OCEAN ENGINEERING DIVISION
UNITED STATES COAST GUARD
WASHINGTON D.C.

SPECIFICATION FOR SELF-CONTAINED, LIGHT EMITTING DIODE (LED) BUOY LANTERN

SPECIFICATION G-SEC-502
CHANGE 4

Please make the following changes to the specification:

Add to paragraph 1.1.7 (after Group Flash):

- Morse Code—Mo( ); a light in which appearances of light of two clearly different durations (dots and dashes) are grouped to represent a character or characters in the Morse code;

- Isophase—Iso( ); A light of which all durations of light and darkness are equal;

Replace paragraph 3.2.2 with the following:

3.2.2 Flash characteristic control system. Each lantern shall be capable of producing all standard U.S. Coast Guard characteristics, as outlined below, and shall include control circuitry to permit field selection of any desired characteristic. The controls needed to set or change the characteristic shall be incorporated into the lantern or accessed by an infrared (IR) remote control (TV remote). The various characteristics which the lantern must be capable of displaying are:

Characteristic		Timing ON/OFF (seconds)	Duty Cycle (%)
Fl:	F1 2.5 (0.3)	0.3/2.2	12
	F1 4 (0.4)	0.4/3.6	10
	F1 6 (0.6)	0.6/5.4	10
Fl():	FI (2+1)6	0.3/0.4/0.3/1.2/0.3/3.5	15
	Fl (2)5	0.4/0.6/0.4/3.6	16
	Fl (2)6	1.0/1.0/1.0/3.0	33
Q:	Q	0.3/0.7	30
Morse Code:	Mo(A)	0.4/0.6/0.4/3.6	30
ISO:	ISO 6	3.0/3.0	50
F:	F	Fixed	100

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12 August 2008
Date

OCEAN ENGINEERING DIVISION
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SPECIFICATION FOR
SELF-CONTAINED,
LIGHT EMITTING DIODE (LED)
BUOY LANTERN

SPECIFICATION G-SEC-502
CHANGE 3

Please make the following changes to the specification:

Replace paragraph 4.4.7 with the following:

4.4.7 Electromagnetic interference. The lanterns shall be tested for electromagnetic radiation immunity in accordance with either EN 61000-4-3 or RTCA/DO-160D. The tested frequency range shall be 100 MHz to 12 GHz. If testing is performed in accordance with EN 61000-4-3 then the test field strength and modulation shall be as follows:

Frequency	Test Field Strength*	Modulation
100 MHz to 1 GHz	10 V/m	80% amplitude modulation @ 1 kHz
1 GHz to 12 GHz	200 V/m	none

*The test field strength is the RMS field strength of the unmodulated signal.

If testing is performed in accordance with RTCA/DO-160D then the tested frequency range, field strength and modulation shall be per RTCA/DO-160D Category Y, except that the field strength shall be reduced to 20 V/m from 100 MHz to1 GHz and testing need not be conducted above 12 GHz.

Throughout the test the lanterns shall be energized, set to a Quick Flash characteristic, and the lantern's operation shall be monitored. The failure of the lantern to operate normally or display the proper characteristic shall constitute failure of this test.

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*8 August 2005*_________
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OCEAN ENGINEERING DIVISION
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SPECIFICATION FOR
SELF-CONTAINED,
LIGHT EMITTING DIODE (LED)
BUOY LANTERN

SPECIFICATION G-SEC-502
CHANGE 2

Please make the following changes to the specification:

Replace the text of paragraph 3.6.1 with the following:

3.6.1 External dimensions. The desired overall height of the lantern (including adapter plate if applicable – see section 3.7.3) and including bird deterrents should not exceed the value shown under “Max Height” in the following table. The maximum horizontal distance from the lantern’s vertical centerline to the outer edge of the lantern, at all heights, shall not exceed the value shown under “Max Radius” in the table.

Add section 3.8 to the specification (next page).

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3.8 DESIRABLE FEATURES

Desirable Features. This section describes some features that exceed the minimum requirements. The desirable features have been grouped into three categories based on their relative importance. Category I features are the most important, followed by Category II and Category III.

Category I - Desirable Features

1. Vertical divergence (reference Section 3.1.4). Favorable consideration will be given to lanterns with a total vertical divergence greater than 7° (to 50% max intensity).

2. Battery (reference Section 3.3.4). Favorable consideration will be given to the use of a high-quality battery.

Category II - Desirable Features

1. Adjustable intensity (reference Section 3.1.3). Favorable consideration will be given to lanterns with adjustable intensities, both above and below 40-cd effective intensity for a FL 4 and above and below 60-cd for a fixed characteristic.

2. Solar Power System (reference Section 3.3.1.3.2). For lanterns with the large power system (the SC LED 103 G and 103 R lanterns), favorable consideration will be given to lanterns with an E_{in} / E_{out} ratio greater than 1 for a lantern with a 30% duty cycle, operating in Portland, ME and calculating E_{in} and E_{out} as described in Section 3.3.2 of the specification.

3. Autonomy (reference Sections 3.3.1.1.1, 3.3.1.2.1, and 3.3.1.3.1). Favorable consideration will be given to lanterns with an autonomy greater than 18 days under the conditions described in these Sections.

