity was still low. This may be due to the second stage of filtering the red and green light has to pass through. A white lens would solve this problem, but an anchor light lens is unsuitable as it is too diffuse and has no cut-offs built in for the sectors.

The other issue is the way the lenses are designed – a cylindrical array of LEDs is never going to perform at its optimum in a lens designed for a single bright filament.

Which should you choose?

Legislation for LED navigation lights is still in its infancy. The MCA insist that commercial vessels are fitted with MCA-approved lights, but say leisure sailors must 'satisfy themselves' that their lights meet the COLREGs. Insurers take a similar stance and could refuse to pay if an incident proves to be due to inadequate lights. However, Pantaenius say that the new ISO standard being developed for navigation lights (ISO 16180) will resolve this in future.

In the meantime, some manufacturers opt to have third-party lab tests carried out on their products to prove they meet the COLREGs. This is essential for sale in some countries: for example, lights shown on any German-flagged vessel must be approved by the Bundesamt für Seeschiffahrt und Hydrographie (BSH). In our test, the Aqua Signal and Lopolight units are approved by one or more European bodies including the MCA, the Blue Water Lights tricolour is approved by the BSH and the Orca lamp is approved by the US Coast Guard.

At present then, the decision relies on a mixture of personal preference and price, but if you're serious about matching the potential performance of the incandescent fitting you're replacing, it makes sense to spend the extra and choose a dedicated fitting. Of those we tested, the Aqua Signal proved the best all-rounder and is competitively priced, although we were impressed by the brightness of the Nasa and the consistency at moderate heel angles of the Orca and Blue Water units.