LED Lighting – A "HOT" Topic for Ships

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It is nearly impossible to enter a home improvement, department or general merchandise store without bumping into an array of options for household lighting using Light Emitting Diode (LED) technology. Why not, with the promise lifetime operation with greatly reduced consumption of electricity? Price per bulb is still a factor but that is dropping quickly so a investment cost versus operation cost review is becoming more favorable. Increasing, the light spectrum from LED sources is becoming very close to natural light, providing higher quality lighting.

Can't Stand the Heat? Wasted heat from lighting puts additional demands on the power grid. The heat by-product from many lighting technologies causes added air conditioning demands and other heat removal methods, especially in confined spaces. LED technologies operating with greater efficiency help reduce the heat production, not only reducing direct electricity demand but also reducing the electrical demand associated with the added heat load. LEDs typically use 75% less energy than an equivalent incandescent (incandescent lighting release about 90% of their energy as heat, for compact fluorescent lights it's about 80%).One could go on and on about the benefits but core to this article is how adoption of this technology affects military ships. For many years, general lighting has been traditionally provided by fluorescent fixtures. The conversion from the traditional T8 and T12 styles requires a change in fixture or fitting the existing fixture with LED-based tubes.

Let's consider some things that have generated a lot of interest in lighting conversion to LED technology.

- Reducing heat load (more efficient operation reduces heat loads)
- Reducing electrical consumption and fuel use to generate the electricity
- Spare parts (longevity allows for fewer spare parts being required, less space, less weight, less loading/unloading, less activity in changing lights)
- Weight (LED tubes are significantly lighter)
- Retention of used tubes (mercury content of fluorescent tubes often meant keeping the used item until return from deployment for recycling. Recycling LED tubes may be accomplished but without the concern about hazardous materials)
- LED lights are "solid state" devices and are less susceptible to the breakage of their gaseous cousins

There are estimates that the conversion on a large ship can remove 90,000 lbs (45 tons, or the weight of about three F-18s) from the ship's physical load.

The US Navy has implemented a program to support the conversion and about every distributor of LED lighting considered bidding. Many soon encountered that the Navy had an established a qualification program to ensure reliability in the harsh shipboard

environment. A couple of primary options were apparent: either build a complete fixture with embedded technology to replace existing fixtures or build LED tubes that fit the existing fixtures.

New fixtures seemed to be the obvious choice – get rid of the weight – which meant that lighter housings, no heavy ballast and using lightweight LED strips, presented the greatest benefit. One downside exists: an LED means replacing the complete fixture, unless the LED array allowed exchange at the array level. Also, the initial cost for complete upgrade could be a bit higher.

Building LED tubes that fit existing fixtures has generated a large interest because of the ease in conversion and continuing maintenance, ie., dealing with a disposable component instead of replacing a fixture. Most tube technologies call for bypassing the ballast in a text fixture. Note that tube recovery and rework with a new LED strip allows for a reduction of waste and separation of parts and supports recycling of most of the plastic materials. These are important environmental considerations, especially when on extended deployment.)

Standard For Lighting MIL-DTL-16377J Once the qualification requirements were understood, many suppliers realized that, as distributors, controlling manufacturing quality adequately to meet the obligations was too difficult and several dropped out of the bidding. MIL-DTL-16377J (SH) (with Supplement 1 and Notice 1) issued June 2014 provides the detail specification for lighting fixtures and associated parts. Supporting this specification standard, many (slant or /) standards dealing with specific lighting applications were in existence and many needed updates to include this technology (solid state lighting (SSL) as part of the options. This topic is quite broad, so we will focus this discussion to MIL-DTL-16377/86A(SH), which addresses vital lighting by replacing fluorescent tubes.

The /86A standard (Feb 2015 is current) has been updated recently to resolve questions and clarify many of the evaluation requirements. I suspect that more updates are to follow to allow alternate methods to demonstrate acceptability. Three variants of tubes are listed in the /86A standard (12 & 35W, 1.5 & 1 inch diameter, 24”& $45^{7}/_{8}$” lengths).

The standard provides a table of first article test and inspection requirements that apply to the tube to confirm acceptability. I like to categorize the list to organize the general nature of the test and evaluation program and report content, as indicated in the table below. The table identifies the particular requirement paragraphs of MIL-DTL-16377J and there you may encounter reference to other standards. There are a few critical details the may be overlooked, in our experience with these programs indicates.

Category	*Test/Evaluation*	*Notes*[1]
Functional/operational	Examination, operation, fail-safe, flammability & smoke, battery discharge	UL flammability is not equivalent
Mechanical	Dielectric withstand (2), insulation resistance (2), shock, vibration, Noise, Continuty of grounding, Magnetic permeability	Test sequence is specified
Photometrics	Photometrics, brightness, chromaticity, CCT, Lumen maintenance, optical uniformity, emergency light output,	Lighting performance
Electromagnetic Compatibility	Electromagnetic Interference (EMI) (MIL-STD-461)	Emissions only
Power Quality	Power interface, power quality (MIL-STD-1399 S300B); voltage spike	

1. Additional note information is part of discussion

Fixture Test fixture symbol 333.1 with three LED lamps is required for many of the tests providing the mounting structure and operation for the tubes. A couple of tests require a symbol 77.4EM (New Emergency Automatic Lighting System, or NEALS) to provide for emergency power operation evaluation and battery discharge testing. Sometimes these fixtures are difficult to obtain; they may be furnished to the supplier/bidder if part of a contract. The test manager may need to consider that these fixtures may have a test history that influences your outcome, for example, battery discharge may be an issue wherein the secondary batteries may have seen undergone many charge/discharge cycles. The charge may appear fine, but the battery capacity has faded, requiring a battery analyzer to confirm the health of the battery system. The testing calls for using a test item with the ballast bypassed (so noted in the /86A has modification instructions). Be sure that the fixture you obtain has this provision (remember if this is government furnished equipment, or GFE, then a modification authorization is necessary).

A test sequence is called out for specific mechanical tests to confirm that the fixture's history has not impaired safety-related isolation. This demands that the tests are accomplished on the same test article and, if there is a failure, the entire sequence be repeated after resolution.

Flammability Many consider that use of UL-approved plastics with a high-level flammability rating will support that approval; this may not be 'automatic.' The standard, however, calls out compliance with ASTM D635 and D2843. The standard (16377J) identifies the particulars on test samples. So, if you are unable to get the specific sample pieces, you will have difficulty getting this done.

Lumen maintenance, which is essentially a lifetime performance evaluation, can be a very lengthy test and it requires a certain level of individual LED element qualification. There is activity in the standards-review process to reduce some of the very lengthy test time but has not been officially released.

Speaking of a lengthy test – you should expect about 100-days to work through the process. This can be helped if multiple test items are available to do parallel testing, but some things just take time. Finishing a complete qualification program under about 85-days would require that the lumen maintenance process change be adopted but even with that, 30 days or so should be planned.

Also, it is critical to tightly coordinate the activity: the government approval of the test procedure, provide for witness by the approving authority and the report approval process is fairly long. If you are expecting to get everything done from start of procedure preparation to report approval in less than 6 months – your expectations may be dashed.

As noted in this discussion, and this breaks the surface just a bit, there may be many elements to consider in a complex test and evaluation program. The key is preparation of a thorough test procedure that give the details. However, the manufacturer must surely play their part. Obligations to provide the samples, components and information must be understood, lest the process encounter costly delays and potential test program cost-overruns. Hopefully, this brief piece sheds a little light on the subject.

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