4. Mass (reference Section 3.6.3). Favorable consideration will be given to lanterns with mass less than the maximum values listed in Section 3.6.3.

5. Service life (reference Section 3.4.1). Favorable consideration will be given to lanterns with a service life, based on producing a characteristic with a 30% duty cycle, of greater than 6 years.

Category III - Desirable Features

1. Signal colors (reference Section 3.1.8). Favorable consideration will be given to lanterns with chromaticity coordinates within the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) preferred region.

2. Intensity (reference Section 3.1.3). For lanterns that do not have an adjustable intensity, favorable consideration will be given to lanterns with an effective intensity greater than 40-cd for a FL 4 and 60-cd for a fixed characteristic.

3. Flash characteristic control system (reference Section 3.2.2). Favorable consideration will be given to lanterns that have more flash characteristics than listed in Section 3.2.2.

OCEAN ENGINEERING DIVISION
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SPECIFICATION FOR
SELF-CONTAINED,
LIGHT EMITTING DIODE (LED)
BUOY LANTERN

SPECIFICATION G-SEC-502
CHANGE 1

Please make the following changes to the specification:

Replace paragraph 4.4.7 with the following:

4.4.7 Electromagnetic interference. The lanterns shall be tested for electromagnetic radiation immunity in accordance EN 61000-4-3. The tested frequency range shall be 100 MHz to 12 GHz. The test field strength and modulation shall be as follows:

Frequency	Test Field Strength*	Modulation
100 MHz to 1 GHz	10 V/m	80% amplitude modulation @ 1 kHz
1 GHz to 12 GHz	200 V/m	none

*The test field strength is the field strength of the unmodulated signal.

Throughout the test the lanterns shall be energized, set to a Quick Flash characteristic, and the lantern's operation shall be monitored. The failure of the lantern to operate normally or display the proper characteristic shall constitute failure of this test.

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15 June 2005

Date

Please direct any questions regarding this specification to:
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UNITED STATES COAST GUARD

OCEAN ENGINEERING DIVISION

WASHINGTON, DC

MARCH 2005

SPECIFICATION 502

FOR PRODUCTION OF A

SELF-CONTAINED, LIGHT EMITTING DIODE (LED) BUOY LANTERN

1. GENERAL. This specification describes requirements for the development and production of a family of self-contained (SC), light emitting diode (LED) buoy lanterns, to be used on aids-to-navigation buoys in the coastal waters of the United States.

1.1 Definitions.

1.1.1 Buoy lantern: A buoy lantern is a lighted beacon placed on a buoy and used as a maritime aid to navigation. It provides an omnidirectional light signal, red or green in color, visible to the mariner at a nominal range of 3 to 6 nautical miles (nm). Most existing lanterns have a fresnel lens and use 12-volt incandescent lamps.

1.1.2 Self-contained lantern: A self-contained lantern is a lantern that integrates into a single package all components necessary to independently power and operate the lantern over an extended period of time. A self-contained lantern integrates all components into a single, cohesive package (it's not merely a collection of parts bolted together). When installed on a buoy, a self-contained lantern does not need to be connected to any other equipment. Some of the components that comprise a self-contained LED lantern are LEDs, electronic power/timer controllers, solar power generation and energy storage devices (i.e. solar panels and batteries), and a housing which incorporates light lensing.

1.1.3 Optic Head: The lantern's optic head consists of the LEDs, the housing which incorporates the necessary lensing to control the vertical light distribution, the electronic power/timer controllers, and all other equipment needed to produce the light signal given power from the battery.

1.1.4 Solar Power System: The solar power system is comprised of solar panels that collect solar photovoltaic energy and produce electrical energy, the battery that receives electrical energy from the solar panels and delivers electrical power to the optic head, and associated wiring and electronic control systems.

1.1.5 Autonomy. The autonomy of a battery is a theoretical concept. The autonomy of a lantern's battery is the time - in days - a battery will take to discharge from a fully-charged state [100% state of charge] to a 20% state of charge **without** any energy input from the solar panels.

1.1.6 Fan beam: A fan beam is one in which the light output of a lantern is concentrated in the horizontal plane. It is the beam that must be projected when a fixed light of uniform intensity around the horizon is required.

1.1.7 Characteristic: To aid in recognition and conspicuity, and reduce power consumption of buoy lanterns, these beacons are flashed. The characteristics include:

- Flashing—Fl; showing a single flash at regular intervals, with the duration of the light always less than the duration of darkness;
- Group Flash—Fl( ); showing at regular intervals groups of two or more flashes (the number inserted within the parentheses);

- Quick Flash—Q; showing 60 flashes per minute; and
- Fixed—F; fixed on (This characteristic will *not* be used in the field. It's for test purposes only. Contact the Specification Preparing Activity if operating with a fixed characteristic poses a problem).

1.1.8 Duty cycle. For a given characteristic, the amount of time a light is energized during one cycle divided the total time period of the cycle. Example: a Quick Flash light is energized for 0.3 seconds then de-energized for 0.7 seconds. The period is 0.3 + 0.7 = 1.0 second. The duty cycle is 0.3 second / 1.0 second = 30%.

1.1.9 Luminous intensity (intensity). As defined by The International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA), in the IALA International Dictionary of Marine Navigation, Chapter 2, Section 2-1, Definition 2-1-035.

1.1.10 Peak luminous intensity (peak intensity). The peak (maximum), <u>in time</u>, luminous intensity of a source in a given direction.

1.1.11 Equivalent peak luminous intensity (equivalent peak intensity). The Talbot-Plateau Law states that if a light is rapidly flashed, at a rate so that it appears fused to the observer, the light will match in brightness a steady light that has the same time-average luminance. Therefore, for an LED source modulated at some frequency above the fusion frequency, an equivalent peak intensity will be calculated using the following equation:

$$I_{eq} = \frac{1}{T}\int_0^T I\,dt$$

where: I_{eq} = equivalent peak intensity, in candela (cd);
T = the time period over which the light signal is rapidly flashed; and
I = luminous intensity, in candela (cd).

1.1.12 Effective luminous intensity (effective intensity): The perceived intensity of a flashing light by the human eye is lower than that of a fixed light of equal peak intensity due to the nature of detecting light by the human eye. The International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) "Recommendations on the Determination of the Luminous Intensity of a Marine Aid-to-Navigation Light;" December 1977, describes several methods for calculating the effective intensity of a rhythmic light. For the purposes of this specification, the Coast Guard will use the method of Schmidt-Clausen. The Coast Guard will assume that the Intensity vs. Time profile for a flashed LED is a square wave. Using the Schmidt-Clausen method, and assuming a square wave Intensity vs. Time profile, the effective intensity (I_e) of a flashing LED signal is given by:

$$I_e = I_o * \left(\frac{\Delta t}{c + \Delta t}\right)$$

where: I_e = effective intensity, in candela (cd);
I_o = peak intensity, in candela (cd), of the light signal (or the equivalent peak intensity for a rapidly flashed light);
c = a visual time constant, taken to be 0.2 seconds for night-time observations; and
Δt = the shortest "on" time for a given characteristic.

1.1.13 Flicker fusion frequency (FFF): There is a frequency at which a rapidly pulsed light signal will transition from an appearance of flicker to a steady state. The frequency at which that transition occurs is the flicker fusion frequency (FFF). Pulsed light signals operating below this frequency will be noted as flickering by observers. Factors which impact on the FFF include the intensity of the light signal, the ambient illumination level of the background, the observable area of the signal, and the level of dark adaptation of the observer. Fusion of a flickering light may occur at frequencies as low as 10 Hz, to as much as 100 Hz. For the purposes of this specification, a frequency of 100 Hz or greater shall be considered sufficient to insure fusion of light pulses at detection levels.

2. SCOPE OF WORK

2.1 General. The family of self-contained LED lanterns will include lanterns that produce either a red or green light using LEDs as a light source, and lanterns with different solar power systems. Lanterns in the family include:

Lantern	Description
SC LED 101 G	Green LEDs - small solar power system
SC LED 102 G	Green LEDs - medium solar power system
SC LED 103 G	Green LEDs - large solar power system
SC LED 101 R	Red LEDs - small power system
SC LED 102 R	Red LEDs - medium power system
SC LED 103 R	Red LEDs - large power system

2.1.1 All of the green lanterns shall have the same optic head and all of the red lanterns shall have the same optic head. For a specific color, the differences between the three lanterns will be the size of the solar power system.

2.1.2 It is anticipated that the buoy lanterns will consist of one or more rings of LEDs, electronic power/timer circuitry, solar power generation and energy storage devices (i.e. solar panels and batteries), and a housing which incorporates the necessary light lensing.

2.2 Deliverables under this procurement are:

a. First article lanterns. One each of the six lanterns specified in section 2.1.

b. Production lanterns in quantities as specified in procurement documents.

c. Delivery of the all lanterns duty paid.

d. An operations and maintenance manual/sheet included with each lantern. The operations and maintenance manual/sheet shall provide general guidelines for setting the lantern characteristics and proper installation/mounting of the lantern. Trouble shooting instructions, if applicable, shall be included.

3. PERFORMANCE REQUIREMENTS

3.1 Optical Performance: The optical performance requirements listed herein shall be met for both red and green light signals.

3.1.1 Intensity Measurements. Intensities are to be measured after values stabilize to account for intensity reduction due to LED junction heating. Intensity requirements shall be met by a lantern operating through the full range of ambient operating temperatures specified in Section 3.5.1. Intensities shall be determined by the value met or exceeded by 90% of the values measured in the horizontally focal plane. Lanterns that use rapidly pulsed LEDs to provide the light signal shall operate at frequencies equal to or greater than 100 Hz. For lanterns using rapidly pulsed LEDs, the time-dependent output of the lantern shall be recorded, and the Talbot-Plateau Law shall be used to determine the equivalent peak intensity.

3.1.2 Effective Intensity. Use the Schmidt-Clausen method to calculate effective luminous intensity. Based on the assumption that the LED intensity-vs-time profile is a square wave, the Schmidt-Clausen method will yield an effective intensity (I_e):

$$I_e = I_o * \frac{0.4}{0.2 + 0.4}$$

for a light with a 0.4 second flash duration where I_o is the peak intensity (or equivalent peak intensity for a pulsed light).

3.1.3 Intensity and effective intensity in the horizontal focal plane. The peak intensity, or equivalent peak intensity for rapidly pulsed LEDs, shall be 60 candela or greater omnidirectionally in the horizontal focal plane. The effective intensity, for a flash characteristic with a 0.4-second duration flash interval, shall be 40 candela or greater omnidirectionally in the horizontal focal plane.

3.1.4 Intensity and effective intensity 3.5° above and below the horizontal focal plane. The peak intensity, or equivalent peak intensity for rapidly pulsed LEDs, shall be 30 candela or greater omnidirectionally, 3.5° above and below the horizontal focal plane. The effective intensity, for a flash characteristic with a 0.4-second duration flash interval, shall be 20 candela or greater omnidirectionally, 3.5° above and below the horizontal focal plane.

3.1.5 Intensity and effective intensity at other angles above and below the horizontal focal plane. The peak intensity, or equivalent peak intensity for rapidly pulsed LEDs, at any vertical angle less than 3.5° above or below the horizontal focal plane, shall be equal to, or greater than what would be obtained by fitting a normal (Gaussian) curve through a value of 60 cd in the focal plane and 30 cd at 3.5° above and below the focal plane. The effective intensity, for a flash characteristic with a 0.4-second duration flash interval, at any vertical angle less than 3.5° above or below the horizontal focal plane, shall be equal to, or greater than what would be obtained by fitting a normal (Gaussian) curve through a value of 40 cd in the focal plane and 20 cd at 3.5° above and below the focal plane.

3.1.6 Horizontal Uniformity of Output: The lantern shall produce an omnidirectional horizontal fan beam. The peak intensity of the beam, in any direction in the focal plane (except in the direction of a lens molding seam), shall not vary by more than ± 20% from the mean. This requirement may require sorting of LEDs. The intensity profile about any lens molding seams shall not be less than 60% of the mean horizontal output over an angle of not more than 2°.

3.1.7 Degradation: The lantern shall be designed to maintain at least 80% of the effective intensity over 6 years of operation when operated at night with a 30% duty cycle.

3.1.8 Signal colors. The chromaticity of the colors provided by the lanterns (separate modules for red and green light signals) shall lie within the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) general region. Corner chromaticity coordinates for the general region are provided in IALA "Recommendations for the Colours of Light Signals on Aids to Navigation;" December 1977 and are repeated in IALA "Recommendation E. 122 on the Photometry of Marine Aids-to-Navigation Signal Lights."

3.2 Optic head power and control. Power and control systems shall be integrated into the lantern such that no other devices shall be necessary to produce a complete marine aid-to-navigation light signal.

3.2.1 Daylight control. The lantern shall switch on and off at sunset and sunrise, respectively. At a minimum, the lantern shall switch on whenever the ambient illumination, measured in the horizontal plane, falls below 250 ± 50 lux. The lantern shall not switch off until the ambient illumination rises above 320 ± 50 lux. The daylight control, and associated illumination control circuitry shall be designed so that when ambient light levels are below the ambient "turn-on" level, the operation of the lantern and its proper display of the desired flash characteristic shall not be affected by the light from the lantern.

3.2.2 Flash characteristic control system. Each lantern shall be capable of producing all standard U.S. Coast Guard characteristics, as outlined below, and shall include control circuitry to permit field selection of any desired characteristic. The controls needed to set or change the characteristic shall be incorporated into the lantern, and shall not require any additional device. The various characteristics which the lantern must be capable of displaying are:

Characteristic		Timing ON/OFF (seconds)	Duty Cycle (%)
Fl:	F1 2.5 (0.3)	0.3/2.2	12
	F1 4 (0.4)	0.4/3.6	10
	F1 6 (0.6)	0.6/5.4	10
Fl():	FI (2+1)6	0.3/0.4/0.3/1.2/0.3/3.5	15
	Fl (2)5	0.4/0.6/0.4/3.6	16
	Fl (2)6	1.0/1.0/1.0/3.0	33
Q:	Q	0.3/0.7	30
F:	F	Fixed	100

3.2.3 Light intensity control system. The LED driver shall be designed to obtain predictable and matched luminous intensity and chromaticity from each LED, and to avoid exceeding the LEDs Absolute Maximum Current Rating and compromising reliability and longevity. The luminous intensity and chromaticity shall remain relatively constant over the full range of environmental operating conditions and for all light characteristics specified in this specification.

3.3 Solar Power System.

3.3.1 Integrated solar power system. The lantern shall include any and all devices required for power generation and energy storage necessary to produce and emit the required light signals. The solar power system's ability to provide enough energy to the optic head for a specific aid to navigation will be greatly dependent on the amount of solar radiation at the aid's geographic location and on the duty cycle of the light. Because of the large variations in solar radiation at U. S. Coast Guard aids-to-navigation sites, and because of the large variations in duty cycles, this specification describes a family of self-contained lanterns that have differently-sized solar power systems. This specification describes 3 differently-sized solar power systems for each LED color:

Small power system - SC LED 101 G and SC LED 101 R lanterns

Medium power system - SC LED 102 G and SC LED 102 R lanterns

Large power system - SC LED 103 G and SC LED 103 R lanterns

3.3.1.1 Small solar power system. The lantern with the small power system shall be capable operating year-round in Portland, ME with a 10% duty cycle.

3.3.1.1.1 Small solar power system battery. The battery shall have an autonomy of not less than 18 days for an aid in Portland, ME with a 10% duty cycle.

3.3.1.1.2 Small solar power system solar panels. On a daily basis, the solar panels shall be capable of producing at least as much energy as will be consumed by a lantern in Portland, ME with a 10% duty cycle. That is, E_{in} (energy in) shall be equal to or greater than E_{out} (energy out). See section 3.3.2 for additional information regarding calculating energy production and energy consumption.

3.3.1.2 Medium solar power system. The lantern with the medium power system shall be capable operating year-round in Portland, ME with a 16% duty cycle.

3.3.1.2.1 Medium solar power system battery. The battery shall have an autonomy of not less than 18 days for an aid in Portland, ME with a 16% duty cycle.

3.3.1.2.2 Medium solar power system solar panels. On a daily basis, the solar panels shall be capable of producing at least as much energy as will be consumed by a lantern in Portland, ME with a 16% duty cycle. That is, E_{in} (energy in) shall be equal to or greater than E_{out} (energy out). See section 3.3.2 for additional information regarding calculating energy production and energy consumption.

3.3.1.3 Large solar power system. The lantern with the large power system shall be capable operating year-round in Portland, ME with a 30% duty cycle.

3.3.1.3.1 Large solar power system battery. The battery shall have an autonomy of not less than 18 days for an aid in Portland, ME with a 30% duty cycle.

3.3.1.3.2 Large solar power system solar panels. On a daily basis, the solar panels shall be capable of producing at least as much energy as will be consumed by a lantern in Portland, ME with a 30% duty cycle. That is, E_{in} (energy in) shall be equal to or greater than E_{out} (energy out). See section 3.3.2 for additional information regarding calculating energy production and energy consumption.

3.3.2 Autonomy and energy calculations.

3.3.2.1 Daily energy consumption calculations. The daily energy consumption shall be calculated as follows:

$$E_{out} = \text{Hours}_{\text{Darkness}} * \text{Duty Cycle} * I_{\text{Lamp}} + 24 \text{ hours} * Q$$

where: E_{out} is the lantern's daily energy consumption in Amp-hours.

$\text{Hours}_{\text{Darkness}}$ is hours of darkness. For Portland, ME set $\text{Hours}_{\text{Darkness}} = 15.25$ hours.

Duty Cycle is the duty cycle of the light characteristic.

I_{Lamp} is the lantern's current draw while the light is on. For a light that is pulsed, I_{Lamp} is the time-averaged current over the period of the flash. I_{Lamp} shall be calculated or measured for a lantern operating at the specified duty cycle and at an ambient (i.e. external to the lantern) temperature of minus 10° C. The value used for I_{Lamp} shall be such that from a random selection of lanterns, 90% or more of the measured current values shall be less than I_{Lamp} at the specified duty cycle and ambient temperature.

Q is the quiescent current in amps.

3.3.2.2 Autonomy Calculations. Autonomy is defined in paragraph 1.1.5. Autonomy shall be calculated as follows:

$$\text{Autonomy} = (0.8 * \text{Rated Battery Capacity}) / E_{out}$$

where: Autonomy is the lantern's autonomy in days.

Rated Battery Capacity is the manufacturer's rated battery capacity in Amp-hours at a temperature of -11° C (12° F).

E_{out} is the lantern's daily energy consumption in Amp-hours as calculated in section 3.3.2.1.

3.3.2.3 Daily energy production calculations. The lantern's daily energy production shall be calculated by summing the daily energy production from each of the lantern's solar panels as follows:

$$E_{in} = \sum_{i=1}^{n} \left(\frac{H_i * W_i}{V_{MPPi}} * Eff \right)$$

where: E_{in} is the combined daily energy production of the solar panels.

n is the number of solar panels.

H is the daily solar radiation on one of the panels in kWh/m^2 (see section 3.3.3).

W is the solar panel's rated power at -11° C (12° F).

V_{MPP} is the solar panel's voltage at its max power point.

Eff is an efficiency factor. Set Eff = 0.80.

3.3.3 Solar radiation values. The solar radiation values below are average radiation values for Portland, ME for the month of December. Use these radiation values to calculate the solar panel's daily energy production as specified in section 3.3.2.3.

3.3.3.1 For 4 vertical solar panels spaced 90-degrees apart: $H_1 = 2.37$, $H_2 = 2.21$, $H_3 = 0.53$, and $H_4 = 0.54$ $kWh/m^2/day$. These are average radiation for vertical surfaces facing 135°, 225°, 315°, and 045° respectively (000° being a north-facing panel and 090° an east-facing panel).

3.3.3.2 For 3 vertical solar panels spaced 120-degrees apart: $H_1 = 3.02$, $H_2 = 0.61$, and $H_3 = 0.66$ kWh/m^2/day. These are average radiation for vertical surfaces facing 180°, 300°, and 060° respectively (000° being a north-facing panel and 090° an east-facing panel).

3.3.3.3 For a horizontal panel use H = 1.56 kWh/m^2/day.

3.3.3.4 For other solar panel configurations contact the Contracting Officer to obtain other radiation values needed to calculate daily solar panel energy production.

3.3.4 Batteries. Battery selection shall be compatible with the lantern's required service life (section 3.4.1), with the autonomy requirements specified in sections 3.3.1.1.1, 3.3.1.2.1 and 3.3.1.3.1, and with operation in the harsh environmental conditions specified section 3.5. Particular attention shall be paid to the selection of a battery that will operate at -30° C and at a low state-of-charge without freezing and without being prone to recharge problems.

3.3.4.1 Maintenance free battery. The battery shall be maintenance-free.

3.3.4.2 Commercially available battery. The battery shall be commercially available so that it can be purchased and replaced by Coast Guard serving personnel. It shall be mounted in the lantern in a manner that will allow replacement of the battery. The battery shall be secured using standard hold-down hardware and electrically connected with commercial fasteners (for example ring lugs or other slip-on connectors).

3.3.4.3 Ready for use. The lantern shall be shipped with the battery installed, and completely ready for use (except for initial charging). The operations and maintenance manual/sheet included with each lantern (section 2.2.d) shall provide instructions regarding charging of the battery prior to initial installation in the field.

3.3.4.4 No-leak. The battery shall not leak when stored for an extended period of time in <u>any</u> orientation.

3.4 <u>Service life and maintenance</u>. For purposes of calculation, one year of service is considered to equal approximately 4,800 hours of lantern use. Depending on the duty cycle, and whether a rapidly pulsed signal is used, the actual emitting time for the LEDs will range from about 240 to 1440 hours. The replacement interval is defined for the purposes of this specification as the mean time for total lumen output of the lantern to be reduced to 80% of initial (rated) output, due to LED failure or fatigue.

3.4.1 The lantern shall have a service life, based on producing a characteristic with a 30% duty cycle, of not less than 6 years.

3.4.2 The lantern and all of its components shall not require preventive maintenance, other than periodic cleaning of external surfaces. The design of the lantern shall be such as to restrict the ability of birds to roost on the lantern or any of its components.

3.5 <u>Environment</u>. The lantern shall meet or exceed all the requirements of this specification under the environmental conditions outlined below.

3.5.1 Ambient temperature. Exposure to temperatures from -30° to +50° C.

3.5.2 Humidity. Exposure to relative humidity from 0 to 100%, including driving rain at 45° from vertical.

3.5.3 Immersion. Complete immersion in salt water to a depth of one meter for a period of 2 hours.

3.5.4 Icing. Exposure to ice loading up to 22 kg per square meter.

3.5.5 Wind speed. Exposure to wind speeds up to 140 knots.

3.5.6 Salt air and seawater spray. Continuous exposure to salt air and seawater spray.

3.5.7 Ultraviolet exposure. All of the external components of the lantern shall operate under and withstand continuous exposure to ultraviolet light for the duration of the advertised service life of the lantern, as is typically encountered at sea level, at 20° North latitude.

3.5.8 Shock and vibration. The lantern shall be constructed to operate under and withstand continuous exposure to the shock and vibration experienced on marine aids-to-navigation buoys.

3.5.9 Electromagnetic interference. The lantern shall not be susceptible to interference from radiating devices normally found in the marine environment. This includes signals from VHF and UHF radio and marine radar. The lantern shall also incorporate protection from static discharges of up to 25K volt, as may occur due to nearby lightning strikes.

3.6 Size and mass. The lantern should be made of lightweight, yet durable, materials, to minimize effects on buoy stability. The lanterns shall not exceed the maximum allowances for size and weight.

3.6.1 External dimensions. The overall height of the lantern (including adapter plate if applicable – see section 3.7.3) and including bird deterrents shall not exceed the value shown under “Max Height” in the following table. The maximum horizontal distance from the lantern’s vertical centerline to the outer edge of the lantern, at all heights, shall not exceed the value shown under “Max Radius” in the table.

Lantern	Max Height	Max Radius
Small power system (101 series)	35 cm	22 cm
Medium power system (102 series)	45 cm	22 cm
Large power system (103 series)	55 cm	22 cm

3.6.2 Height of LEDs. The lowest LEDs shall be not less than 15 cm above the base of the lantern.

3.6.3 Mass. The mass of the complete lantern shall not exceed the value shown in the following table.

Lantern	Max Mass
Small power system (101 series)	12 kg
Medium power system (102 series)	16 kg
Large power system (103 series)	22 kg

3.7 Mounting provisions. The lanterns shall be designed so that it can be attached to the buoy using three bolts, equally spaced on a 200-mm diameter bolt hole circle. Any of the following three mounting methods is acceptable:

3.7.1 Mounting method 1. The base of the lantern shall have three, unthreaded bolt holes, equally spaced on a 200 mm diameter bolt circle. The bolt holes shall be 16 ± 1 mm in diameter, and may be elongated to form closed, arced slots. The working space shall be sufficient to allow installation of ½"-13 UNC bolts or nuts and to secure with conventional hand tools. The bottom of the lantern base shall be parallel to the focal plane of the lantern.

3.7.2 Mounting method 2. The base of the lantern shall have three, threaded bolt holes, equally spaced on a 200 mm diameter bolt circle. The threaded bolt holes shall accept ½"-13 UNC bolts that will be inserted straight up through holes in the buoy's lantern mounting plate then into the lantern's threaded bolt holes. The threaded bolt holes shall be not less than 1 inch deep. The depth of the bolt holes and the material composition of the threaded bolt holes shall be such that the lantern can withstand the environmental conditions specified in section 3.5. The bottom of the lantern base shall be parallel to the focal plane of the lantern.

3.7.3 Mounting method 3. The lantern can be supplied with an adapter to be positioned between the lantern and the buoy's lantern mounting plate. The lantern shall be bolted to the top of the adapter using hardware supplied by the manufacturer. The adapter shall be designed so that it can be attached to the buoy's lantern mounting plate using either Mounting Method 1 or 2 described in sections 3.7.1 or 3.7.2 respectively. The bottom of the adapter shall be parallel to the focal plane of the lantern. If an adapter is used, lantern/adapter combination shall meet all requirements of the specification including the size and weight requirements in section 3.6.

4. INSPECTION AND ACCEPTANCE.

4.1 First article inspections. First articles shall be inspected as specified in section 4. Two small-solar-power-system lanterns shall be inspected (one red and one green); two medium-solar-power-system lanterns shall be inspected (one red and one green); and two large-solar-power-system lanterns shall be inspected (one red and one green). If the contractor proposes that one lantern will satisfy the requirements of more than one lantern in the family of lanterns in this specification (i.e. one contractor-supplied lantern meets the requirements for both the medium and large solar-power-system in this specification), then two identical lanterns need not be tested.

4.2 Classification of inspections. The inspection requirements specified herein are classified as follows:

a. Environmental inspections – see section 4.4.

b. Optical inspections – see section 4.5.

c. Miscellaneous inspections – see section 4.6.

4.3 General inspections requirements. The inspections required in section 4 are not intended to replace or substitute any controls, examinations, inspections, or tests normally employed by the contractor to assure the quality of this product.

4.3.1 Responsibility. All tests in section 4.4, 4.5 and 4.6 are the responsibility of the contractor and shall be conducted at a facility acceptable to the Government. A test plan shall be submitted to the Specification Preparing Activity not later than 20 days prior to the commencement of testing. At a minimum this plan shall include:

a. a chronological listing of the tests to be performed;
b. location of the test facility;
c. a complete listing of all equipment to be used;
d. detailed test procedures for each test and with wiring diagrams of test setups and pass/fail criteria;
e. all information necessary to fully describe the test;
f. test data sheets shall be provided with the test plan and shall be used to record observed performance data; and
g. examples of calculations needed to evaluate test data.

4.3.2 Report on tests. A final report shall be submitted to the Specification Preparing Activity within 10 days after completion of the tests. The report shall include at a minimum:

a. all test data sheets with recorded measurements and observations;
b. all calculations and graphics used to evaluate the data; and
c. a list of all failed tests.

4.3.3 Acceptance/rejection criteria. Failure of any one lantern to comply with the requirements of sections 4.4 through 4.6 inclusive shall constitute failure and shall be reason to reject a manufacturer's product.

4.4 Environmental tests. Unless otherwise noted, checking "lantern operation" means visually observing that the lantern is operating normally and displaying the proper characteristic.

4.4.1 Extreme temperature. The lanterns shall be placed in an environmental chamber with the light energized and set to a Fl 4 characteristic. Bring the chamber to a temperature of –30° ± 2° C. The chamber shall be maintained at that temperature for a period of 24 ± 1 hours. The chamber temperature shall then be raised to 50° ± 2° C, over a period of 2 hours (± 30 minutes), and held constant for 4 hours (± 30 minutes). Lantern operation shall be noted and recorded at one-hour intervals throughout the time in the environmental chamber. The lanterns shall then be returned to ambient temperature. After one hour at ambient temperature lantern operation should be noted and recorded. The failure of the lantern to operate normally or display the proper characteristic during any of the observations shall constitute failure of this test. Any visible damage of permanent deformation shall also constitute failure of this test.

4.4.2 Humidity. The lanterns shall be tested in accordance with Test Condition B, Method 103B of MIL-STD-202F, Humidity (Steady State). The lanterns shall be placed in the environmental chamber with the light energized and set to a Fl 4 characteristic. Lantern operation shall be noted and recorded at the end of the conditioning period and upon completion of the exposure period, while the lanterns are still in the chamber. The failure of the lantern to operate normally or display the proper characteristic during any of the observations shall constitute failure of this test.

4.4.3 Wind Speed. The lantern shall be bolted to a secure surface and subject to a horizontal force to simulate a wind force. The horizontal force shall be:

$$F_{horizontal} = 0.056 * \text{area}$$

where: $F_{horizontal}$ is the force in pounds.

area is the lantern's largest cross-sectional area in cm^2

A strap shall be wrapped around the lantern and centered vertically at the center of the lantern's cross-sectional area. A horizontal force calculated using the formula above shall be applied to the strap and the force shall be held for a period of 15 minutes. The lantern shall withstand this force without any damage or permanent deformation. The process shall be repeated two times, each time with the horizontal force applied in a new direction, 30° from the previous direction. The test report shall include a sketch showing the three directions of pull referenced to the lantern's orientation.

4.4.4 Immersion. The lanterns shall be tested in accordance with Test Condition B, Method 104A of MIL-STD-202F, Immersion. After the final cycle of immersion testing, the lanterns shall be quickly rinsed in fresh (tap) water and air-blasted clean and dry. Lantern operation shall be recorded under conditions of light (light signal off) and dark (light signal on). The lantern shall then be opened, and all interior areas inspected for evidence of water intrusion or the appearance of salt crystals. The failure of the lantern to operate normally or display the proper characteristic during any of the observations shall constitute failure of this test. Any evidence of water intrusion or the appearance of salt crystals shall also constitute failure of this test.

4.4.5 Shock. The lanterns shall be tested in accordance with Test Condition H, Method 213B of MIL-STD-202F, Shock (Specified Pulse). Shock tests shall be performed as soon as possible after removing the lanterns from a one-hour confinement in a chamber at -10° F. Lantern power shall be applied throughout the test, with the lantern set to display a fixed-on characteristic. Discontinuities in the light signal shall be recorded. Any discontinuity in the light signal shall constitute failure of this test. Any visible damage of permanent deformation shall also constitute failure of this test.

4.4.6 Vibration. The lanterns shall be tested in accordance with MIL-STD-202, Method 204, Test Condition B, with the peak G-value reduced to 5G and the number of cycles performed in each of the three mutually perpendicular directions reduced from 12 to 3. Lantern power shall be applied throughout the test, with the lantern set to display a fixed-on characteristic. Light performance shall be visually monitored and discontinuities in the light signal shall be recorded. The lantern shall be mounted to a planar supporting structure by three 1/2 –inch diameter bolts through the base mounting holes. Vibration tests shall be conducted as soon as possible after removing the lanterns from a one-hour confinement at -10° F. Discontinuities in the light signal shall be recorded. Any discontinuity in the light signal shall constitute failure of this test. Any visible damage of permanent deformation shall also constitute failure of this test.

4.4.7 Electromagnetic interference. The lanterns shall be tested for electromagnetic radiation immunity in accordance EN 61000-4-3 except that tested frequency range shall be 100 MHz to 20 GHz to performance criteria A at 200 V/m. Throughout the test the lanterns shall be energized, set to a Fl 4 characteristic, and the lantern's operation shall be monitored. The failure of the lantern to operate normally or display the proper characteristic shall constitute failure of this test.

4.5 Optical tests. Optical tests shall be conducted after the completion of all environmental tests. Lenses shall be cleaned before performance of these tests.

4.5.1 Horizontal intensity photometric test. The lanterns shall be rotated about a vertical axis through the lens focal point, and the peak intensity in the horizontal plane measured at intervals of one degree of azimuth. The rated intensity shall be determined by the value met or exceeded by 90% of the measured values. The average horizontal intensity shall be calculated. The values obtained in this test shall meet or exceed the requirements specified in sections 3.1.3 and 3.1.6.

4.5.2 Vertical intensity profile photometric test. The lanterns shall be rotated about a horizontal axis and the light intensity in the vertical plane shall be recorded as a function of angle of elevation. This vertical profile test shall be conducted at three positions, 120-horizontal-degress apart for each lantern. Measurements between the 10% intensity points shall be recorded. The values obtained shall meet or exceed the requirements specified in sections 3.1.3, 3.1.4 and 3.1.5.

4.5.3 Signal colors. The colorimetric output of the lanterns shall be measured and recorded. The color of the light signal shall be plotted on a copy of the 1931 CIE Chromaticity Diagram. The values obtained shall meet the requirements specified in section 3.1.8.

4.6 Miscellaneous tests.

4.6.1 Size and weight. The size and weight of each lantern shall be measured and recorded. The values obtained shall meet the requirements of section 3.6.

4.6.2 Mounting provisions. The mounting method shall be examined. The size and location of the mounting holes shall be measured and recorded. The values obtained shall meet the requirements specified in section 3.7.

4.7 Coast Guard tests. At the conclusion of the first article tests listed in sections 4.4, 4.5 and 4.6, the lanterns shall be shipped to the Coast Guard. The Coast Guard will test the lanterns to verify *some* of the test results.

5. PACKAGING

5.1 Packaging. The lanterns shall be packaged individually in accordance with standard commercial practice, suitable for reshipment.

5.2 Marking. The lanterns shall clearly marked with the contents (example: “Red LED lantern Model SC LED 102 R”), manufacturer, weight, unit quantity, stock number and bar code.

SPECIFICATION FOR SELF CONTAINED, LIGHT EMITTING DIODE (LED) BUOY LANTERN

SPECIFICATION NUMBER: G-SEC-502

MARCH 2005

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